Pure & Appl. Chem., Vol.52, pp.2349-2384. 0033-4545/80/1001-2349$02.00/0
Pergamon Press Ltd. 1980. Printed in Great Britain.

INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY

INORGANIC CHEMISTRY DIVISION

COMMISSION ON ATOMIC WEIGHTS AND ISOTOPIC ABUNDANCES*

ATOMIC WEIGHTS OF THE ELEMENTS 1979

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Abstract - The biennial review of atomic weight determinations and other cognate data has resulted in the following changes in recommended values (1977 values in parentheses): Neon 20.179 (20.179*), Argon 39.948 (39.948*), Potassium 39.0983 (39.0983*), Titanium 47.88* (47.90*), Nickel 58.69 (58.70), Palladium 106.42 (106.4), Xenon 131.29* (131.30), Samarium 150.36* (150.4), Tantalum 180.9479 (180.9479*), Platinum 195.08* (195.09*), Thallium 204.383 (204.37*), Uranium 238.0289 (238.029). These values are considered to be reliable to ±1 in the last digit or ±3 when followed by an asterisk (*) and are incorporated in the full Table of Atomic Weights of the Elements 1979. The Report outlines various problems which arise from the present imprecise definition of "atomic weight (mean relative atomic mass)" and contains a new definition to overcome the difficulties. The importance of having informative labels on commercially available chemicals is emphasized, particularly in order to warn or reassure users of the presence or absence of materials containing elements with unusual atomic weights due to the enrichment or depletion of isotopes. The Report includes a complete review of the natural isotopic composition of the elements and also tabulates the Relative Atomic Masses for Selected Radioisotopes. The Report contains a review of stable isotope abundances of elements from non-terrestrial sources.

INTRODUCTION

The Commission on Atomic Weights met under the chairmanship of Professor E. Roth, on 3-6 September 1979, during the XXXth IUPAC General Assembly in Davos, Switzerland. Work done by the Commission members during the preceding two years in assessing atomic weights and other cognate data was reviewed and, as a result, the recommended values for the atomic weights of twelve elements were changed and footnotes added for two elements. The new values were immediately disseminated through an IUPAC News Release. The justifications for these changes are set out in the next section. This is followed by the definitive Table of Standard Atomic Weights of the Elements 1979 of the International Union of Pure and Applied Chemistry. General problems of terminology are discussed in the next section, and the Commission has a new definition of "atomic weight (mean relative atomic mass)." It is hoped that this will remove various operational difficulties which at present face the Commission in preparing its recommendations for the atomic weights of the elements, and place the whole concept of an atomic weight on a sounder basis.

An increasing number of commercially available materials contain elements whose isotopic composition has been altered, either intentionally or inadvertently, from that of the element in nature. This problem afflicts some elements more than others and the Commission has been active in seeking to alert both manufacturers and suppliers to the need for appropriate phrases on labels. Suggestions are made for such explanatory statements which, in many cases, may well add to the usefulness of the products described.

A working group had been constituted as a Subcommittee for the Assessment of Isotopic Composition, at the request of the Inorganic Division (the parent body of the Commission). This will, in due course, enable the Commission to publish a completely self-consistent set of isotopic compositions and atomic weights of the elements incorporating not only mass-spectrometric data but also results obtained from all other relevant methods. The present Report tabulates the range of published mass-spectrometrically determined isotopic abundances 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 1979 knowledge nor does it necessarily provide the best atomic weight value in terms of all techniques. In future years the definitive self-consistent tabulation of isotopic compositions will also include a precise relative atomic mass of each nuclide and this will obviate the need for their separate tabulation. As an interim measure, however, the present Report continues the practice of tabulating the relative atomic masses of selected nuclides, but restricts these to certain nuclides of radioactive elements, including those such as technetium, promethium, and the elements of highest atomic number, for which the Table of Atomic Weights lists only an atomic mass number in parentheses. The Report tabulates examples of variations in isotopic composition for selected elements in non-terrestrial samples along with an introductory discussion of this topic of increasing interest.

CHANGES IN ATOMIC WEIGHT VALUES

Neon

The value of $\underline{A}_r(Ne)=20.183$ for the atomic weight of neon was adopted by the Atomic Weights Commission in its 1961 Report (Ref. 1) based on gas density measurements by Baxter and Starkweather (Ref. 2) and Baxter (Ref. 3). In its 1967 Report, the atomic weight was changed to $\underline{A}_r(Ne)=20.179\pm.003$ on the basis of two calibrated isotopic composition determinations which appeared almost simultaneously. Eberhardt (Ref. 4) prepared one standard by mixing known amounts of atmospheric neon with ^{20}Ne enriched to 99.70%. They also recovered neon from air without distillation. Walton and Cameron (Ref. 5) prepared five usable standards from separated neon isotopes of high purity. Six samples of neon from commercial suppliers, separated from air at different times were run alternately with a standard. No significant differences were observed among the samples within the limits of error of the measurements. Based on the agreement between the two calibrated measurements and the absence of observed variations, the Commission recommends $\underline{A}_r(Ne)=20.179\pm0.001$ as the most reliable value.

Argon

The value of $\underline{A}_r(Ar)=39.942$ (converted to the ^{12}C scale) for the atomic weight of argon was adopted by the Atomic Weights Commission based on gas density measurements by Baxter and Starkweather (Ref. 6) believed by the workers to be good to ±0.001. In its 1961 Report (Ref. 1) the atomic weight was changed to $\underline{A}_r(Ar)=39.948\pm0.003$ on the basis of a calibrated measurement of isotopic composition from carefully prepared mixture of $^{36}A_r$ and $^{40}A_r$ of high isotopic purity by Nier (Ref. 7). The Commission has reexamined the calibrated measurements by Nier and now recommends $\underline{A}_r(Ar)=39.948\pm0.001$ with the lowered uncertainty as the most reliable value for argon.

Potassium

The value of $\underline{A}_r(K)=39.102$ for the atomic weight of potassium was adopted by the Atomic Weights Commission in its 1961 Report (Ref. 1) based on the mass-spectrometric measurements of Nier (Ref. 8). In the 1969 Report (Ref. 9), the Commission noted that this value was known "less reliably" and introduced the uncertainty of ±0.003. In the 1971 Report (Ref. 10), the Commission recommended a change to 39.098±.003 based on a new analysis by Marinenko (Ref. 11) of older data by Bates and Wickers (Ref. 12). In the 1975 Report (Ref. 13), the Commission recommended $\underline{A}_r(K)=39.0983\pm0.0003$ based on the absolute measurement and survey of possible variations by Garner et al. (Ref. 14). The Commission has now completed an evaluation of possible variations of the isotopic abundances and the effects of small errors in the abundance measurements and recommends the present value with a reduced uncertainty of $\underline{A}_r(K)=39.0983\pm0.0001$.

Titanium

The value of $\underline{A}_r(Ti)=47.90$ for the atomic weight of titanium was adopted by the Atomic Weights Commission in 1927 based on the chemical determinations of Baxter and Butler (Ref. 15) and (Ref. 16). In its 1969 Report (Ref. 9), the Commission examined the uncertainty on the above value and recommended $\underline{A}_r(Ti)=47.90\pm0.03$ based on Baxter with some consideration of the isotopic abundance measurements, by Nier (Ref. 17), Hibbs (Ref. 18), Mattraw (Ref. 19), Hogg (Ref. 20), Drawin (Ref. 21), and Belsheim (Ref. 22).
The Commission has reexamined both the chemical and the mass-spectrometric determinations and recommends $\underline{A}_r(Ti)=47.88\pm0.03$ for the atomic weight of titanium, which includes the above references but is weighted toward the calibrated measurement of Belsheim. The uncertainty covers both the mass-spectrometric determinations and the chemical measurement.

Nickel

The value of $\underline{A}_r(Ni)=58.69$ for the atomic weight of nickel was adopted by the Atomic Weights Commission in 1925 based on the measurement of the ratios NiO/Ni by Baxter and Parsons (Ref. 23) and of $NiCl_2/2\,AgCl$ by Baxter and Hilton (Ref. 24). These were confirmed by the work of Baxter and Ishimaru (Ref. 25) on the ratios $NiBr_2/2Ag$ and $NiBr_2/2AgBr$. In 1955, the atomic weight was changed to $\underline{A}_r(Ni)=58.71$ based on the isotopic abundance measurement of White and Cameron (Ref. 26). In their 1969 Report (Ref. 9), the Commission introduced an uncertainty of 0.03 to encompass both the physical and chemical values. Concerned that the ^{64}Ni abundance may have been overestimated by White and Cameron, the Commission recommended an atomic weight value of 58.70±0.01 in its 1973 Report (Ref. 27). The Commission has reviewed both the chemical and mass-spectrometric determinations including the newer, more precise measurement by Barnes et al. (Ref. 28) and now recommends an atomic weight for nickel of $\underline{A}_r(Ni)=58.69\pm0.01$.

Palladium
The value of $\underline{A}_r$(Pd)=106.4 for the atomic weight of palladium was adopted by the Atomic Weights Commission in its 1961 Report (Ref. 1) based on the isotopic abundance measurement of Sites et al. (Ref. 29). In its 1969 Report (Ref. 9), the Commission considered the uncertainty on this value and recommended $\underline{A}_r$(Pd)=106.4±0.1. A new calibrated measurement of the isotopic abundance values of palladium has been made by Shima et al. (Ref. 30). Using these new abundance values and the evidence of lack of significant natural variations, the Commission now recommends $\underline{A}_r$(Pd)=106.42±0.01 as the most reliable value.

Xenon
The value of $\underline{A}_r$(Xe)=131.3 for the atomic weight of xenon was adopted by the Atomic Weights Commission in 1932 (Ref. 31) based on the measurements by Whytlaw-Gray et al., of the ratio of the pressures at which the densities of xenon and oxygen were equal (Ref. 32). This value was supported by the xenon isotopic composition measurement by Aston (Ref. 33) with the mass spectrograph. In 1955, the Commission recommended $\underline{A}_r$(Xe)=130.30 (on the 0=16 scale) based on the isotopic composition measurement by Nier (Ref. 34) and the atomic mass measurement of Halsted (Ref. 35). In their 1961 Report, the Commission continued the same value which was based on Nier's abundance values and atomic masses from Mattauch (Ref. 36) and known to be slightly in error. This report states, "With the same abundances and the masses from EKMW (1960), the calculated atomic weight is 131.29. The Commission recommended 131.30 for the present table, based on an earlier calculation which was slightly in error." The Commission now corrects that error and recommends $\underline{A}_r$(Xe)=131.29±0.03 for the atomic weight of xenon.

Samarium
In 1955, the Atomic Weights Commission recommended $\underline{A}_r$(Sm)=150.35 for the atomic weight of samarium based upon the isotopic abundance measurement by Inghram et al. (Ref. 37) and atomic masses of Hogg and Duckworth (Ref. 38). This value was revised to $\underline{A}_r$(Sm)=150.4±0.1 in the 1969 Report (Ref. 9) based on an evaluation of the uncertainty in the previously recommended value. After a critical review of the high precision chemical measurement of Hönigschmid and Hirschbold-Wittner (Ref. 39) and the mass-spectrometric measurements by Inghram and Lugmair et al. (Ref. 40), the Commission now recommends $\underline{A}_r$(Sm)=150.36±0.03.

Tantalum
A very precise atomic weight value can be expected for this element because it has two isotopes, one of which is overwhelmingly predominant. In their 1969 Report (Ref. 9), the Atomic Weights Commission recommended $\underline{A}_r$(Ta)=180.9479±0.0003 for the atomic weight of tantalum based on the isotopic abundance measurements of White et al. (Ref. 41, 42) and of Palmer (Ref. 43). The Commission has reviewed the published measurements and uncertainties and now recommends $\underline{A}_r$(Ta)=180.9479±0.0001 as the most reliable value.

Platinum
The value of $\underline{A}_r$(Pt)=195.09 for the atomic weight of platinum was adopted by the Commission in 1955 based upon isotopic abundance measurements by Inghram et al. (Ref. 44) and Leland (Ref. 45), and masses measured by Duckworth et al. (Ref. 46). This value had a calculational error. With the correct conversion factor between chemical and physical scales, the atomic weight should be $\underline{A}_r$(Pt)=195.08. The Commission has reviewed the published data on recommends $\underline{A}_r$(Pt)=195.08±0.03 as the most reliable values based on White's isotopic composition (Ref. 42) and Wapstra's atomic masses (Ref. 47).

Thallium
The value of $\underline{A}_r$(Tl)=204.39 for the atomic weight of thallium was adopted by the Commission in 1925 based on the measurement of the combining weights of TlCl/Ag and TlCl/AgCl by Hönigschmid et al. (Ref. 48). Later work by Hönigschmid and Striebel (Ref. 49) gave an identical value. On the ^{12}C scale, this value was recalculated to 204.37. In the 1961 Report (Ref. 1), the Commission recommended the value 204.37±0.03, although the mass-spectrometric determinations of White and Cameron (Ref. 26) and Hibbs (Ref. 50) gave a value of 204.38. Dunstan et al. (Ref. 51) reports a calibrated measurement and survey of thallium materials and minerals which indicate no variation in nature. The Commission now recommends $\underline{A}_r$(Tl)=204.383±0.001 as the most reliable value.

Uranium
A relatively precise atomic weight value can be expected for uranium because one of its three isotopes is predominant. In 1937, the Commission recommended $\underline{A}_r$(U)=238.07 based on the measurements of the ratio UCl_4/4Ag by Hönigschmid and Wittner (Ref. 52). On the ^{12}C scale, this value recalculates to 238.05. In the 1961 Report (Ref. 1), the Commission recommended $\underline{A}_r$(U)=238.03 based on the isotopic abundance measurements of White (Ref. 42), and Boardman and Meservey (Ref. 53), the variations reported by Smith (Ref. 54) and Senftle et al. (Ref. 55) and the atomic masses of Mattauch (Ref. 36). After a review of uncertainties, the Commission recommended the value 238.029±0.001 in the 1969 Report (Ref. 9). The Commission has now reviewed published data on isotopic compositions, and the ^{235}U variation in nature by Cowan and Adler (Ref. 56) and the ^{234}U variation in nature by Smith

and Jackson (Ref. 57). Based on the range of ^{235}U (0.7198-0.7202 atom percent) and the range of ^{234}U (0.00509-0.00548 atom percent), the Commission now recommends $A_r(U)=238.0289\pm0.0001$ for natural uranium.

CHANGES IN FOOTNOTES

Hydrogen

As mentioned in the 1977 Report (Ref. 58), the atomic weight of hydrogen has a recommended value of 1.0079±0.0001, while electrolytic hydrogen (Ref. 59), and Russian water source (Ref. 60) have deuterium contents which lead to atomic weight values which are outside the range, 0.0001, of an atomic weight value of either 1.0080, or 1.0079, respectively. The Commission retains the previously recommended atomic weight but now adds the footnotes x and y to account for the above mentioned cases. Hydrogen will be reconsidered in the overall review in 1981 when the Commission revises the policy on quoted uncertainties on atomic weights.

Oxygen

Oxygen is another element for which the uncertainty presents a problem. The recommended atomic weight value $A_r(O)=15.9994\pm0.0003$ is based on the isotopic composition in the atmosphere as measured by Nier (Ref. 7) and reanalyzed by Craig (Ref. 61). Lorius (Ref. 62) measured the $^{18}O/^{16}O$ value in antarctic ice, which corresponds to an atomic weight of 15.9990 outside the quoted range. The Commission adds the footnote x to account for this source of oxygen.

THE TABLE OF STANDARD ATOMIC WEIGHTS 1979

The changes listed in the previous Section are incorporated in the 1979 Table of Standard Atomic Weights (see next section). As has been customary, the Table is presented, firstly, in alphabetic order by English names of the elements (Table 1) and, secondly, in order of atomic numbers (Table 2). This year, the Commission's Subcommittee for the Assessment of Isotopic Composition (SAIC) has carefully reviewed all significant experimental and interpreative evidence bearing on atomic weights for all the elements. The results of this study are the above changes in atomic weight values and footnotes.

The need for new and better atomic weight determinations is felt as strongly as ever. The margin in precision between the best atomic weight determinations and the results of routinely available analytical techniques is shrinking and is nonexistent for elements such as Zn and Ge. The Commission notes work underway on the atomic weight of silver which directly affects the determination of the Faraday constant.

TERMINOLOGY

Previous discussions by the Commission on Atomic Weights (see especially the 1975 Report (Ref. 13)) have revealed difficulties arising from the current definition of "atomic weight." These stem from the fact that, for some elements, the atomic weight value stated to the precision available with present experimental techniques can differ for different samples, because these elements occur with different isotopic composition (in nature or by artificial alteration). In some fields of modern chemistry and technology an operational problem therefore exists which can no longer be disregarded. Such different "atomic weight" values are more precise than indicated by the uncertainties associated with the present definition of atomic weight. At the 1975 IUPAC General Assembly in Madrid, and the 1977 assembly in Warsaw, the Commission received the comments and advice from an Open Meeting conducted in cooperation with the IUPAC Inorganic Division, the Interdivisional Committee on Education and other IUPAC commissions concerned with terminology. After those open meetings, the Atomic Weights Commission accepted the responsibility to propose a new definition of an atomic weight of an element at the 1979 Davos General Assembly. At a joint meeting in Davos of IUPAC Commissions on Inorganic Nomenclature, Atomic Weights, Organic Nomenclature, Analytical Nomenclature, Physico-Chemical Symbols, Terminology and Units, Committee on Teaching of Chemistry and the Interdivisional Committee on Nomenclature and Symbols, a new definition resulted.

The definition of an atomic weight (mean relative atomic mass) of an element from a specified source is "The ratio of the average mass per atom of the element to 1/12 of the mass of an atom of ^{12}C."

Remarks on the definition:

(1) Atomic weights can be defined for any sample.

(2) Atomic weights are evaluated for atoms in their electronic and nuclear ground states.

(3) The "average mass per atom" in a specified source is the total mass of the element divided by the total number of atoms of that element.

(4) Dated Tables of Standard Atomic Weights published by the Commission refer to our best knowledge of the elements in natural terrestrial sources.

The new definition by itself does not solve the principal problem of the Commission namely how to present the most accurate available values for those who need to use them. The concept of accuracy implies the existence of a true value and the definition purposely denies or at any rate fails to recognize the existence of one true value for every element.

TABLE 1. Standard Atomic Weights 1979

(Scaled to the relative atomic mass, $\underline{A}_r(^{12}C)=12$)

The atomic weights of many elements are not invariant but depend on the origin and treatment of the material. The footnotes to this Table elaborate the types of variation to be expected for individual elements. The values of $\underline{A}_r(E)$ given here apply to elements as they exist naturally on earth and to certain artificial elements. When used with due regard to the footnotes they are considered reliable to ±1 in the last digit or ±3 when followed by an asterisk*. Values in parentheses are used for radioactive elements whose atomic weights cannot be quoted precisely without knowledge of the origin of the elements; the value given is the atomic mass number of the isotope of that element of longest known half life.

Alphabetical order in English

Name	Symbol	Atomic number	Atomic weight	Footnotes
Actinium	Ac	89	227.0278	z
Aluminium	Al	13	26.98154	
Americium	Am	95	(243)	
Antimony (Stibium)	Sb	51	121.75*	
Argon	Ar	18	39.948	w x
Arsenic	As	33	74.9216	
Astatine	At	85	(210)	
Barium	Ba	56	137.33	x
Berkelium	Bk	97	(247)	
Beryllium	Be	4	9.01218	
Bismuth	Bi	83	208.9804	
Boron	B	5	10.81	w y
Bromine	Br	35	79.904	
Cadmium	Cd	48	112.41	x
Caesium	Cs	55	132.9054	
Calcium	Ca	20	40.08	x
Californium	Cf	98	(251)	
Carbon	C	6	12.011	w
Cerium	Ce	58	140.12	x
Chlorine	Cl	17	35.453	
Chromium	Cr	24	51.996	
Cobalt	Co	27	58.9332	
Copper	Cu	29	63.546*	w
Curium	Cm	96	(247)	
Dysprosium	Dy	66	162.50*	
Einsteinium	Es	99	(252)	
Erbium	Er	68	167.26*	
Europium	Eu	63	151.96	x
Fermium	Fm	100	(257)	
Fluorine	F	9	18.998403	
Francium	Fr	87	(223)	
Gadolinium	Gd	64	157.25*	x
Gallium	Ga	31	69.72	
Germanium	Ge	32	72.59*	
Gold	Au	79	196.9665	
Hafnium	Hf	72	178.49*	
Helium	He	2	4.00260	x
Holmium	Ho	67	164.9304	
Hydrogen	H	1	1.0079	w x y
Indium	In	49	114.82	x
Iodine	I	53	126.9045	
Iridium	Ir	77	192.22*	
Iron	Fe	26	55.847*	
Krypton	Kr	36	83.80	x y
Lanthanum	La	57	138.9055*	x
Lawrencium	Lr	103	(260)	
Lead	Pb	82	207.2	w x
Lithium	Li	3	6.941*	w x y
Lutetium	Lu	71	174.967*	
Magnesium	Mg	12	24.305	x
Manganese	Mn	25	54.9380	
Mendelevium	Md	101	(258)	

TABLE 1. Standard Atomic Weights 1979 (cont'd)

Name	Symbol	Atomic number	Atomic weight	Footnotes
Mercury	Hg	80	200.59*	
Molybdenum	Mo	42	95.94	
Neodymium	Nd	60	144.24*	x
Neon	Ne	10	20.179	y
Neptunium	Np	93	237.0482	z
Nickel	Ni	28	58.69	
Niobium	Nb	41	92.9064	
Nitrogen	N	7	14.0067	
Nobelium	No	102	(259)	
Osmium	Os	76	190.2	x
Oxygen	O	8	15.9994*	w x
Palladium	Pd	46	106.42	x
Phosphorus	P	15	30.97376	
Platinum	Pt	78	195.08*	
Plutonium	Pu	94	(244)	
Polonium	Po	84	(209)	
Potassium (Kalium)	K	19	39.0983	
Praseodymium	Pr	59	140.9077	
Promethium	Pm	61	(145)	
Protactinium	Pa	91	231.0359	z
Radium	Ra	88	226.0254	x z
Radon	Rn	86	(222)	
Rhenium	Re	75	186.207	
Rhodium	Rh	45	102.9055	
Rubidium	Rb	37	85.4678*	x
Ruthenium	Ru	44	101.07*	x
Samarium	Sm	62	150.36*	x
Scandium	Sc	21	44.9559	
Selenium	Se	34	78.96*	
Silicon	Si	14	28.0855*	
Silver	Ag	47	107.868	x
Sodium (Natrium)	Na	11	22.98977	
Strontium	Sr	38	87.62	x
Sulfur	S	16	32.06	w
Tantalum	Ta	73	180.9479	
Technetium	Tc	43	(98)	
Tellurium	Te	52	127.60*	x
Terbium	Tb	65	158.9254	
Thallium	Tl	81	204.383	
Thorium	Th	90	232.0381	x z
Thulium	Tm	69	168.9342	
Tin	Sn	50	118.69*	
Titanium	Ti	22	47.88*	
Tungsten (Wolfram)	W	74	183.85*	
(Unnilhexium)	(Unh)	106	(263)	
(Unnilpentium)	(Unp)	105	(262)	
(Unnilquadium)	(Unq)	104	(261)	
Uranium	U	92	238.0289	x y
Vanadium	V	23	50.9415	
Xenon	Xe	54	131.29*	x y
Ytterbium	Yb	70	173.04*	
Yttrium	Y	39	88.9059	
Zinc	Zn	30	65.38	
Zirconium	Zr	40	91.22	x

w Element for which known variations in isotopic composition in normal terrestrial material prevent a more precise atomic weight being given; $\underline{A}_r$(E) values should be applicable to any "normal" material.

x Element for which geological specimens are known in which the element has an anomalous isotopic composition, such that the difference between the atomic weight of the element in such specimens and that given in the Table may exceed considerably the implied uncertainty.

y Element for which substantial variations in $\underline{A}_r$ from the value given can occur in commercially available material because of inadvertent or undisclosed change of isotopic composition.

z Element for which the value of $\underline{A}_r$ is that of the radioisotope of longest half-life.

TABLE 2. Standard Atomic Weights 1979

(Scaled to the relative atomic mass $\underline{A}_r(^{12}C) = 12$)

The atomic weights of many elements are not invariant but depend on the origin and treatment of the material. The footnotes to this Table elaborate the types of variation to be expected for individual elements. The values of $\underline{A}_r$ (E) given here apply to elements as they exist naturally on earth and to certain artificial elements. When used with due regard to the footnotes they are considered reliable to ±1 in the last digit or ±3 when followed by an asterisk.* Values in parentheses are used for radioactive elements whose atomic weights cannot be quoted precisely without knowledge of the origin of the elements; the value given is the atomic mass number of the isotope of that element of longest known half life.

Order of Atomic Number

Atomic Number	Name	Symbol	Atomic Weight	Footnotes
1	Hydrogen	H	1.0079	w x y
2	Helium	He	4.00260	x
3	Lithium	Li	6.941*	w x y
4	Beryllium	Be	9.01218	
5	Boron	B	10.81	w y
6	Carbon	C	12.011	w
7	Nitrogen	N	14.0067	
8	Oxygen	O	15.9994*	w x
9	Fluorine	F	18.998403	
10	Neon	Ne	20.179	y
11	Sodium (Natrium)	Na	22.98977	
12	Magnesium	Mg	24.305	x
13	Aluminium	Al	26.98154	
14	Silicon	Si	28.0855*	
15	Phosphorus	P	30.97376	
16	Sulfur	S	32.06	w
17	Chlorine	Cl	35.453	
18	Argon	Ar	39.948	w x
19	Potassium (Kalium)	K	39.0983	
20	Calcium	Ca	40.08	x
21	Scandium	Sc	44.9559	
22	Titanium	Ti	47.88*	
23	Vanadium	V	50.9415	
24	Chromium	Cr	51.996	
25	Manganese	Mn	54.9380	
26	Iron	Fe	55.847*	
27	Cobalt	Co	58.9332	
28	Nickel	Ni	58.69	
29	Copper	Cu	63.546*	w
30	Zinc	Zn	65.38	
31	Gallium	Ga	69.72	
32	Germanium	Ge	72.59*	
33	Arsenic	As	74.9216	
34	Selenium	Se	78.96*	
35	Bromine	Br	79.904	
36	Krypton	Kr	83.80	x y
37	Rubidium	Rb	85.4678*	x
38	Strontium	Sr	87.62	x
39	Yttrium	Y	88.9059	
40	Zirconium	Zr	91.22	x
41	Niobium	Nb	92.9064	
42	Molybdenum	Mo	95.94	
43	Technetium	Tc	(98)	
44	Ruthenium	Ru	101.07*	x
45	Rhodium	Rh	102.9055	
46	Palladium	Pd	106.42	x
47	Silver	Ag	107.868	x
48	Cadmium	Cd	112.41	x
49	Indium	In	114.82	x
50	Tin	Sn	118.69*	
51	Antimony (Stibium)	Sb	121.75*	
52	Tellurium	Te	127.60*	x
53	Iodine	I	126.9045	
54	Xenon	Xe	131.29*	x y
55	Caesium	Cs	132.9054	

TABLE 2. Standard Atomic Weights 1979 (cont'd)

Atomic Number	Name	Symbol	Atomic Weight	Footnotes
56	Barium	Ba	137.33	x
57	Lanthanum	La	138.9055*	x
58	Cerium	Ce	140.12	x
59	Praseodymium	Pr	140.9077	
60	Neodymium	Nd	144.24*	x
61	Promethium	Pm	(145)	
62	Samarium	Sm	150.36*	x
63	Europium	Eu	151.96	x
64	Gadolinium	Gd	157.25*	x
65	Terbium	Tb	158.9254	
66	Dysprosium	Dy	162.50*	
67	Holmium	Ho	164.9304	
68	Erbium	Er	167.26*	
69	Thulium	Tm	168.9342	
70	Ytterbium	Yb	173.04*	
71	Lutetium	Lu	174.967*	
72	Hafnium	Hf	178.49*	
73	Tantalum	Ta	180.9479	
74	Wolfram (Tungsten)	W	183.85*	
75	Rhenium	Re	186.207	
76	Osmium	Os	190.2	x
77	Iridium	Ir	192.22*	
78	Platinum	Pt	195.08*	
79	Gold	Au	196.9665	
80	Mercury	Hg	200.59*	
81	Thallium	Tl	204.383	
82	Lead	Pb	207.2	w x
83	Bismuth	Bi	208.9804	
84	Polonium	Po	(209)	
85	Astatine	At	(210)	
86	Radon	Rn	(222)	
87	Francium	Fr	(223)	
88	Radium	Ra	226.0254	x z
89	Actinium	Ac	227.0278	z
90	Thorium	Th	232.0381	x z
91	Protactinium	Pa	231.0359	z
92	Uranium	U	238.0289	x y
93	Neptunium	Np	237.0482	z
94	Plutonium	Pu	(244)	
95	Americium	Am	(243)	
96	Curium	Cm	(247)	
97	Berkelium	Bk	(247)	
98	Californium	Cf	(251)	
99	Einsteinium	Es	(252)	
100	Fermium	Fm	(257)	
101	Mendelevium	Md	(258)	
102	Nobelium	No	(259)	
103	Lawrencium	Lr	(260)	
104	(Unnilquadium)	(Unq)	(261)	
105	(Unnilpentium)	(Unp)	(262)	
106	(Unnilhexium)	(Unh)	(263)	

w Element for which known variations in isotopic composition in normal terrestrial material prevent a more precise atomic weight being given; $\underline{A}_r$(E) values should be applicable to any "normal" material.

x Element for which geological specimens are known in which the element has an anomalous isotopic composition, such that the difference between the atomic weight of the element in such specimens and that given in the Table may exceed considerably the implied uncertainty.

y Element for which substantial variations in $\underline{A}_r$ from the value given can occur in commercially available material because of inadvertent or undisclosed change of isotopic composition.

z Element for which the value of $\underline{A}_r$ is that of the radioisotope of longest half-life.

LABELLING OF WELL CHARACTERIZED MATERIALS

As pointed out in the 1975 and 1977 Reports (Ref. 13,58) the Commission is concerned that the useful practice of quoting atomic or molecular weights on bottles could be misleading for compounds prepared from residues of an undisclosed isotope separation process. One of the following statements continues to be recommended when additional labelling is judged advisable to avoid possible misconceptions or errors by the user, or to reassure the user of the "normality" of the material.
(1) Atomic weights conform with values published in the IUPAC Table of Standard Atomic Weights. (It might be considered desirable, though not essential, to include the date of the IUPAC Table referred to.)
(2) The actual atomic weights of element(s)....in this particular sample is (are)....(In this statement "atomic weight(s)" could be replaced by "isotopic composition(s).")
(3) Element X is enriched (depleted) in isotope ^{y}X.
In some materials statement (1) can be applied to some elements and statement (2) can be made for one or more other elements in the same sample. Probable error limits would often be helpful in statement (2), and also in statement (3) when it is combined with quantitative data expressed as isotopic composition. Some manufacturers have already started quoting isotopic composition on their labels. The Reagents Committee of the American Chemical Society has already added a warning to reagent grade uranium, boron and lithium chemicals.
The Commission has requested the widest possible dissemination of these proposals and welcomes comments especially before its next meeting in 1981. Such comments and related questions should be directed to the Commission's Secretary, Prof. R.L. Martin, Vice Chancellor, Monash University, Clayton, Victoria, 3168, Australia.

THE ISOTOPIC COMPOSITION OF THE ELEMENTS

At the request of the IUPAC Inorganic Division, a Subcommittee for the Assessment of Isotopic Composition (SAIC) was formed within the Commission on Atomic Weights and Isotopic Abundances (Ref. 13). SAIC is concerned with all measurements for deriving isotopic compositions. SAIC has produced another interim version of the "Table of Isotopic Compositions of the Elements as Determined by Mass Spectrometry," and it is reproduced here (Table 3). The interim values when converted to atomic weights are not all fully consistent with the 1979 Table of Standard Atomic Weights. Discrepancies are most noticeable in the cases of zinc, germanium, and selenium where the interim values lie outside the limit of uncertainty on the recommended atomic weight. For germanium, this corresponds to a difference of 0.06%.
For the 1981 meeting of the Commission, SAIC has been asked to include uncertainties from ±1 to ±9 on all isotopic compositions and atomic weights.
Present members of SAIC are P. De Bièvre (Chairman), I.L. Barnes, A.E. Cameron, R. Hagemann, N.E. Holden and H. Thode. Additional assistance has been provided by E. Roth, H.S. Peiser and T.J. Murphy.
The Commission thanks SAIC for its efforts in preparing Table 3.

NON-TERRESTRIAL DATA

The values of stable isotope abundances of elements from non-terrestrial sources form a rich and rapidly expanding body of information. Many significant variations from normal terrestrial isotopic abundance values have already been reported and more will undoubtedly be found in the future. The intention of the Commission on Atomic Weights and Isotopic Abundances to tabulate non-terrestrial isotopic abundances was signaled in the 1977 Report (Ref. 58). For the present Report, it seems appropriate to illustrate some of the most significant variations with the intention of considering later the completion of a more comprehensive listing.
Information about non-terrestrial isotopic abundances comes from several sources. The study of meteoritic materials provided the earliest samples of non-terrestrial material for direct analysis. More recently, the analysis of lunar samples has produced a large number of new results. Space probes carrying mass spectrometers or other abundance measuring equipment have been employed to analyze the atmospheres and surface materials of other planets and satellites. Finally, earth-based optical observations of various astronomical objects have led to the determination of some isotopic abundances for these objects.
There are many processes which can alter isotopic abundances. Firstly, there is mass fractionation, where the rate of a process is dependent on the mass of the atoms or molecules involved in the process. This mass fractionation will result from either unidirectional or equilibrium processes. This category included chemical reactions as well as processes dependent on thermal gradients, pressure gradients, interaction with electric, magnetic fields, diffusion fields or gravitational fields. A systematic variation in isotopic abundance for a series of isotopes in a multiisotopic element is usually considered to be sufficient proof that mass fractionation has occurred.
Secondly, isotopic abundances can be modified in various specific nuclear reactions. For example, there is the possibility that variations in the nucleosynthesis processes involved in element building may result in differing isotopic abundances for elements in matter from

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

Introduction

The Subcommission for the Assessment of Isotopic Composition (SAIC) has examined all of the literature available to it through August, 1979. The Subcommission has evaluated this data to produce a table of recommended isotopic abundances for the elements and the atomic weights calculated from these abundances. The table is intended to include values for terrestrial samples only and does not include values published for meteoritic or other extra terrestrial materials. A description of the contents of each of the columns contained within this table is given below:

Column Headings

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 elemental isotope is listed.

Column 4: Given are the highest and lowest abundances published for each isotope from measurements which have been evaluated and accepted by the Subcommission. The range given includes natural variations but does not include values for certain, exceptional, or unusual samples (these are noted with a "G" in column 5). No data are given in this column when the absence of a range has been, in the opinion of SAIC, reliably established.

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

"R" is appended when the range given corresponds to that of established natural variations.

"D" is appended when the range corresponds to differences between published values not supported by established natural variations.

"G" is appended when the element is known to have an anomalous composition in certain, natural terrestrial specimens.

"X" is appended when data from only one measurement are available.

"I" is appended when, as a result of reliable surveys, the isotopic composition is not believed to vary in terrestrial samples within the limits established. Though "I" is appended there may be rare or unusual samples where the values may differ and a "G" is also appended.

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 values given in parenthesis are the errors on the last corresponding digits and are given as in the original publication. Where no errors are given none were available in the literature. The errors are, of course, not given in any uniform manner in the literature and SAIC indicates this as follows: 1,2,3σ indicates 1, 2, or 3 sigma or standard deviations, P indicates probable error (as defined by the author) and SE indicates standard error. "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 since the data are reproduced from the literature the sum of the isotopic abundances may not be equal to 100 percent. The user is also cautioned that, when a range of compositions has been established, the samples used for the best measurement may come from any part of the range. Attention is drawn to the fact that 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 content 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 compositions should not be used for other than average properties.

2) The reader is reminded that for more precise work, as for example to work out 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.

Column 10: Listed are the atomic weights and uncertainties calculated from the data in the preceding column. For these calculations nuclidic masses were used as given by: A. H. Wapstra and K. Bos, "The 1977 Atomic Mass Evaluation", Atomic Data and Nuclear Data Tables, 19, 177 (1977). The values listed for mononuclidic elements are taken from the same source with the given uncertainties multiplied by a factor of six.

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

Atomic Number	Element	Mass Number	Evaluated Range of Published Values	Notes	Best Measurement from a Single Natural Source	Reference (Appendix A)	Available Reference Materials (Appendix B)	Representative Isotopic Composition
1	H	1	99.9918 - 99.9770	R,G	99.984426 (5) 2σ C	70HAG1	IAEA-V-SMOW*	99.985 (1)
		2	0.0230 - 0.0082		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 (5)
		4	100 - 99.9959		99.9998616 (6)			99.999862 (5)
								(for air only)
3	Li	6	7.65 - 7.30	R,G	7.68 (2) σ C	73FLE1	NBS-RS LSVEC*	7.5 (2)
		7	92.70 - 92.35		92.32 (2)			92.5 (2)
4	Be	9	---		100	63LEI1		100
5	B	10	20.316 - 19.098	R	19.82 (2) 2σ C	69BIE1	JRC-GEEL*,	20.0 (2)
		11	80.902 - 79.684		80.18 (2)		NBS-SRM 951	80.0 (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	99.63 (1)
		15	0.375 - 0.361		0.366 (1)		NBS-RS NSVEC*	0.37 (1)
8	O	16	99.7771 - 99.7539	R	99.7628 (5) σ C	76BAE1	NBS-RS 20	99.762 (15)
		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 (3)
		21	1.71 - 0.266		0.266 (5)			0.27 (1)
		22	9.96 - 9.20		9.220 (29)			9.22 (3)
11	Na	23	---		100	56WHI1		100
12	Mg	24	---	I	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)

Atomic Number	Element	Mass Number	Evaluated Range of Published Values	Notes	Best Measurement from a Single Natural Source	Reference (Appendix A)	Available Reference Materials (Appendix B)	Representative Isotopic Composition
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	---	I	75.771 (45) 3σ C	62SHI2	NBS-SRM 975*	75.77 (5)
		37			24.229 (45)			24.23 (5)
18	Ar	36	---	G,I	0.337 (1) C	50NIE1	Air*	0.337 (2)
		38			0.063 (1)			0.063 (2)
		40			99.600 (1)			99.600 (3)
19	K	39	---	I	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	---	G,I	96.941 (1) 2σ	72MOO1	NBS-SRM 915*	96.941 (2)
		42			0.647 (1)			0.647 (2)
		43			0.135 (1)			0.135 (2)
		44			2.086 (1)			2.086 (2)
		46			0.004 (1)			0.004 (2)
		48			0.187 (1)			0.187 (2)
21	Sc	45	---		100	50LEL1		100
22	Ti	46	---	I	8.24 (46) σ C	68BEL1		8.2 (5)
		47			7.44 (22)			7.4 (3)
		48			73.71 (48)			73.8 (5)
		49			5.43 (16)			5.4 (2)
		50			5.18 (31)			5.2 (3)
23	V	50	---	G,I	0.2497 (6) S.E. C	66FLE1		0.250 (1)
		51			99.7503 (6)			99.750 (1)

Atomic Number	Element	Mass Number	Evaluated Range of Published Values	Notes	Best Measurement from a Single Natural Source	Reference (Appendix A)	Available Reference Materials (Appendix B)	Representative Isotopic Composition
24	Cr	50	---	I	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	D	5.81	47VAL1		5.8 (1)
		56	91.79 - 91.52		91.75			91.7 (3)
		57	2.25 - 2.11		2.15			2.2 (1)
		58	0.34 - 0.28		0.29			0.3 (1)
27	Co	59	---		100	63LEI1		100
28	Ni	58	68.274 - 67.76	D	68.274 (1) 2σ	73BAR1		68.27 (2)
		60	26.424 - 26.095		26.095 (1)			26.10 (3)
		61	1.25 - 1.134		1.134 (1)			1.13 (2)
		62	3.711 - 3.593		3.593 (1)			3.59 (4)
		64	1.16 - 0.904		0.904 (1)			0.91 (3)
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	D	48.63 (13) 2σ	72ROS1		48.6 (2)
		66	27.9 - 27.6		27.90 (8)			27.9 (1)
		67	4.17 - 4.07		4.10 (3)			4.1 (1)
		68	18.75 - 18.48		18.75 (16)			18.8 (2)
		70	0.69 - 0.62		0.62 (1)			0.6 (1)
31	Ga	69	60.5 - 59.988	D	60.078 (108) 2σ C	76LAE1		60.1 (1)
		71	40.012 - 39.5		39.922 (108)			39.9 (1)
32	Ge	70	20.96 - 19.92	D	20.52 (17) P	53REY1		20.5 (3)
		72	27.64 - 27.26		27.43 (21)			27.4 (3)
		73	7.88 - 7.51		7.76 (8)			7.8 (1)
		74	37.41 - 36.27		36.53 (23)			36.5 (3)
		76	7.97 - 7.46		7.76 (8)			7.8 (1)
33	As	75	---		100	63LEI1		100

Atomic Number	Element	Mass Number	Evaluated Range of Published Values	Notes	Best Measurement from a Single Natural Source	Reference (Appendix A)	Available Reference Materials (Appendix B)	Representative Isotopic Composition
34	Se	74	0.888 - 0.877	R[a]	0.88 (1)	48WHI1		0.9 (1)
		76	9.002 - 8.932		8.95 (3)			9.0 (1)
		77	7.680 - 7.640		7.65 (3)			7.6 (1)
		78	23.560 - 23.497		23.51 (11)			23.5 (3)
		80	49.538 - 49.655		49.62 (14)			49.6 (4)
		82	9.331 - 9.399		9.39 (9)			9.4 (3)
35	Br	79	---	I	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,D	0.360 (4) P	73WAL1	Air*	0.35 (2)
		80	2.29 - 2.223		2.277 (4)			2.25 (2)
		82	11.58 - 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,D	72.1654 (132) 3σ C	69CAT1	NBS-SRM 984*	72.17 (2)
		87	27.86 - 27.76		27.8346 (132)			27.83 (2)
38	Sr	84	0.58 - 0.55	G,R	0.5574 (15) 3σ C	80MOO1	NBS-SRM's 987*, 988, 607	0.56 (1)
		86	9.99 - 9.75		9.8566 (26)			9.86 (1)
		87	7.14 - 6.94		7.0015 (14)			7.00 (1)
		88	82.75 - 82.29		82.5845 (46)			82.58 (1)
39	Y	89	---		100	57COL1		100
40	Zr	90	51.7 - 51.12	D,G	51.449 (59) σ	78SHI2		51.45 (18)
		91	11.23 - 10.8		11.320 (15)			11.32 (5)
		92	17.4 - 17.1		17.189 (21)			17.19 (6)
		94	17.57 - 17.38		17.283 (21)			17.28 (6)
		96	2.9 - 2.79		2.759 (4)			2.76 (1)
41	Nb	93	---		100	56WHI1		100

[a] A range has been established which is smaller than values reported in the literature.

Atomic Number	Element	Mass Number	Evaluated Range of Published Values	Notes	Best Measurement from a Single Natural Source	Reference (Appendix A)	Available Reference Materials (Appendix B)	Representative Isotopic Composition
42	Mo	92	15.05 - 14.74	D,G	14.8362 (148) 2σ	74MOO1		14.84 (2)
		94	9.35 - 9.11		9.2466 (92)			9.25 (1)
		95	15.93 - 15.78		15.9201 (159)			15.92 (2)
		96	16.71 - 16.56		16.6756 (167)			16.68 (2)
		97	9.6 - 9.48		9.5551 (96)			9.55 (1)
		98	24.42 - 24.00		24.1329 (241)			24.13 (3)
		100	9.63 - 9.60		9.6335 (96)			9.63 (1)
43	Tc	--	---		---			---
44	Ru	96	5.57 - 5.47	D,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	---	G,I	1.020 (8) 2σ C	78SHI1		1.020 (12)
		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	---	I	51.830 (26) 3σ C	62SHI1	NBS-SRM 978*	51.83 (3)
		109			48.170 (26)			48.17 (3)
48	Cd	106	---	G,I	1.25 (1) 2σ C	75ROS1		1.25 (2)
		108			0.894 (1)			0.89 (1)
		110			12.51 (1)			12.51 (2)
		111			12.81 (1)			12.81 (2)
		112			24.13 (1)			24.13 (2)
		113			12.22 (1)			12.22 (2)
		114			28.71 (1)			28.72 (2)
		116			7.47 (1)			7.47 (2)
49	In	113	4.33 - 4.16	D,G	4.33 (4)	56WHI1		4.3 (2)
		115	95.84 - 95.67		95.67 (4)			95.7 (2)

Atomic Number	Element	Mass Number	Evaluated Range of Published Values	Notes	Best Measurement from a Single Natural Source	Reference (Appendix A)	Available Reference Materials (Appendix B)	Representative Isotopic Composition
50	Sn	112	1.017 - 0.90	D,G	1.01 (3)	65LAE1		1.0 (2)
		114	0.681 - 0.61		0.67 (3)			0.7 (2)
		115	0.376 - 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	---	X	57.25 (3)	48WHI1		57.3 (9)
		123			42.75 (3)			42.7 (9)
52	Te	120	---	G,I	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	D,G	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	4.07 - 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	Element	Mass Number	Evaluated Range of Published Values	Notes	Best Measurement from a Single Natural Source	Reference (Appendix A)	Available Reference Materials (Appendix B)	Representative Isotopic Composition
56	Ba	130	---	G,I	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	-[b]	G	0.089 (2)	56WHI1		0.09 (2)
		139			99.911 (2)	47ING2		99.91 (2)
58	Ce	136	0.195 - 0.190	D,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	D,G	27.157	74BAR1		27.16 (7)
		143	12.32 - 12.12		12.177	76NAK1		12.18 (3)
		144	23.97 - 23.795		23.795			23.80 (7)
		145	8.35 - 8.23		8.293			8.29 (2)
		146	17.35 - 17.06		17.188			17.19 (3)
		148	5.78 - 5.66		5.755			5.75 (2)
		150	5.69 - 5.53		5.635			5.63 (2)
61	Pm	---	---		---			---
62	Sm	144	3.16 - 2.87	D,G	3.12	75LUG1		3.1 (1)
		147	15.10 - 14.87		15.10			15.1 (2)
		148	11.35 - 11.22		11.30			11.3 (1)
		149	13.96 - 13.82		13.86			13.9 (1)
		150	7.47 - 7.36		7.38			7.4 (1)
		152	26.90 - 26.55		26.65			26.6 (2)
		154	22.88 - 22.43		22.59			22.6 (2)
63	Eu	151	47.86 - 47.75	D,G	47.77 (20)	48HES1		47.8 (5)
		153	52.25 - 52.14		52.23 (20)			52.2 (5)

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

Atomic Number	Element	Mass Number	Evaluated Range of Published Values	Notes	Best Measurement from a Single Natural Source	Reference (Appendix A)	Available Reference Materials (Appendix B)	Representative Isotopic Composition
64	Gd	152	0.205 - 0.20	D,G	0.20 (1)	48HES1		0.20 (3)
		154	2.23 - 2.1		2.15 (2)			2.1 (1)
		155	15.1 - 14.68		14.78 (15)			14.8 (4)
		156	20.67 - 20.36		20.59 (21)			20.6 (5)
		157	15.73 - 15.64		15.71 (16)			15.7 (4)
		158	24.96 - 24.5		24.78 (25)			24.8 (6)
		160	22.01 - 21.6		21.79 (22)			21.8 (6)
65	Tb	159	---		100	57COL1		100
66	Dy	156	0.064 - 0.0524	D,G	0.057 (1) σ	57COL1		0.06 (1)
		158	0.105 - 0.0902		0.100 (1)			0.10 (1)
		160	2.36 - 2.294		2.35 (2)			2.34 (4)
		161	19.0 - 18.73		19.0 (1)			19.0 (2)
		162	25.53 - 25.36		25.5 (2)			25.5 (4)
		163	24.97 - 24.9		24.9 (2)			24.9 (4)
		164	28.47 - 28.1		28.1 (2)			28.1 (4)
67	Ho	165	---		100	57COL1		100
68	Er	162	0.154 - 0.136	D,G	0.136 (3) P	50HAY1		0.14 (1)
		164	1.60 - 1.56		1.56 (3)			1.56 (6)
		166	33.41 - 33.36		33.41 (30)			33.4 (6)
		167	22.94 - 22.82		22.94 (20)			22.9 (4)
		168	27.07 - 27.02		27.07 (30)			27.1 (6)
		170	15.04 - 14.88		14.88 (20)			14.9 (4)
69	Tm	169	---		100	57COL1		100
70	Yb	168	---	G,I	0.136 (1) 2 S.E.	77MCC1		0.14 (1)
		170			3.063 (3)			3.06 (3)
		171			14.334 (9)			14.3 (1)
		172			21.879 (10)			21.9 (1)
		173			16.122 (9)			16.1 (1)
		174			31.768 (20)			31.8 (2)
		176			12.698 (6)			12.7 (1)
71	Lu	175	---	G,I	97.393 (5) 2σ	76MCC1		97.39 (2)
		176			2.607 (5)			2.61 (2)

Atomic Number	Element	Mass Number	Evaluated Range of Published Values	Notes	Best Measurement from a Single Natural Source	Reference (Appendix A)	Available Reference Materials (Appendix B)	Representative Isotopic Composition
72	Hf	174	0.199 - 0.163	D	0.163 (2)	56WHI1		0.2 (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)			13.7 (3)
		180	35.44 - 35.07		35.22 (10)			35.2 (5)
73	Ta	180	0.0123 - 0.0117	D	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	D	0.126 (6)	48WHI1		0.10 (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)			30.7 (2)
		186	28.85 - 28.38		28.64 (3)			28.6 (2)
75	Re	185	---	I	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	D,G	0.018 (2) P	37NIE1		0.020 (4)
		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	---	X	37.3	54BAL1		37.3 (3)
		193			62.7			62.7 (3)
78	Pt	190	0.0127 - 0.012	D	0.0127 (5)	56WHI1		0.010 (3)
		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	Element	Mass Number	Evaluated Range of Published Values	Notes	Best Measurement from a Single Natural Source	Reference (Appendix A)	Available Reference Materials (Appendix B)	Representative Isotopic Composition
80	Hg	196	0.16 - 0.147	D	0.156 (10) σ	55DIB1		0.2 (1)
		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)			29.6 (8)
		204	6.85 - 6.69		6.79 (5)			6.8 (3)
81	Tl	203	---	I	29.524 (9) 3σ C	80DUN1	NBS-SRM 997*	29.524 (18)
		205			70.476 (9)			70.476 (18)
82	Pb	204	1.65 - 1.04	R,G	1.4245 (12) 3σ C	68CAT1	NBS-SRM 981*	1.4 (1)[c]
		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	---		100	36DEM1		100
91	Pa	---	---					---
92	U	234	0.0059 - 0.0050	R,G[a]	0.0054 C	57SMI1	NBS-SRM's	0.005 (1)
		235	0.7202 - 0.7198		0.7200	76COW1	U0002-U970*	0.720 (1)
		238	99.2752 - 99.2739		99.2746		C.E.A.	99.275 (2)
93	Np	237	---					---

[a] A range has been established which is smaller than values reported in the literature.
[c] Representative isotopic composition is for most but not all commercial samples.

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Appendix B

Sources of Reference Materials

I.A.E.A.

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

International Atomic Energy Agency
Section of Hydrology
A-1011 Vienna, Kaerntnerring, (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.)

JRC-GEEL

Reference Materials may be obtained through:

Dr. Paul De Bievre
European Commission
Central Bureau for Nuclear Measurements
B-2440 Geel, (Belgium)

NBS-RS (Reference Samples)

Samples may be obtained through:

Chief, Inorganic Analytical Research Division
National Bureau of Standards
A219 Chemistry 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 de Saclay
B.P. n°2 - 91190 Gif-sur-Yvette (France)

TABLE 4. Examples of variations in isotopic composition for selected elements in non-terrestrial samples.

Element	Stable Mass Numbers	Source of Sample	Range of Value	1979 SAIC Representative Value	Probable Process	Ref.
H	1 2	Optical measurements on interstellar matter	$\frac{D}{H}$ greater than 2×10^{-6} and less than 2×10^{-4}	$\frac{D}{H} = 1.5\times10^{-4}$	Varying nucleosynthesis?	73 Bla
		Lunar soil	δD as low as -846 ‰	-	Bombardment by solar wind	73 Eps
He	3 4	Lunar surface material	$^{3}He/^{4}He \sim 4.4\times10^{-4}$ $\sim$400 times earth ratio	$^{3}He/^{4}He = 4\times10^{-6}$	Solar wind and spallation reaction	71 Meg
C	12 13	Lunar soil	$\delta^{13}C$ from +20 to -30 ‰	-	Solar wind carbon	73 Eps
O	16 17 18	Lunar soil, surface	$\delta^{18}O$ as large as +49 ‰	$\delta^{18}O = 0$ for Standard Mean Ocean Water	Mass fractionation in surface processes	73 Tay
		Lunar rocks (minerals)	$\delta^{18}O$ up to 6.5 ‰		Mass fractionation at different temperatures	70 Onu
		Allende meteorite				
		(1) Minerals	$\delta^{18}O > 10$ ‰		Mass fractionation isotope exchange equilibria	74 Onu 77 Cla
		(2) Bulk	Up to 1% pure ^{16}O component		Nucleosynthesis anomaly + mass fractionation	77 Cla

TABLE 4. Examples of variations in isotopic composition for selected elements in non-terrestrial samples. (cont'd)

Element	Stable Mass Numbers	Source of Sample	Range of Value	1979 SAIC Representative Value (in atom %)	Probable Process	Ref.
O	16 17 18	(3) Mineral separates	Up to 5% pure ^{16}O		Nucleosynthesis anomaly + mass fractionation	77 Cla
N	14 15	Lunar soil surface	$\delta^{15}N$ up to +120 ‰	-	Present day solar wind nitrogen	77 Bec
		Lunar drill core	$\delta^{15}N$ up to -105 ‰	-	Early solar wind nitrogen	77 Bec
		Lunar step heating	Pure ^{15}N	-	Spallation component	77 Bec
Ne	20 21 22	Sodium rich minerals in meteorites	30.3 to 30.88% 33.05 to 32.89% 36.64 to 36.72%	90.51% .27% 9.22%	Cosmic ray spallation reactions	75 Smi
Mg	24 25 26	Allende meteorite inclusions	$\delta^{26}Mg$ up to +400 ‰	-	Extinct radioactive decay of ^{26}Al	79 Bra
Si	28 29 30	Lunar soil surface	$\delta^{30}Si$ as high as +18 ‰	-	Mass fractionation	73 Tay
		Meteorite minerals	$\delta^{30}Si$ as high as +12 ‰	-	Mass fractionation	73 Tay
S	32 33 34 36	Lunar soil grain size < 5μ	$\delta^{34}S$ as high as +20 ‰	-	Mass fractionation	76 Tho
		Lunar soil bulk	$\delta^{34}S$ as high as +11 ‰	-	Mass fractionation	76 Tho

TABLE 4. Examples of variations in isotopic composition for selected elements in non-terrestrial samples. (cont'd)

Element	Stable Mass Numbers	Source of Sample	Range of Value	1979 SAIC Representative Value (in atom %)	Probable Process	Ref.
S	32 33 34	Carbonaceous meteorites	$\delta^{34}S$ as high as +2.5 ‰ and as low as -1.7 ‰	-	Mass fractionation	65 Hul
	33	Allende meteorite	$\delta^{33}S$ up to 1 ‰	-	Nucleosynthesis anomaly	77 Ree
Ar	36 38 40	Mars Atmosphere	0.030% 0.006% 99.96%	0.33% 0.06% 99.6%	Atmospheric mass fractionation?	76 Nie
Ca	40 42 43 44 46 48	Allende meteorite (Hibonite)	Isotope shift uniform 7.5 ‰ per mass unit favoring heavy isotopes	-	Mass fractionation	79 Lee
			Non-lunar effect 2 ‰ per mass unit	-	Nuclear effect	79 Lee
Cd	106 108 110 111 112 113 114 115 116	Meteorite Tieschitz	2.3 ‰ per mass unit for isotopes from 110 to 116	-	Mass fractionation	78 Ros
Xe	124 126 128	Meteorites	$^{129}Xe/^{132}Xe$ as large as 12 times atmospheric ratio.	-	Radiogenic, from the decay of trapped ^{129}I to Xe^{129}	74 Rey

TABLE 4. Examples of variations in isotopic composition for selected elements in non-terrestrial samples. (cont'd)

Element	Stable Mass Numbers	Source of Sample	Range of Value	1979 SAIC Representative Value	Probable Process	Ref.
Xe	129 130 131 132 134	Meteorites	Excess of heavy isotopes. For example, ^{136}Xe excess as large as 150%.	-	Fission product components	74 Rey
U	234 235 238	Meteorites	$\delta^{238}U$ from -2 ‰ to -225 ‰	-	Nucleosynthesis or chemical fractionation of ^{247}Cf with uranium and subsequent decay of ^{247}Cf to ^{235}U	77 Ard

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different parts of the universe. Other nuclear processes such as radioactive decay, nuclear fission or fusion and nuclear reactions induced by cosmic ray bombardment or natural radioactivity can enhance or deplete specific isotopes in a sample.
Finally, solar wind implantation is an example of a third series of processes that can modify isotopic abundances. Bulk currents of particles with modified isotope ratios which originate in other parts of the universe can be implanted in samples by collision sometimes in sufficient quantities to measurably modify the isotopic abundance of these elements in the samples.
It is often the case that more than one of these processes can occur in a given sample. For example, the measurements of magnesium isotope ratios in Allende meteorite samples by Wasserburg et al. (Ref. 63) have led to the conclusion that both mass fractionation and an unknown nuclear process have contributed to the isotopic abundance variations.
Table 4 lists a series of examples of measurements of isotopic abundance for various elements in indicated non-terrestrial samples in which variation in isotopic composition from terrestrial values is reported. We have chosen these table entries to illustrate the range of variation as well as the variety of processes which can produce them.
Isotopic abundance variations are reported in several different but related ways. In some cases a numerical isotope ratio such as $D/H = 1.5 \times 10^{-4}$ is employed. For multi-isotopic elements the percentage abundance of each isotope is sometimes listed and can be compared directly to similar abundance information for terrestrial material. In many cases, the variation given is reported as a 'del' value which is expressed in parts per thousand (‰) where

$$\delta(A), ‰ = \frac{(\text{measured isotope ratio A/B} - (\text{standard isotope ratio A/B})}{\text{standard isotope ratio A/B}} \times 1000$$

One of these three quantities is employed in Table 4 to illustrate isotopic variation for a given element and sample. Where comparison is required (i.e., for isotope ratio and isotopic abundance data), the 1979 SAIC representative value is listed for comparison.
Although this discussion has concentrated on variations of isotope ratios in non-terrestrial samples, in a number of cases isotopic abundances are the same in non-terrestrial and terrestrial samples. For example, agreement has been reported for lutetium (Ref. 64) and tellurium (Ref. 65) in meteoritic samples, and for magnesium, calcium, nickel, chromium, rubidium and uranium (Ref. 28) and potassium, strontium, lead and thorium (Ref. 66) in various lunar samples.

RELATIVE ATOMIC MASSES AND HALF-LIVES OF SELECTED RADIONUCLIDES

For many years the Commission on Atomic Weights has included in its Reports tables of relative atomic masses of selected nuclides and half-lives of some radionuclides, although it has no prime responsibility for the dissemination of such values. No attempt has, therefore, been made to state these values at the best precision possible or to make them any more complete than is needed to enable users to calculate the atomic weights of materials of abnormal or changing isotopic composition. In future years the Commission intends to tabulate the relative atomic masses within the isotopic composition tables. In this year's Table of relative atomic masses of selected radionuclides (Table 5) the values are again those recommended by A.H. Wapstra (Ref. 47) and the half-lives were provided by N.E. Holden (Ref. 67). The latest atomic mass data were surveyed and no significant changes have resulted.

OTHER PROJECTS

The Commission contemplates issuing a four or five place table of atomic weights in order to provide practicing chemists with all the necessary data but no more, and to avoid at the same time quoting uncertainties that do not affect everyday use of the data.
The four and five place values will change very infrequently compared to the definitive table. In addition, the Commission will continue to publish the definitive Table of Standard Atomic Weights biennially, and plans to unify, as far as possible, the footnotes or annotations in all tables to simplify their understanding.

TABLE 5. Relative Atomic Masses and Half-Lives of Selected Radionuclides

Name	Symbol	Atomic number	Mass number	Relative atomic mass	Half-life	+
Technetium	Tc	43	97	96.906	2.6×10^6	a
			98	97.907	4.2×10^6	a
			99	98.906	2.13×10^5	a
Promethium	Pm	61	145	144.913	18.	a
			147	146.915	2.62	a

TABLE 5. Relative Atomic Masses and Half-Lives of Selected Radionuclides (Cont'd)

Name	Symbol	Atomic number	Mass number	Relative atomic mass	Half-life	+
Polonium	Po	84	208	207.981	2.90	a
			209	208.982	102.	a
			210	209.983	138.38	d
Astatine	At	85	209	208.986	5.4	h
			210	209.987	8.1	h
			211	210.987	7.21	h
Radon	Rn	86	211	210.991	14.6	h
			222	222.018	3.824	d
Francium	Fr	87	212	211.996	19.3	m
			222	222.018	15.	m
			223	223.020	22.	m
Radium	Ra	88	226	226.025	1600.	a
			228	228.031	5.75	a
Actinium	Ac	89	225	225.023	10.0	d
			227	227.028	21.77	a
Thorium	Th	90	230	230.033	$7.7x10^{4}$	a
			232	232.038	$1.40x10^{10}$	a
Protactinium	Pa	91	230	230.035	17.4	d
			231	231.036	$3.28x10^{4}$	a
			233	233.040	27.0	d
Uranium	U	92	233	233.040	$1.59x10^{5}$	a
			234	234.041	$2.44x10^{5}$	a
			235	235.044	$7.04x10^{8}$	a
			236	236.046	$2.34x10^{7}$	a
			238	238.051	$4.47x10^{9}$	a
Neptunium	Np	93	236	236.047	$1.1x10^{5}$	a
			237	237.048	$2.14x10^{6}$	a
Plutonium	Pu	94	238	238.050	87.7	a
			239	239.052	$2.41x10^{4}$	a
			240	240.054	$6.54x10^{3}$	a
			241	241.057	14.7	a
			242	242.059	$3.8x10^{5}$	a
			244	244.064	$8.3x10^{7}$	a
Americium	Am	95	241	241.057	$4.32x10^{2}$	a
			243	243.061	$7.37x10^{3}$	a
Curium	Cm	96	242	242.059	163.	d
			243	243.061	28.5	a
			244	244.063	18.1	a
			245	245.065	$8.5x10^{3}$	a
Curium			246	246.067	$4.71x10^{3}$	a
			247	247.070	$1.55x10^{7}$	a
			248	248.072	$3.5x10^{5}$	a
			250	250.078	$8.x10^{3}$	a
Berkelium	Bk	97	247	247.070	$1.4x10^{3}$	a
			249	249.075	$3.2x10^{2}$	d
Californium	Cf	98	248	248.072	334.	d
			249	249.075	$3.51x10^{2}$	a
			251	251.080	$9.0x10^{2}$	a
			252	252.082	2.64	a
			254	254.087	6.x10	d

TABLE 5. Relative Atomic Masses and Half-Lives of Selected Radionuclides (Cont'd)

Name	Symbol	Atomic number	Mass number	Relative atomic mass	Half-life	+
Einsteinium	Es	99	252	252.083	472.	d
			253	253.085	20.47	d
			254	254.088	276.	d
Fermium	Fm	100	255	255.090	20.1	h
			257	257.095	100.5	d

+a=year; d=day; h=hour; m=minute.

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