ATOMIC WEIGHT SCALE $^{12}C = 12$ AND NEW TABLES OF ATOMIC WEIGHTS OF ELEMENTS AND NUCLIDE MASSES

V. A. KRAVTSOV

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AT the beginning of the last century, Dalton proposed to use the weight of the hydrogen atom as the unit of atomic weights. Somewhat later, Berzelius suggested that oxygen be used as the atomic weight standard. At the beginning of the present century the International Commission on Atomic Weights established an atomic-weight unit equal to $\frac{1}{16}$ that of oxygen.

After the discovery of isotopes, Aston [1] proposed in 1927 the scale $^{16}O = 16$ for the mass of the isotope atoms (nuclides), that is, a scale in which the mass of the isotope oxygen-16 is equal precisely to 16. It was initially assumed that this scale coincided with the scale of chemical atomic weights.

But as early as in 1929 Giaugne and Johnston discovered the rare oxygen isotopes ^{17}O and ^{18}O, and Aston's scale, subsequently called the "physical scale of atomic masses," turned out to be different from the chemical scale of atomic weights. To convert the chemical atomic weight (awu) into the physical scale of atomic mass units (amu) it is necessary to multiply the atomic weight by 1.000275:

$$1\ \text{awu} = 1.000275\ \text{amu}.$$

This undesirable disparity between the two scales used for the measurement of the same quantities, namely relative atomic masses or weights, has led to an intolerable confusion and has become the subject of an examination of international scientific organizations. In this connection, the International Union of Pure and Applied Chemistry (IUPAC) turned in 1956 to the International Union of Pure and Applied Physics (IUPAP) with a suggestion of reviewing the question of the changing to a new unified scale of atomic masses and weights, see [2].

1. PHYSICAL DETERMINATION OF THE NUCLIDE MASSES

Kohman [3] suggested the term "nuclide" to designate a specific type of atom—a neutral atom of an isotope (that is, a given nucleus neutralized by electrons). Nuclides differ in the composition of the atomic nucleus, that is, in the number of protons Z, in the number of neutrons N, or in the mass number A = Z + N (the number of all the nucleons in the nucleus). Nuclides with the same Z and different A are called "isotopes," nuclides with the same A and different Z are called "isobars," while nuclides with the same N and different A and Z are called "isotones."

The relative masses of nuclides are determined physically by mass-spectroscopic measurements and from the energies of nuclear reactions and radioactive transformations of the isotopes.

The unit for the nuclide mass is chosen such as to make the mass M of the nuclide close to an integer (close to the mass numbers A), that is, so that the mass excess

$$\Delta = M - A \tag{1}$$

be a regular fraction much smaller than $\frac{1}{2}$ for all the known nuclides. In this case the mass excess Δ can be either positive or negative; consequently

$$M = A + \Delta.$$

The nuclide mass consists of the mass of the nucleus (M_{nuc}), the masses of the electrons (Zm_e) in the neutral atom, and the electron binding energy b_e

$$M = M_{nuc} + Zm_e - b_e. \tag{2}$$

The binding energy B of the nuclide is determined from the formula

$$B = ZM_H + (A - Z)M_n - M(A, Z), \tag{3}$$

where M_H is the mass of the hydrogen atom H and M_n is the neutron mass expressed in energy units. In this case the binding energy of the electrons b_e is not taken into account, since it is appreciably smaller than the smallest error in the nuclide-mass measurements.

The mass of each nuclide is a constant quantity, and is the main characteristic of the nuclide. The accuracy of the physical methods used to measure the nuclide masses has been increasing continuously. At the present time the two methods of measuring the nuclide mass, namely the mass-spectroscopic method and the method of nuclear reactions, yield, in most cases, as can be seen from Table IV, mass values with a relative error less than 10^{-7}.

2. CHEMICAL DETERMINATION OF ATOMIC WEIGHTS

The atomic weight of a given element is determined in chemistry from the equivalent weights. The equivalent weight is the quantity of an element combining with or replacing a unit (more accurately, 1.008) weight of hydrogen. Since the isotopes are practically indistinguishable chemically, a chemical element is a mixture of different isotopic nuclides. The connection between the atomic weight W(Z) of an element of atomic number Z and the masses of the compound nuclides is expressed as:

$$W(Z)=\frac{M_1a_1+M_2a_2+\ \dots\ +M_ia_i}{a_1+a_2+\ \dots\ +a_i}, \qquad (4)$$

where a_1, a_2, ..., a_i—abundances of the i isotopes of the given Z-th element, and $M_1 + M_2 + \dots + M_i$ are the masses of their nuclides.

Measurement of the abundances of isotopes has shown that the isotopic composition of one and the same element can vary, depending on the origin of the specimen of this element. The reason for this is that processes, capable of increasing or decreasing the amount of one isotope in the isotopic mixture forming the chemical element take place in nature.

The enrichment of a mixture by a particular isotope occurs in nature as the result of evaporation, sublimation, melting, chemical exchange reactions, crystallization, and other processes [5,6].

V. I. Vernadskiĭ also pointed out that a change in the isotopic composition of elements occurs under all possible biological processes in living matter.

Table I, compiled by Hoekstra and Katz [7] gives different deviations from the mean ratio of the abundances of the nuclides $^{16}O/^{18}O$ in different specimens of oxygen. These variations lead to noticeable changes of the atomic weights of the oxygen, as can be seen from Table II, reaching 0.0013 per cent.

It must be noted that the factor 1.000275 given above for the conversion from the chemical scale to the physical scale is true only for the atomic weights of approximately half the chemical elements.

Table II. Atomic weights of oxygen of different origin in the chemical scale $^{16}O = 16$

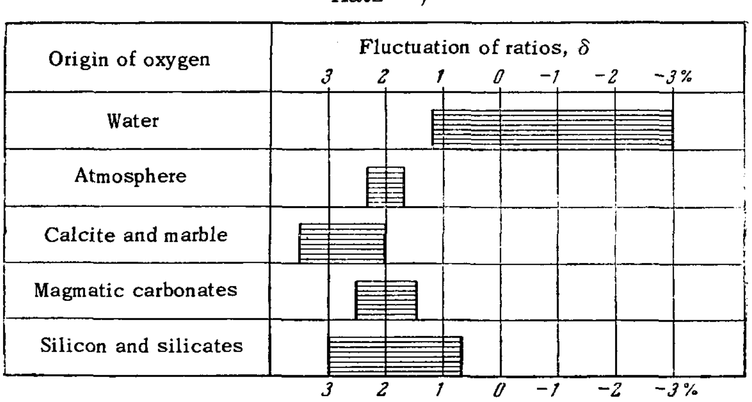
Origin of oxygen	Atomic weight
Water from the Atlantic	16.00000
Water from Lake Michigan	15.99998
Air	16.00012
Carbonate rocks	16.00015
Carbonic acid	16.00019

The atomic weight of oxygen from the Atlantic is taken equal to 16.

The atomic weights of other elements, measured by comparison with the atomic weight of silver, have a somewhat different conversion factor, 1.000279. This is connected with the fact that the atomic weight of silver was measured by comparison with oxygen, which had an isotopic composition different from the so-called "natural mixture of oxygen isotopes." This can be readily understood by taking into account the fluctuations in the atomic weight of oxygen as given in Table II. As can be seen from this table, the atomic weights of oxygen can fluctuate by as much as 0.000012 of their value, that is, by an amount considerably larger than the relative error of the measurements. The change in the atomic weights due to natural enrichment with individual isotopes exceeds the accuracy of measurement of atomic weights not only for oxygen but also for lithium, chlorine, sulfur, and a few other elements.

Particularly large changes in the atomic weights can occur in radiogenic elements: the natural contents of their isotopes is due to the decay of natural radioactive substances or is the result of nuclear reactions in nature. For example, ordinary lead has an

Table I. Fluctuations of relative abundances of the isotopes $^{16}O/^{18}O$ in different samples of oxygen (Hoekstra and Katz [7])



$$\delta=\left(\frac{\text{Ratio in sample}}{\text{Standard ratio}}-1\right)\cdot 100\ \%.$$

The standard ratio adopted is the ratio of abundances for oxygen from sea water.

atomic weight 207.21, while lead from the mineral curite (Katanga) has an atomic weight 206.03. The atomic weight of osmium is 190.2, while osmium from molybdenite, produced by beta decay of the long-lived nuclide ^{187}Re, has an atomic weight 187.0. Helium formed in iron meteorite from Mt. Iliffe as a result of disintegration of iron by high energy cosmic particles has an atomic weight 3.767, that is, very small compared with the atomic weight of helium (4.003).

The only accurate atomic weights can be those of anisotopic elements, that is, elements consisting of one stable isotope.

All these facts show that the atomic weights of the elements, unlike the masses of the nuclides, are not universal constants and vary with the origin of the specimen. Fluctuations in the atomic weight of oxygen of different origin lead to a situation wherein the oxygen scale of atomic weights turns out to be unsuitable even at the present day measurement accuracy.

3. PROPOSED NEW UNITS FOR THE MASSES OF THE NUCLIDES

At first the disparity between the chemical scale ($O = 16$) and the physical scale ($^{16}O = 16$) of the atomic weight apparently caused no great inconvenience while the accuracy of measurement was still low. Gamow [9] and somewhat later Bethe [10] proposed a scale in which $^4He = 4$.

Selinov [11] proposed for the nuclide masses a scale in which the nuclide ^{19}F has a mass exactly equal to 19. This unit was supposed to be convenient for both chemists and physicists. Fluorine is an anisotopic element, and its neighboring nuclides ^{18}F and ^{20}F are radioactive with short half lives. According to the table of atomic weights, the atomic weight of fluorine is 19.00, so that the transition to the scale $^{19}F = 19$ will affect the chemical weights very little. Selinov's suggestion to introduce the scale $^{19}F = 19$ was later supported by Dole [8], by President of the IUPAC Council Wichers [13], and by Gaglioti [14].

Shortly after, the well known mass spectroscopist Nier [15] and the chemist Olander proposed a scale in which the mass of the nuclide ^{12}C would be exactly equal to 12.

In addition, Olander proposed simultaneously a scale with the mass of the nuclide ^{18}O exactly equal to 18. The proposal to use the mass of the ^{12}C nuclide as the base was supported by the well known specialist on atomic constants, Birge [17].

Birge proposed that the mass of the nuclide be assumed equal to 12.003816 so as to make the mass of the nuclide ^{16}O almost exactly equal to 16, and thereby avoid recalculation of various constants connected with atomic masses.

4. DISCUSSION OF ATOMIC MASS SCALES

The fluctuations in the atomic weights of oxygen, shown in Table II (see Table I) make the chemical unit of atomic weights $O = 16$ indeterminate, since these fluctuations considerably exceed the error in the physical measurements of the nuclide masses. For many elements the chemical methods of determining atomic weights have reached the limit of measurement precision, owing to variations of the nuclide abundance in the compositions of elements from different origins. At the present time the only exact method of finding atomic weights is to calculate them from the masses of the nuclides and from their abundances [see formula (4)]. Consequently, the most exact methods of determining the chemical atomic weights are likewise the mass-spectroscopic and other physical methods.

The old physical scale $^{16}O = 16$ is quite reliable, since the mass of the ^{16}O is a universal constant.

The shortcoming of this scale is the difficulty of comparing masses of other nuclides with the standard nuclide ^{16}O. The main method of comparing the masses of the nuclides is to measure the mass spectroscopic doublets. For the doublets, the ^{16}O nuclides is of little convenience, since it forms a few ions, namely the ion $^{16}O_2$ and the ions of the hydrides $^{16}O^1H$, $^{16}O^1H_2$, $^{16}O_2^1H$, and $^{16}O_2^1H_2$. Most frequently the mass spectroscopic measurements are carried out by comparing the mass of the nuclide with the mass of the nuclide ^{12}C. For this purpose one measures the mass difference of the three fundamental doublets

$$\left.\begin{array}{l} {}^1H_2 - {}^2D, \\ {}^2D_3 - \frac{1}{2}\,{}^{12}C, \\ {}^{12}C^1H_3 - {}^{16}O, \end{array}\right\} \qquad (4)$$

which make it possible to determine the mass of the nuclide ^{12}C from the scale $^{16}O = 16$. Further measurements are carried out using ions of hydrocarbon molecules, with which it is possible to compare the masses of almost all the nuclides.

Nier [4,19] used only one doublet $^{12}C_4 - {}^{32}S^{16}O$ to determine the mass of a nuclide, using the $^{16}O = 16$ scale, but made a large systematic error in measuring this doublet. The resultant contradictions were detected and eliminated by measuring other doublets, for example the doublet $\frac{1}{2}\,{}^{12}C_4{}^1H^{16}O - {}^{16}O_2{}^1H_2$. This latter doublet is apparently one of the best for the determination of the mass difference between ^{16}O and ^{12}C.

The use of the $^{16}O = 16$ scale calls for changes in the chemical atomic weights and the constants associated with them by the appreciable amount 0.0275 per cent, which leads to great inconveniences during the transition period.

The scale $^4He = 4$ is unsuitable primarily because of the large corrections that must be introduced in this case in both previous scales. The masses based on the physical scales must be corrected by −0.07 per cent, and the atomic weights and the associated constants by 0.067 per cent. In addition, the nuclide

^{4}He does not enter into any compounds, so that a possibility of comparing its masses with the masses of other nuclides by mass spectroscopic methods are highly limited. Measurement by chemical methods is also very difficult for the same reasons. All these causes make this scale unsuitable.

The Selinov scale, in which $^{19}F = 19$, deserves much attention. It influences very little the chemical atomic weights, which will have to be corrected by merely 0.0041 per cent.

The shortcomings of the $^{19}F = 19$ scale are very similar to the shortcomings of the $^{16}O = 16$ scale. To compare the nuclide ^{19}F with other nuclides is even more difficult than to compare ^{16}O. In practice it is possible to carry out a mass comparison with the nuclides ^{32}S, ^{16}O, ^{12}C, ^{1}H, ^{2}D, and perhaps also with a few others, and through them with the remaining ones.

Direct comparison of ^{19}F with ^{12}C is impossible. Thus, comparison with the majority of nuclides should occur only via the secondary standard ^{12}C and ^{1}H.

The scale $^{18}O = 18$ is particularly attractive since it deviates from the old chemical scale by merely 0.0004 per cent, that is, by an amount less than the error of the scale itself. In all other respects this scale is no better for the comparison by the mass-spectroscopic doublet method than the scale $^{16}O = 16$. Moreover, the small abundance of the ^{18}O nuclide (0.204 per cent) makes it difficult to obtain pure specimens and makes the use of ^{18}O as a standard inconvenient.

Dole [11] proposed to use as standards the nuclides ^{23}Na or ^{1}H. He furthermore proposed to assume their masses to be not integers, but such as to make the chemical scale $O = 16$ approximately the same as before. This is very inconvenient. Any scale in which the mass of the standard nuclide is not an integer (in other words, if the mass excess of the standard is $\Delta_{st} \neq 0$) greatly complicates the calculations of masses from the mass spectroscopic doublets and from the reaction energies.

For the same reason, Birge's suggestion to use as a standard the ^{12}C nuclide but to set its mass equal to 12.003816, so as to retain the scale $^{16}O = 16$ in first approximation, is not acceptable.

The most convenient scale for the nuclide masses is the scale of Nier and Olander, in which it is proposed to make the mass of the nuclide ^{12}C exactly equal to 12. This scale has tremendous advantages for the measurement of nuclide masses by the most exact method of mass-spectroscopic doublets. It is also perfectly convenient for obtaining the masses from the energies of the nuclear reactions. The nuclide ^{12}C can be obtained doubly, triply, and quadruply ionized, so that it can be easily compared with the basic light nuclides ^{6}Li and $^2D_3$, ^{4}He and $^2D_2$, and ^{3}He and $^1H_3$.

No less essential is the possibility of obtaining ions of the molecules $^{12}C_n$ with a number of atoms n reaching 10 and even more. This makes it possible to compare directly the mass of the standard nuclide ^{12}C with the heaviest nuclides. It is also possible to measure the mass difference of the doublets $^{12}C_{10} - {}^{120}Sn$, $^{12}C_{10} - \frac{1}{2}\,{}^{240}Pu$, $^{12}C_5 - \frac{1}{2}\,{}^{120}Sn$, $^{12}C_5 - \frac{1}{3}\,{}^{180}Hf$ and other doublets. The mass difference of these doublets δM yields immediately the mass excess of the compared nuclides Δ by multiplying the mass difference by the ion charge q, that is,

$$\Delta = q\delta M,$$

since the excess mass of the ^{12}C nuclide is equal to zero.

In addition, the nuclide ^{12}C can form a series of hydrides of the form $^{12}C_n{}^1H_m$ or $^{12}C_n{}^2D_k$. If the masses of the nuclides ^{1}H and ^{2}D are measured with sufficient accuracy, say with the aid of doublets [5], then the ions of these molecules can be conveniently used for measurements. Ions of the hydride molecules can be compared with ions of nuclides with all mass numbers from 1 to 210.

All this makes the nuclide ^{12}C the best standard for mass spectroscopic measurements. The presence of ^{13}C impurities when using a natural mixture of carbon isotopes may reduce somewhat the accuracy of the measurements on mass spectroscopes of low resolution. In order to resolve the ions $^{12}C_9$, ^{13}C, and $^{12}C_{10}{}^1H$ it is necessary to use a mass spectroscope with a resolution not less than 27,000. Modern instruments have a resolution of 50,000—100,000 and can separate ions with ^{13}C from ions with $^{12}C^1H$. New instruments under construction have even higher resolution, and no difficulties are involved in using the pure nuclide ^{12}C with the old instruments.

The nuclide mass unit $^{12}C = 12$ differs from the unit of the earlier chemical scale by 0.0043 per cent, that is, by an amount which is merely three or four times larger than 0.0012 per cent (relative fluctuations in the atomic weight of oxygen, which is the basis of the chemical scale). This makes the changeover to the new scale easy for chemists, since in most cases in approximate calculations the atomic weight and the associated constants can be assumed to be the same as before.

A discussion of new scales for nuclide masses and for atomic weights has been underway for several years, see [2,13,21] and others.

In August of 1959 the IUPAC Commission on Atomic Weight approved in Munich (West Germany) the scale $^{12}C = 12$ for atomic weights and presented its resolution for approval to the IUPAC Conference of 1961.

In September 1960, the IUPAP Tenth General Assembly was held in Ottawa (Canada), in which I. Mattauch, the chairman of the IUPAP Commission on Nuclide Masses, recommended in his paper that the physicists adopt the scale $^{12}C = 12$. At the same Assembly, the IUPAC president E. Wichers promised that the IUPAC will recommend this scale also for chemical atomic weights.

In this connection, the Bureau of the Division of Physical Mathematical Sciences and the Division of Chemical Sciences of the U.S.S.R. Academy of Sciences have adopted a resolution to change over to the new scale of atomic weights.

The new unit for the nuclide masses (atomic weights or masses) is one-twelfth of the mass of the nuclide (atom of the isotope) ^{12}C. The new mass unit will be designated by the symbol "u" (for unit) or with the Russian letter "e".

The conversion of the new mass units into energy units—kiloelectron volts and into the old units of the physical scale (amu) $^{16}O = 16$ (kev) will be based on the formulas

$$1e = (931\,441 \pm 10)\ \text{keV},$$

$$1e = (1.000\,317\,917 \pm 0.000\,000\,017)\ \text{amu}\ (^{16}O = 16).$$

The conversion of the old chemical atomic weight (O = 16) into the new scale will be by means of the formula

Table III. Relative atomic weights (masses) (1961) (in scale $^{12}C = 12$)

Atm. No.	Name of element	Symbol	Atomic weight (mass)	Atm. No.	Name of element	Symbol	Atomic weight (mass)
1	Hydrogen	H	1.00797	48	Cadmium	Cd	112.40
			±0.00001 p	49	Indium	In	114.82
2	Helium	He	4.0026	50	Tin	Sn	118.69
3	Lithium	Li	6.939	51	Antimony	Sb	121.75
4	Beryllium	Be	9.0122	52	Tellurium	Te	127.60
5	Boron	B	10.811	53	Iodine	I	126.9044
			±0.003 p	54	Xenon	Xe	131.30
6	Carbon	C	12.01115	55	Cesium	Cs	132.905
			±0.00005 p	56	Barium	Ba	137.34
7	Nitrogen	N	14.0067	57	Lanthanum	La	138.91
8	Oxygen	O	15.9994	58	Cerium	Ce	140.12
			±0.0001 p	59	Praseodymium	Pr	140.907
9	Fluorine	F	18.9984	60	Neodymium	Nd	144.24
10	Neon	Ne	20.183	61	Promethium	Pm	—
11	Sodium	Na	22.9898	62	Samarium	Sm	150.35
12	Magnesium	Mg	24.312	63	Europium	Eu	151.96
13	Aluminum	Al	26.9815	64	Gadolinium	Gd	157.25
14	Silicon	Si	28.086	65	Terbium	Tb	158.924
			±0.001 p	66	Dysprosium	Dy	162.50
15	Phosphorus	P	30.9738	67	Holmium	Ho	164.930
16	Sulfur	S	32.064	68	Erbium	Er	167.26
			±0.003 p	69	Thulium	Tm	168.934
17	Chlorine	Cl	35.453	70	Ytterbium	Yb	173.04
			±0.001	71	Lutetium	Lu	174.97
18	Argon	Ar	39.948	72	Hafnium	Hf	178.49
19	Potassium	K	39.102	73	Tantalum	Ta	180.948
20	Calcium	Ca	40.08	74	Tungsten	W	183.85
21	Scandium	Sc	44.956	75	Rhenium	Re	186.2
22	Titanium	Ti	47.90	76	Osmium	Os	190.2
23	Vanadium	V	50.942	77	Iridium	Ir	192.2
24	Chromium	Cr	51.996	78	Platinum	Pt	195.09
			±0.001	79	Gold	Au	196.967
25	Manganese	Mn	54.9381	80	Mercury	Hg	200.59
26	Iron	Fe	55.847	81	Thallium	Tl	204.37
			±0.003	82	Lead	Pb	207.19
27	Cobalt	Co	58.9332	83	Bismuth	Bi	208.980
28	Nickel	Ni	58.71	84	Polonium	Po	—
29	Copper	Cu	63.54	85	Astatine	At	—
30	Zinc	Zn	65.37	86	Radon	Em	—
31	Gallium	Ga	69.72	87	Francium	Fr	—
32	Germanium	Ge	72.59	88	Radium	Ra	—
33	Arsenic	As	74.9216	89	Actinium	Ac	—
34	Selenium	Se	78.96	90	Thorium	Th	232.038
35	Bromine	Br	79.909	91	Protactinium	Pa	—
			±0.002	92	Uranium	U	238.03
36	Krypton	Kr	83.80	93	Neptunium	Np	—
37	Rubidium	Rb	85.47	94	Plutonium	Pu	—
38	Strontium	Sr	87.62	95	Americium	Am	—
39	Yttrium	Y	88.905	96	Curium	Cm	—
40	Zirconium	Zr	91.22	97	Berkelium	Bk	—
41	Niobium	Nb	92.906	98	Californium	Cf	—
42	Molybdenum	Mo	95.94	99	Einsteinium	Es	—
43	Technetium	Tc	—	100	Fermium	Fm	—
44	Ruthenium	Ru	101.07	101	Mendelevium	Md	—
45	Rhodium	Rh	102.905	102	Nobelium	No	—
46	Palladium	Pd	106.4	103	Lawrencium	Lw	—
47	Silver	Ag	107.870				
			+0.003				

The quantities followed by the letter p are possible deviations of the atomic weights, due to natural fluctuations in the isotopic compositions of the elements.

In those cases when no errors are given, the atomic weights are known accurate to ±0.5 of the last significant figure.

Table IV. Relative masses of nuclides according to the $^{12}C = 12$ scale and the binding energies of the nuclides*

Atomic number Z	Mass number A	Symbol	Mass excess (microunit)	Binding energy (keV)
0	1	*n*	8 665.44±0.43	
1	1	H	7 825.22±0.08	
1	2	D	14 102.19±0.11	2 224.71±0.40
1	3	T	16 049.40±0.23	8 482.3±0.8
2	3	He	16 029.94±0.23	7 717.87±0.44
2	4	He	2 603.61±0.37	28 295.0±0.9
2	5	He	12 296±21	27 338±20
3	5	Li	12 541±40	26 328±37
2	6	He	18 900±18	29 259±17
3	6	Li	15 126.3±1.0	31 991.0±1.5
4	6	Be	19 780±150	26 870±140
3	7	Li	16 005.3±1.1	39 243.6±1.8
4	7	Be	16 930.7±1.3	37 599.0±1.4
3	8	Li	22 488.4±1.6	41 276.3±2.4
4	8	Be	5 308.3±0.8	56 495.9±1.8
5	8	B	24 611.7±1.7	37 733.3±2.2
3	9	Li	27 300±900	44 900±800
4	9	Be	12 185.8±0.9	58 161.3±2.1
5	9	B	13 334.7±2.0	56 308.5±2.7
4	10	Be	13 535.3±2.3	64 975.6±3.2
5	10	B	12 938.9±0.7	64 748.5±2.3
6	10	C	16 830±60	60 340±60
4	11	Be	21 660±16	65 480±15
5	11	B	9 305.09±0.43	76 204.6±2.6
6	11	C	11 431.3±1.5	73 441.3±2.0
5	12	B	14 352.9±1.0	79 574.2±3.0
6	12	C	0±0	92 160.5±2.7
7	12	N	18 709±44	73 952±41
5	13	B	17 779.4±4.3	84 454±5
6	13	C	3 354.3±0.7	97 107.5±3.1
7	13	N	5 738.9±1.4	94 103.7±3.2
6	14	C	3 241.93±0.41	105 283.5±3.3
7	14	N	3 074.38±0.17	104 656.9±3.1
8	14	O	8 597.0±0.7	98 730.3±2.8
6	15	C	10 600.0±1.2	106 501.2±3.8
7	15	N	108.1±0.9	115 491.2±3.6
8	15	O	3 071.9±1.9	111 948.0±3.9
6	16	C	14 702±17	110 752±17
7	16	N	6 089±6	117 991±7
8	16	O	−5 085.06±0.28	127 617.0±3.5
9	16	F	11 707±13	111 194±12
7	17	N	8 449±16	123 865±16
8	17	O	−866.6±0.9	131 759.1±4.1
9	17	F	2 098.4±2.4	128 214.8±4.5

*The table is based on the paper of König, Mattauch, and Wapstra[22] with supplements and corrections made by the author on the basis of measurements by Demirkhanov, Dorokhov, and Dzkuya[26] and others.

Table IV. (continued)

Atomic number Z	Mass number A	Symbol	Mass excess (microunit)	Binding energy (keV)
8	18	O	−840.17±0.34	139 805.9±4.3
9	18	F	949.9±4.3	137 356±6
10	18	Ne	5 715±6	132 135±7
8	19	O	3 577.3±4.3	143 763±6
9	19	F	−1 595.4±0.7	147 798.1±4.4
10	19	Ne	1 883.2±2.0	143 775.0±2.2
8	20	O	4 071±16	151 374±16
9	20	F	−14.5±4.0	154 397±6
10	20	Ne	−7 559.6±0.5	160 642.1±4.4
11	20	Na	8 890±320	144 540±300
9	21	F	−49±11	162 501±10
10	21	Ne	−6 150.8±1.7	167 401±5
11	21	Na	−2 362±18	163 089±18
10	22	Ne	−8 615.5±0.6	177 768±5
11	22	Na	−5 565±5	174 144±7
12	22	Mg	−152±90	168 320±80
10	23	Ne	−5 525±5	182 961±7
11	23	Na	−10 227.4±1.6	186 558±5
12	23	Mg	−5 865±6	181 712±7
10	24	Ne	−6 389±11	191 838±11
11	24	Na	−9 033.1±2.9	193 517±6
12	24	Mg	−14 955.4±1.9	198 251±6
13	24	Al	90±320	183 450±300
11	25	Na	−10 080±210	202 560±200
12	25	Mg	−14 160.3±2.0	205 582±6
13	25	Al	−9 586±7	200 538±8
11	26	Na	−8 260±320	208 940±300
12	26	Mg	−17 409.1±2.4	216 679±6
13	26	Al	−13 100±5	211 882±8
14	26	Si	−7 680±90	206 050±80
12	27	Mg	−15 654.5±3.9	223 116±7
13	27	Al	−18 465.1±2.1	224 951±6
14	27	Si	−13 299±6	219 356±8
12	28	Mg	−16 120±7	231 621±9
13	28	Al	−18 091.9±3.9	232 675±7
14	28	Si	−23 072.9±3.1	236 532±7
15	28	P	−8 260±320	221 950±300
13	29	Al	−19 558±7	242 112±9
14	29	Si	−23 509.2±3.6	245 010±7
15	29	P	−18 184±11	239 267±12
13	30	Al	−18 413±270	249 120±250
14	30	Si	−26 239.3±4.3	255 624±8
15	30	P	−21 680±11	250 595±12
16	30	S	−15 270±120	243 840±110
14	31	Si	−24 651±5	262 216±9
15	31	P	−26 235.6±1.5	262 910±7
16	31	S	−20 401±18	256 692±18
14	32	Si	−25 980±50	271 530±50
15	32	P	−26 092.1±2.4	270 847±8
16	32	S	−27 926.2±1.1	271 773±7
17	32	Cl	−13 970±320	257 990±300
15	33	P	−28 272.2±3.7	280 949±9

Table IV. (continued)

Atomic number Z	Mass number A	Symbol	Mass excess (microunit)	Binding energy (keV)
16	33	S	−28 539.5±3.0	280 415±8
17	33	Cl	−22 554±13	274 058±14
15	34	P	−26 660±210	287 520±200
16	34	S	−32 135.5±3.1	291 836±8
17	34	Cl	−26 236±22	285 558±22
16	35	S	−30 965.8±2.8	298 818±9
17	35	Cl	−31 145.5±2.8	298 203±8
18	35	A	−24 725±43	291 440±41
16	36	S	−32 909±9	308 700±13
17	36	Cl	−31 688±6	306 780±10
18	36	A	−32 451.9±3.4	306 708±9
16	37	S	−28 960±100	313 090±90
17	37	Cl	−34 104.1±2.2	317 101±9
18	37	A	−33 228.0±2.7	315 503±9
19	37	K	−26 640±44	308 584±42
16	38	S	−28 780±160	320 990±150
17	38	Cl	−31 998±9	323 211±12
18	38	A	−37 275.5±3.4	327 344±9
19	38	K	−30 910±11	320 632±14
17	39	Cl	−31 997±23	331 281±23
18	39	A	35 679±6	333 929±11
19	39	K	−36 286.0±3.0	333 711±9
20	39	Ca	−29 294±27	326 416±27
17	40	Cl	−29 600±500	337 100±500
18	40	A	−37 616.2±0.8	343 804±10
19	40	K	−35 992.1±3.6	341 509±10
20	40	Ca	−37 410.8±3.7	342 048±10
21	40	Sc	−22 490±430	327 360±400
18	41	A	35 497±6	349 901±6
19	41	K	−38 164.9±4.6	351 604±11
20	41	Ca	−37 721±9	350 408±12
21	41	Sc	−30 747±12	343 129±14
18	42	A	36 957±43	359 332±41
19	42	K	−37 583±22	359 133±23
20	42	Ca	−41 372.3±4.4	361 880±11
21	42	Sc	−34 660±60	354 850±60
19	43	K	−39 269±12	368 775±15
20	43	Ca	−41 220.0±4.8	369 810±11
21	43	Sc	−38 837±12	366 807±15
22	43	Ti	−31 504±24	359 194±24
19	44	K	−37 960±210	375 630±200
20	44	Ca	−44 510,3±4.8	380 946±11
21	44	Sc	−40 594±7	376 515±12
22	44	Ti	−40 427±13	375 577±15
20	45	Ca	−43 810,6±4,6	388 365±12
21	45	Sc	−44 081,1±4,2	387 835±11
22	45	Ti	—41 871±6	384 994±12
20	46	Ca	−46 311±10	398 766±15
21	46	Sc	−44 827±6	396 601±12
22	46	Ti	−47 366,6±3,7	398 184±11
23	46	V	−39 774±32	390 329±32
20	47	Ca	−45 488±23	406 071±24

Table IV. (continued)

Atomic number Z	Mass number A	Symbol	Mass excess (microunit)	Binding energy (keV)
21	47	Sc	−47 598±8	407 253±13
22	47	Ti	−48 242±8	407 070±13
23	47	V	−45 116±13	403 376±16
20	48	Ca	−47 637±15	416 143±18
21	48	Sc	−47 769±10	415 483±15
22	48	Ti	−52 052,2±3,6	418 691±11
23	48	V	−47 740±6	413 891±12
24	48	Cr	−46 240±210	411 710±200
20	49	Ca	−44 338±16	421 142±19
21	49	Sc	−49 975±6	425 610±14
22	49	Ti	−52 133,4±3,5	426 837±12
23	49	V	−51 477±6	425 443±12
24	49	Cr	−48 729±12	422 101±16
21	50	Sc	−48 400±500	432 300±500
22	50	Ti	−55 210,9±4,8	437 775±12
23	50	V	52 835,4±4,0	434 780±12
24	50	Cr	−53 949,3±4,5	435 035±12
25	50	Mn	−46 010±320	426 850±300
22	51	Ti	−53 376±22	444 137±24
23	51	V	−56 022,1±4,2	445 820±12
24	51	Cr	−55 214,1±4,5	444 284±12
25	51	Mn	−51 800±50	440 320±50
23	52	V	−55 198±8	453 124±14
24	52	Cr	−59 486,3±3,6	456 335±12
25	52	Mn	−54 437±9	450 849±14
26	52	Fe	−51 879±19	447 684±20
23	53	V	−56 630±50	462 530±50
24	53	Cr	−59 348,9±3,7	464 278±13
25	53	Mn	−58 707±9	462 898±15
26	53	Fe	−54 422±43	458 124±42
24	54	Cr	−61 120,6±4,8	474 000±13
25	54	Mn	−59 640±7	471 838±14
26	54	Fe	−60 379±6	471 744±13
27	54	Co	−51 570±320	462 760±300
24	55	Cr	−58 920±150	480 020±140
25	55	Mn	−61 946,4±4,1	482 058±13
26	55	Fe	−61 697,6±4,6	481 044±13
27	55	Co	−57 983±12	476 801±16
24	56	Cr	−59 360±160	488 500±150
25	56	Mn	−61 086±6	489 328±14
26	56	Fe	−65 068±6	492 254±14
27	56	Co	−60 130±17	486 872±20
25	57	Mn	−61 710±320	497 980±300
26	57	Fe	−64 606±6	499 896±14
27	57	Co	−63 708±7	498 277±15
28	57	Ni	−60 235±17	494 259±21
26	58	Fe	−66 728±7	509 943±15
27	58	Co	−64 246±15	506 849±19
28	58	Ni	−64 658±6	506 450±14
29	58	Cu	−55 496±28	497 133±26
26	59	Fe	−65 133±7	516 529±15
27	59	Co	−66 810,9±4,6	517 309±14
28	59	Ni	−65 656±5	515 451±14
29	59	Cu	−60 504±22	509 870±24

Table IV. (continued)

Atomic number Z	Mass number A	Symbol	Mass excess (microunit)	Binding energy (keV)
27	60	Co	66 194±6	524 806±15
28	60	Ni	−69 217±6	526 839±14
29	60	Cu	62 650±17	519 940±16
27	61	Co	67 566±43	534 155±43
28	61	Ni	−68 951±9	534 662±16
29	61	Cu	−66 556±10	531 649±16
30	61	Zn	60 760±210	525 460±200
27	62	Co	−66 051±43	540 815±43
28	62	Ni	71 655±7	545 252±15
29	62	Cu	−67 436±13	540 540±18
30	62	Zn	−65 621±16	538 067±20
27	63	Co	−66 470±210	549 280±200
28	63	Ni	−70 334±6	552 094±15
29	63	Cu	−70 405±6	551 378±15
30	63	Zn	−66 792±7	547 229±15
28	64	Ni	−72 041±6	561 755±16
29	64	Cu	−70 239±6	559 294±15
30	64	Zn	−70 855±5	559 085±15
31	64	Ga	−63 262±33	551 230±34
28	65	Ni	−69 959±22	567 887±26
29	65	Cu	−72 214±6	569 204±16
30	65	Zn	−70 766±6	567 074±16
31	65	Ga	−67 267±17	563 032±21
32	65	Ge	−62 200±430	557 530±400
28	66	Ni	70 914±33	576 848±35
29	66	Cu	−71 129±9	576 265±18
30	66	Zn	−73 952±10	578 112±18
31	66	Ga	−68 401±34	572 160±35
32	66	Ge	−65 230±160	568 430±150
29	67	Cu	−72 237±14	585 369±20
30	67	Zn	−72 851±11	585 158±18
31	67	Ga	−71 779±12	583 377±19
32	67	Ge	−67 060±110	578 190±100
30	68	Zn	−75 135±9	595 357±18
31	68	Ga	−72 003±11	591 657±18
32	68	Ge	−71 300±600	590 200±600
30	69	Zn	−73 347±29	601 762±31
31	69	Ga	−74 318±28	601 885±30
32	69	Ge	−71 917±30	598 865±32
33	69	As	−67 730±320	594 180±300
30	70	Zn	−74 652±16	611 050±22
31	70	Ga	−73 952±17	609 615±23
32	70	Ge	−75 723±20	610 482±24
33	70	As	−68 700±110	603 160±100
30	71	Zn	−72 358±74	616 980±70
31	71	Ga	−75 160±50	618 810±50
32	71	Ge	74 910±50	617 790±50
33	71	As	−72 750±50	615 000±50
34	71	Se	−68 030±330	609 820±300
30	72	Zn	−72 260±220	624 960±210
31	72	Ga	−73 970±50	625 770±50
32	72	Ge	−78 260±50	628 980±50
33	72	As	−73 570±60	623 840±60
31	73	Ga	−74 980±80	634 780±80
32	73	Ge	−76 640±70	635 550±70
33	73	As	−76 240±80	634 400±80
34	73	Se	−73 290±80	630 870±80
31	74	Ga	−72 780±220	640 810±210
32	74	Ge	−78 850±60	645 670±50
33	74	As	−76 090±50	642 330±50
34	74	Se	−77 550±60	642 900±50
35	74	Br	−71 110±430	636 120±400
36	74	Kr	−66 690±450	631 220±420
32	75	Ge	−77 160±60	652 170±50
33	75	As	−78 420±50	652 570±50
34	75	Se	−77 490±50	650 920±50
35	75	Br	−74 570±60	647 420±50
32	76	Ge	−78 640±90	661 620±90
33	76	As	−77 583±48	659 857±49
34	76	Se	−80 771±48	662 044±48
35	76	Br	−75 800±80	656 630±80
32	77	Ge	−76 380±70	667 590±70
33	77	As	−79 332±49	669 560±49
34	77	Se	−80 066±48	669 459±48
35	77	Br	−78 601±48	667 314±48
36	77	Kr	−75 510±50	663 650±50
32	78	Ge	−77 290±160	676 510±150
33	78	As	−78 250±120	676 620±110
34	78	Se	−82 652±48	679 939±48
35	78	Br	−78 860±40	675 620±40
36	78	Kr	−79 632±5	675 560±19
33	79	As	−79 010±110	685 400±100
34	79	Se	−81 479±20	686 917±27
35	79	Br	−81 652±19	686 295±26
36	79	Kr	−79 911±20	683 892±26
33	80	As	−77 050±220	691 650±200
34	80	Se	−83 488±17	696 859±25
35	80	Br	−81 459±16	694 188±24
36	80	Kr	−83 612±13	695 410±22
37	80	Rb	−78 100±500	689 500±500
33	81	As	−78 060±220	700 660±210
34	81	Se	−82 140±60	703 680±60
35	81	Br	−83 656±37	704 305±40
36	81	Kr	−83 390±100	703 280±90
37	81	Rb	−80 990±100	700 260±100
34	82	Se	−83 340±70	712 860±70
35	82	Br	−83 198±8	711 953±22
36	82	Kr	−86 517±8	714 259±21
37	82	Rb	−82 041±33	709 309±37
34	83	Se	−81 090±100	718 850±90
35	83	Br	−84 795±23	721 512±30
36	83	Kr	−85 869±8	721 726±22
35	84	Br	−83 450±50	728 330±50
36	84	Kr	−88 496±5	732 244±21
37	84	Rb	−85 648±7	728 809±22
38	84	Sr	−86 624±11	728 936±23

Table IV. (continued)

Atomic number Z	Mass number A	Symbol	Mass excess (microunit)	Binding energy (keV)
35	85	Br	−84 560±120	737 440±110
36	85	Kr	−87 570±60	739 450±60
37	85	Rb	−88 290±69	739 340±60
38	85	Sr	−87 100±60	737 450±60
39	85	Y	−83 880±120	733 670±120
36	86	Kr	−89 383±8	749 213±23
37	86	Rb	−88 844±30	747 932±30
38	86	Sr	−90 746±30	748 921±30
39	86	Y	−85 131±37	742 908±40
35	87	Br	−78 040±430	747 510±400
36	87	Kr	−86 630±50	754 720±50
37	87	Rb	−90 833±30	757 854±30
38	87	Sr	−91 125±30	757 343±30
39	87	Y	−89 310±220	754 870±200
40	87	Zr	−85 540±220	750 580±200
36	88	Kr	−85 780±230	762 000±220
37	88	Rb	−88 790±90	764 020±80
38	88	Sr	−94 363±40	768 433±40
39	88	Y	−90 470±40	764 024±40
37	89	Rb	−88 390±60	771 710±60
38	89	Sr	−92 586±23	774 849±24
39	89	Y	−94 155±20	775 527±22
40	89	Zr	−91 113±22	771 912±22
41	89	Nb	−86 950±100	767 250±100
37	90	Rb	−85 180±110	776 800±100
38	90	Sr	−92 252±32	782 608±32
39	90	Y	−92 836±32	782 370±32
40	90	Zr	−95 255±30	783 840±30
41	90	Nb	−88 688±44	776 941±42
42	90	Mo	−85 961±120	773 618±110
38	91	Sr	−89 814±42	788 409±41
39	91	Y	−92 680±40	790 297±40
40	91	Zr	−94 343±40	791 063±40
41	91	Nb	−92 530±130	788 590±120
42	91	Mo	−87 740±120	783 350±110
38	92	Sr	−89 020±100	795 740±100
39	92	Y	−91 074±70	796 870±70
40	92	Zr	−94 939±40	799 689±40
41	92	Nb	−92 690±90	797 003±80
42	92	Mo	−93 160±80	796 464±70
43	92	Tc	−86 300±700	789 280±600
39	93	Y	−90 330±64	804 250±60
40	93	Zr	−93 432±60	806 357±60
41	93	Nb	−93 500±60	805 638±60
42	93	Mo	−92 960±74	804 349±70
43	93	Tc	−89 560±80	800 406±80
39	94	Y	−88 348±230	810 475±220
40	94	Zr	−93 716±60	814 693±60
41	94	Nb	−92 570±110	812 843±110
42	94	Mo	−94 840±90	814 174±80
43	94	Tc	−90 200±100	809 072±90
40	95	Zr	−94 146±60	821 115±60
41	95	Nb	−93 151±60	821 454±60
42	95	Mo	−94 146±60	821 599±60

Table IV. (continued)

Atomic number Z	Mass number A	Symbol	Mass excess (microunit)	Binding energy (keV)
43	95	Tc	−92 368±64	819 160±70
44	95	Ru	−90 010±130	816 180±130
40	96	Zr	−91 610±120	828 880±120
41	96	Nb	−91 960±80	828 412±70
42	96	Mo	−95 320±70	830 759±70
43	96	Tc	−92 120±330	827 000±310
44	96	Ru	−92 620±80	826 680±80
40	97	Zr	−89 120±100	834 624±90
41	97	Nb	−91 970±90	836 501±90
42	97	Mo	−94 050±90	837 650±90
41	98	Nb	−89 560±220	842 323±220
42	98	Mo	−94 500±80	846 141±80
43	98	Tc	−93 440±530	844 400±520
44	98	Ru	−95 260±480	845 300±470
45	98	Rh	−90 750±600	840 300±550
41	99	Nb	−89 090±360	849 960±350
42	99	Mo	−92 530±160	852 380±160
43	99	Tc	−94 010±160	852 980±160
44	99	Ru	−94 325±160	852 490±160
45	99	Rh	−92 070±160	849 600±160
46	99	Pd	−87 990±270	845 020±260
42	100	Mo	−92 520±80	860 440±74
43	100	Tc	−92 250±210	859 410±210
44	100	Ru	−95 870±200	861 990±200
45	100	Rh	−91 960±200	857 570±200
46	100	Pd	−91 530±230	856 389±230
42	101	Mo	−90 020±170	866 190±170
43	101	Tc	−93 050±160	868 220±160
44	101	Ru	−94 800±160	869 070±160
45	101	Rh	−94 430±250	867 943±250
46	101	Pd	−92 540±260	865 400±260
42	102	Mo	−90 450±470	874 660±440
43	102	Tc	−91 740±350	875 080±320
44	102	Ru	−96 140±130	878 390±120
45	102	Rh	−93 660±130	875 290±120
46	102	Pd	−94 890±130	875 660±120
44	103	Ru	−94 200±140	884 658±130
45	103	Rh	−95 010±140	884 626±130
46	103	Pd	−94 410±140	883 283±130
47	103	Ag	−92 050±250	880 300±240
44	104	Ru	−94 910±200	893 390±200
45	104	Rh	−93 640±140	891 420±130
46	104	Pd	−96 260±140	893 080±130
47	104	Ag	−91 660±140	888 020±130
44	105	Ru	−92 710±270	899 410±250
45	105	Rh	−94 750±270	900 530±250
46	105	Pd	−95 360±270	900 310±250
47	105	Ag	−93 200±600	897 500±500
44	106	Ru	−92 970±120	907 720±110
45	106	Rh	−93 010±120	906 980±110
46	106	Pd	−96 800±120	909 720±110
47	106	Ag	−93 610±120	905 970±110
48	106	Cd	−94 050±370	905 600±350
45	107	Rh	−93 380±120	915 390±120

Table IV. (continued)

Atomic number Z	Mass number A	Symbol	Mass excess (microunit)	Binding energy (keV)
46	107	Pd	−94 990±110	916 110±110
47	107	Ag	−95 030±110	915 360±110
48	107	Cd	−93 480±110	913 140±110
46	108	Pd	−96 080±120	925 190±120
47	108	Ag	−94 110±110	922 570±110
48	108	Cd	−96 000±120	923 560±120
49	108	In	−90 530±160	917 680±150
46	109	Pd	−94 100±110	931 430±110
47	109	Ag	−95 300±110	931 750±110
48	109	Cd	−95 130±110	930 820±110
49	109	In	−92 960±110	928 010±110
46	110	Pd	−95 500±320	940 800±300
47	110	Ag	−93 950±110	938 570±110
48	110	Cd	−97 030±110	940 660±110
49	110	In	−92 780±120	935 920±120
46	111	Pd	−92 509±190	946 086±190
47	111	Ag	−94 871±190	947 503±190
48	111	Cd	−95 998±190	947 770±180
49	111	In	−94 965±210	946 030±200
50	111	Sn	−92 295±210	942 760±200
46	112	Pd	−92 386±120	954 040±120
47	112	Ag	−92 708±120	953 560±120
48	112	Cd	−97 045±110	956 820±110
49	112	In	−94 212±110	953 400±120
50	112	Sn	−94 912±120	953 260±120
47	113	Ag	−93 240±110	962 130±110
48	113	Cd	−95 387±100	963 340±100
49	113	In	−95 720±100	962 870±100
50	113	Sn	−94 986±100	961 400±100
47	114	Ag	−91 505±440	968 580±410
48	114	Cd	−96 443±90	972 400±80
49	114	In	−94 922±100	970 200±90
50	114	Sn	−97 057±100	971 400±90
51	114	Sb	−90 320±230	964 340±220
47	115	Ag	−91 472±340	976 620±320
48	115	Cd	−94 585±100	978 740±100
49	115	In	−96 153±100	979 420±100
50	115	Sn	−96 669±110	979 120±100
51	115	Sb	−93 415±110	975 300±100
47	116	Ag	−89 086±450	982 480±500
48	116	Cd	−94 990±120	987 190±300
49	116	In	−94 663±120	986 100±110
50	116	Sn	−98 207±110	988 620±100
51	116	Sb	−93 286±150	983 250±170
52	116	Te	−91 616±190	980 910±180
48	117	Cd	−92 756±230	993 180±220
49	117	In	−95 482±100	994 940± 90
50	117	Sn	−97 060±100	995 620± 90
51	117	Sb	−95 107±110	993 020±100
52	117	Te	−91 371±120	988 760±110
49	118	In	−93 930±440	1 001 560±410
50	118	Sn	−98 443±100	1 004 980± 90
51	118	Sb	−94 270±150	1 000 310±140

Table IV. (continued)

Atomic number Z	Mass number A	Symbol	Mass excess (microunit)	Binding energy (keV)
49	119	In	−94 270±180	1 009 950±170
50	119	Sn	−96 815± 90	1 011 540±80
51	119	Sb	−96 193± 90	1 010 180±80
52	119	Te	−93 730± 90	1 007 110±80
50	120	Sn	−97 930± 90	1 020 650±80
51	120	Sb	−95 020± 90	1 017 150±80
52	120	Te	−95 490±400	1 016 800±370
53	120	I	−90 120±450	1 011 020±420
50	121	Sn	−95 944± 70	1 026 870±60
51	121	Sb	−96 356± 70	1 026 470±60
50	122	Sn	−96 830± 70	1 035 760±60
51	122	Sb	−95 070± 80	1 033 340±70
52	122	Te	−97 186± 70	1 034 530±70
53	122	I	−92 774±100	1 029 630±90
50	123	Sn	−94 548± 80	1 041 710±80
51	123	Sb	−96 079± 70	1 042 350±70
52	123	Te	−95 820±130	1 041 320±120
50	124	Sn	−94 929±140	1 050 140±130
51	124	Sb	−94 124±130	1 048 600±120
52	124	Te	−97 254±130	1 050 740±120
53	124	I	−93 797±130	1 046 730±130
54	124	Xe	−93 880±160	1 046 020±150
50	125	Sn	−92 344±110	1 055 800±100
51	125	Sb	−94 844±110	1 057 350±100
52	125	Te	−95 649±130	1 057 310±100
53	125	I	−95 493±130	1 056 390±120
52	126	Te	−96 758± 37	1 066 413±47
53	126	I	−94 488± 31	1 063 516±43
54	126	Xe	−95 831± 32	1 063 984±43
55	126	Cs	−90 680±430	1 058 410±400
51	127	Sb	−93 190± 60	1 071 950±60
52	127	Te	−94 908± 25	1 072 766±40
53	127	I	−95 648± 23	1 072 668±39
54	127	Xe	−94 900±380	1 071 190±350
55	127	Cs	−92 660±380	1 068 320±350
52	128	Te	−95 290±140	1 081 190±130
53	128	I	−94 182± 13	1 079 374±35
54	128	Xe	−96 462± 10	1 080 715±33
55	128	Cs	−92 268± 29	1 076 030±41
52	129	Te	−93 424± 12	1 087 526±35
53	129	I	−95 013± 11	1 088 224±34
54	129	Xe	−95 216± 10	1 087 625±34
52	130	Te	−93 300±140	1 095 480±140
53	130	I	−93 315± 33	1 094 709±45
54	130	Xe	−96 490± 9	1 096 883±34
55	130	Cs	−93 279± 23	1 093 110±39
56	130	Ba	−93 753± 24	1 092 769±39
52	131	Te	−91 424± 23	1 101 806±40
53	131	I	−93 872± 8	1 103 304±34
54	131	Xe	−94 913± 7	1 103 486±34
55	131	Cs	−94 532± 10	1 102 353±34
52	132	Te	−91 432± 32	1 109 884±30
53	132	I	−91 974± 17	1 109 607±20

Table IV. (continued)

Atomic number Z	Mass number A	Symbol	Mass excess (microunit)	Binding energy (keV)
54	132	Xe	−95 838±8	1 112 418±34
55	132	Cs	−93 800±150	1 109 820±140
56	132	Ba	−94 850±320	1 109 950±300
57	132	La	89 700±330	1 104 360±310
53	133	I	−92 540±150	1 118 210±150
54	133	Xe	−94 450±150	1 119 200±140
55	133	C	94 910±150	1 118 840±140
56	133	Ba	−94 390±150	1 117 580±140
57	133	La	92 020±260	1 114 590±240
53	134	I	−90 160±50	1 124 060±60
54	134	Xe	94 602±8	1 127 410±35
55	134	Cs	93 480±150	1 125 580±140
56	134	Ba	95 690±150	1 126 850±140
57	134	La	91 710±260	1 122 380±250
54	135	Xe	−92 960±270	1 133 950±250
55	135	C	−94 200±270	1 134 330±250
56	135	Ba	−94 430±260	1 133 750±250
57	135	La	−93 300±310	1 131 930±290
53	136	I	−85 260±110	1 135 640±110
54	136	Xe	−92 779±10	1 141 854±36
55	136	C	−92 870±140	1 141 170±130
56	136	Ba	−95 640±140	1 142 960±130
57	136	La	−92 560±150	1 139 310±150
58	136	Ce	−92 900±500	1 138 850±490
55	137	Cs	−93 180±130	1 149 520±130
56	137	Ba	−94 440±130	1 149 910±130
55	138	Cs	−89 800±100	1 154 450±100
56	138	Ba	−94 990±80	1 158 490±80
57	138	La	−93 190±80	1 156 030±80
58	138	Ce	−94 280±80	1 156 260±80
55	139	Cs	−86 770±230	1 159 700±220
56	139	Ba	−91 390±80	1 163 210±80
57	139	La	−93 940±80	1 164 810±80
58	139	Ce	−93 650±80	1 163 750±80
59	139	Pr	−91 510±130	1 160 980±130
56	140	Ba	−89 540±60	1 169 560±70
57	140	La	−90 670±60	1 169 820±60
58	140	Ce	−94 720±50	1 172 810±60
59	140	Pr	−91 218±49	1 168 770±60
56	141	Ba	−86 260±330	1 174 580±310
57	141	La	−89 380±60	1 176 700±60
58	141	Ce	−91 987±47	1 178 340±60
59	141	Pr	−92 610±46	1 178 140±60
60	141	Nd	−90 678±48	1 175 560±60
61	141	Pm	−86 790±220	1 171 160±210
58	142	Ce	−90 960±80	1 185 460±80
59	142	Pr	−90 210±47	1 183 980±60
60	142	Nd	−92 522±47	1 185 350±60
61	142	Pm	87 370±330	1 179 770±310
57	143	La	−84 280±120	1 188 100±120
58	143	Ce	−87 830±50	1 190 610±60
59	143	Pr	89 370±50	1 191 270±60
60	143	Nd	−90 380±50	1 191 420±60
61	143	Pm	−89 200±170	1 189 540±160
62	143	Sm	85 540±230	1 185 360±210
58	144	Ce	86 570±50	1 197 510±60
59	144	Pr	86 900±50	1 197 040±60
60	144	Nd	−90 100±50	1 199 230±60
62	144	Sm	−88 350±240	1 196 040±220
58	145	Ce	83 760±190	1 202 970±180
59	145	Pr	85 900±150	1 204 180±150
60	145	Nd	87 840±150	1 205 200±150
61	145	Pm	87 690±150	1 204 280±150
62	145	Sm	−87 000±150	1 202 860±150
58	146	Ce	−81 730±280	1 209 150±270
59	146	Pr	−82 800±260	1 209 370±250
60	146	Nd	−87 310±150	1 212 780±150
61	146	Pm	85 460±70	1 210 280±80
62	146	Sm	−87 100±70	1 211 020±80
63	146	Eu	−82 520±110	1 205 975±100
60	147	Nd	−84 170±50	1 217 930±60
61	147	Pm	−85 140±50	1 218 050±60
62	147	Sm	−85 380±50	1 217 490±60
63	147	Eu	−83 410±200	1 214 880±190
60	148	Nd	−83 520±160	1 225 390±150
61	148	Pm	−82 800±150	1 223 940±140
62	148	Sm	85 440±130	1 225 610±120
64	148	Gd	−82 260±260	1 221 090±250
60	149	Nd	80 160±150	1 230 330±150
61	149	Pm	−81 920±130	1 231 190±130
62	149	Sm	−83 070±130	1 231 470±120
64	149	Gd	−81 080±220	1 228 060±210
60	150	Nd	−79 290±150	1 237 590±150
61	150	Pm	−78 910±450	1 236 460±420
62	150	Sm	−82 990±130	1 239 480±120
63	150	Eu	−80 390±160	1 236 270±150
64	150	Gd	−81 540±160	1 236 560±150
60	151	Nd	−75 780±240	1 242 400±220
61	151	Pm	−78 360±210	1 244 020±200
62	151	Sm	−80 290±180	1 245 040±170
63	151	Eu	−80 370±180	1 244 320±170
65	151	Tb	−77 020±230	1 239 640±210
62	152	Sm	−80 510±120	1 253 320±110
63	152	Eu	−78 520±120	1 250 680±110
64	152	Gd	−80 470±120	1 251 710±110
66	152	Dy	−75 620±270	1 245 620±250
62	153	Sm	−78 280±180	1 259 310±170
63	153	Eu	−79 140±180	1 259 330±170
64	153	Gd	−78 910±180	1 258 330±170
66	153	Dy	−74 630±230	1 252 780±220
62	154	Sm	−77 990±280	1 267 110±260
63	154	Eu	−77 160±190	1 265 550±180
64	154	Gd	−79 280±190	1 266 750±180
66	154	Dy	−75 220±160	1 261 400±160
62	155	Sm	−75 280±200	1 272 650±190
63	155	Eu	−77 150±180	1 273 610±170
64	155	Gd	−77 410±180	1 273 080±170

Table IV. (continued)

Atomic number Z	Mass number A	Symbol	Mass excess (microunit)	Binding energy (keV)
62	156	Sm	−74 290±180	1 279 810±180
63	156	Eu	−75 260±180	1 279 930±170
64	156	Gd	−77 930±180	1 281 600±170
66	156	Dy	76 240±420	1 278 490±390
63	157	Eu	−74 700±190	1 287 470±180
64	157	Gd	−76 060±180	1 287 960±170
64	158	Gd	−75 930±180	1 295 890±170
65	158	Tb	−74 990±250	1 294 240±240
66	158	Dy	−76 000±250	1 294 410±240
67	158	Ho	−75 720±270	1 292 850±260
68	158	Er	−73 720±270	1 290 720±260
63	159	Eu	−71 670±280	1 300 800±250
64	159	Gd	−74 030±250	1 302 210±240
65	159	Tb	75 050±250	1 302 380±240
66	159	Dy	−74 640±250	1 301 220±240
64	160	Gd	72 880±190	1 309 210±180
65	160	Tb	−73 240±190	1 308 760±180
66	160	Dy	−75 170±190	1 309 780±180
64	161	Gd	−70 680±220	1 315 240±210
65	161	Tb	−72 830±210	1 316 450±200
66	161	Dy	−73 400±210	1 316 210±200
66	162	Dy	−73 530±190	1 324 400±180
67	162	Ho	−71 210±200	1 321 450±190
68	162	Er	−71 220±350	1 320 680±330
66	163	Dy	−71 630±210	1 330 700±200
67	163	Ho	−71 620±210	1 329 910±200
66	164	Dy	−71 170±240	1 338 340±230
67	164	Ho	−69 650±250	1 336 140±230
68	164	Er	−70 710±250	1 336 350±230
69	164	Tm	−66 460±250	1 331 600±230
66	165	Dy	−68 300±250	1 343 740±230
67	165	Ho	−69 700±250	1 344 260±230
68	165	Er	69 610±250	1 343 390±230
66	166	Dy	−67 100±170	1 350 690±170
67	166	Ho	−67 620±170	1 350 390±170
68	166	Er	−69 600±170	1 351 460±170
69	166	Tm	−67 030±200	1 348 270±190
67	167	Ho	−66 880±190	1 357 770±180
68	167	Er	67 950±160	1 357 990±150
68	168	Er	−67 620±160	1 365 750±160
69	168	Tm	−65 670±270	1 363 150±260
70	168	Yb	−66 100±270	1 362 770±260
68	169	Er	−65 290±260	1 371 650±250
69	169	Tm	−65 650±260	1 371 210±250
68	170	Er	−64 490±300	1 378 980±230
69	170	Tm	−64 080±140	1 377 820±130
70	170	Yb	−65 120±140	1 378 000±130
71	170	Lu	−61 320±170	1 373 680±170
68	171	Er	−61 830±170	1 384 580±170
69	171	Tm	−63 430±170	1 385 280±170
70	171	Yb	−63 540±170	1 384 600±170

Table IV. (continued)

Atomic number Z	Mass number A	Symbol	Mass excess (microunit)	Binding energy (keV)
68	172	Er	−60 440±160	1 391 350±160
69	172	Tm	−61 420±160	1 391 480±160
70	172	Yb	−63 440±160	1 392 580±150
69	173	Tm	−59 800±170	1 398 040±170
70	173	Yb	−61 700±160	1 399 030±160
71	173	Lu	−60 960±170	1 397 560±160
70	174	Yb	−60 980±140	1 406 430±140
71	174	Lu	−59 400±170	1 404 170±160
72	174	Hf	−59 740±150	1 403 710±150
69	175	Tm	−55 920±200	1 410 560±190
70	175	Yb	−58 610±160	1 412 300±150
71	175	Lu	−59 110±160	1 411 980±150
72	175	Hf	−58 470±170	1 410 600±160
70	176	Yb	−57 260±130	1 419 110±130
71	176	Lu	−57 260±80	1 418 320±90
72	176	Hf	−58 350±80	1 418 560±90
70	177	Yb	−54 500±110	1 424 610±110
71	177	Lu	−55 980±90	1 425 210±100
72	177	Hf	−56 520±90	1 424 920±100
73	177	Ta	−55 260±100	1 422 970±100
71	178	Lu	−53 710±110	1 431 170±110
72	178	Hf	−56 130±90	1 432 640±100
73	178	Ta	−54 090±230	1 429 950±220
71	179	Lu	−52 300±110	1 437 920±100
72	179	Hf	−53 980±100	1 438 700±100
73	179	Ta	−53 860±100	1 437 800±100
72	180	Hf	−53 190±110	1 446 030±110
73	180	Ta	52 480±60	1 444 590±70
74	180	W	−53 020±60	1 444 310±70
75	180	Re	−49 880±170	1 440 610±170
72	181	Hf	−50 920±50	1 451 990±70
73	181	Ta	−52 020±50	1 452 230±70
74	181	W	−51 810±60	1 451 260±70
72	182	Hf	−49 320±220	1 458 580±210
73	182	Ta	−49 860±50	1 458 300±70
74	182	W	−51 730±50	1 459 250±70
72	183	Hf	−46 200±220	1 463 740±210
73	183	Ta	−48 560±50	1 465 160±70
74	183	W	−49 710±50	1 465 450±70
73	184	Ta	−46 150±90	1 470 930±100
74	184	W	−49 010±50	1 472 870±70
75	184	Re	−47 290±320	1 470 480±300
76	184	Os	−47 440±250	1 469 840±240
73	185	Ta	−44 480±90	1 477 500±100
74	185	W	−46 520±80	1 478 620±90
75	185	Re	−46 980±80	1 478 260±80
76	185	Os	−45 930±80	1 476 500±80
73	186	Ta	−41 690±220	1 482 970±210
74	186	W	−45 660±60	1 485 890±70
75	186	Re	−44 910±80	1 484 410±90
76	186	Os	−46 060±80	1 484 700±90
77	186	Ir	−41 970±100	1 480 100±100

Table IV. (continued)

Atomic number Z	Mass number A	Symbol	Mass excess (microunit)	Binding energy (keV)
74	187	W	−42 630±60	1 491 140±70
75	187	Re	−44 040±60	1 491 670±70
76	187	Os	−44 040±60	1 490 890±70
74	188	W	−41 300±80	1 497 960±90
75	188	Re	−41 760±80	1 497 610±90
76	188	Os	−44 030±80	1 498 940±90
77	188	Ir	−40 990±90	1 495 330±90
78	188	Pt	−40 430±100	1 494 020±110
76	189	Os	−41 750±100	1 504 890±100
75	190	Re	−37 850±440	1 510 120±410
76	190	Os	−41 400±80	1 512 640±90
77	190	Ir	−39 200±180	1 509 800±180
78	190	Pt	−40 050±90	1 509 810±100
76	191	Os	−38 810±60	1 518 300±70
77	191	Ir	−39 150±60	1 517 830±70
76	192	Os	−38 590±60	1 526 160±70
77	192	Ir	−37 010±60	1 523 910±70
78	192	Pt	−38 570±60	1 524 580±70
79	192	Au	−35 100±80	1 520 560±90
76	193	Os	−35 500±70	1 531 360±90
77	193	Ir	−36 720±70	1 531 710±90
78	193	Pt	−36 670±80	1 530 880±90
77	194	Ir	−34 790±60	1 537 980±70
78	194	Pt	−37 190±60	1 539 430±70
79	194	Au	−34 490±60	1 536 140±70
80	194	Hg	−34 300±80	1 535 180±80
78	195	Pt	−35 180±38	1 545 640±60
79	195	Au	−34 890±44	1 544 580±60
78	196	Pt	−35 019±36	1 553 560±60
79	196	Au	−33 446±20	1 551 310±50
80	196	Hg	−34 178±18	1 551 210±50
81	196	Tl	−29 940±160	1 545 830±160
78	197	Pt	−32 643±20	1 559 420±50
79	197	Au	33 448±16	1 559 380±50
78	198	Pt	−32 470±310	1 567 310±290
79	198	Au	−31 758±16	1 565 870±50
80	198	Hg	−33 231±15	1 566 460±50
81	198	Tl	−29 470±80	1 562 180±90
78	199	Pt	−29 340±110	1 572 490±110
79	199	Au	−31 255±21	1 573 480±60
80	199	Hg	−31 744±20	1 573 150±50
81	199	Tl	−30 560±360	1 571 260±360
79	200	Au	−29 190±110	1 579 630±110
80	200	Hg	−31 656±14	1 581 150±50
81	200	Tl	29 026±17	1 577 910±50
79	201	Au	28 070±110	1 586 660±110
80	201	Hg	29 685±18	1 587 380±50
81	201	Tl	29 240±70	1 586 190±80
80	202	Hg	−29 370±23	1 595 160±50
81	202	Tl	−28 178±30	1 593 260±40
82	202	Pb	28 124±50	1 592 430±50

Table IV. (continued)

Atomic number Z	Mass number A	Symbol	Mass excess (microunit)	Binding energy (keV)
80	203	Hg	−27 147±40	1 601 160±60
81	203	Tl	−27 669±40	1 600 860±60
82	203	Pb	−26 600±50	1 599 080±70
83	203	Bi	−23 170±70	1 595 110±80
80	204	Hg	−26 518±19	1 608 640±50
81	204	Tl	−26 110±24	1 607 480±50
82	204	Pb	−26 931±24	1 607 460±50
83	204	Bi	−22 300±500	1 602 400±500
80	205	Hg	−23 770±110	1 614 150±110
81	205	Tl	−25 538±27	1 615 020±60
82	205	Pb	−25 484±40	1 614 190±60
83	205	Bi	−22 640±50	1 610 760±70
81	206	Tl	−23 920±16	1 621 580±50
82	206	Pb	−25 541±12	1 622 310±50
83	206	Bi	−21 680±160	1 617 930±160
84	206	Po	−19 810±60	1 615 406±60
81	207	Tl	−22 554±15	1 628 380±50
82	207	Pb	−24 102±12	1 629 040±50
83	207	Bi	−21 526±45	1 625 860±60
84	207	Po	−18 406±45	1 622 170±60
85	207	At	−14 280±80	1 617 540±80
81	208	Tl	−17 994±14	1 632 210±50
82	208	Pb	−23 356±12	1 636 420±50
83	208	Bi	−20 269±29	1 632 760±60
84	208	Po	−18 736±25	1 630 550±50
85	208	At	−13 500±500	1 624 900±500
81	209	Tl	−14 705±44	1 637 220±60
82	209	Pb	−18 906±25	1 640 350±50
83	209	Bi	−19 583±27	1 640 190±60
84	209	Po	−17 543±41	1 637 510±60
85	209	At	−13 860±50	1 633 290±70
81	210	Tl	−9 998±35	1 640 900±60
82	210	Pb	−15 823±14	1 645 550±60
83	210	Bi	−15 890±14	1 644 830±60
84	210	Po	−17 134±12	1 645 200±60
85	210	At	−13 030±160	1 640 590±160
86	210	Em	−10 590±60	1 637 540±60
82	211	Pb	−11 197±39	1 649 310±60
83	211	Bi	−12 706±15	1 649 930±60
84	211	Po	−13 351±20	1 649 750±60
85	211	At	−12 504±45	1 648 180±70
86	211	Em	−9 400±45	1 644 500±70
82	212	Pb	−8 104±16	1 654 500±60
83	212	Bi	−8 729±14	1 654 300±60
84	212	Po	−11 141±12	1 655 760±60
86	212	Em	−9 274±26	1 652 460±60
87	212	Fr	−3 900±500	1 646 700±500
83	213	Bi	−5 671±31	1 659 520±60
84	213	Po	−7 163±29	1 660 130±60
85	213	At	−6 910±220	1 659 110±200
82	214	Pb	−240±60	1 663 310±80
83	214	Bi	−1 366±35	1 663 580±60
84	214	Po	−4 808±14	1 666 010±60
85	214	At	−3 670±60	1 664 170±70

Table IV. (continued)

Atomic number Z	Mass number A	Symbol	Mass excess (microunit)	Binding energy (keV)
83	215	Bi	1 900±130	1 668 610±120
84	215	Po	−531±41	1 670 090±41
85	215	At	−1 342±26	1 670 070±60
86	215	Em	−1 330±110	1 669 270±110
84	216	Po	1 917±16	1 675 880±60
85	216	At	2 405±35	1 674 650±60
86	216	Em	234±34	1 675 890±60
85	217	At	4 647±33	1 680 630±60
86	217	Em	3 917±44	1 680 530±70
87	217	Fr	4 780±310	1 678 940±280
84	218	Po	8 930±60	1 685 500±70
85	218	At	8 554±36	1 685 060±60
86	218	Em	5 592±18	1 687 040±60
87	218	Fr	7 520±80	1 684 460±90
85	219	At	11 360±120	1 690 520±120
86	219	Em	9 523±41	1 691 450±70
87	219	Fr	9 249±34	1 690 920±60
88	219	Ra	10 030±150	1 689 410±150
86	220	Em	11 396±16	1 697 780±60
87	220	Fr	12 330±48	1 696 120±70
88	220	Ra	10 972±41	1 696 610±70
87	221	Fr	14 176±35	1 702 480±60
88	221	Ra	13 860±50	1 701 980±70
89	221	Ac	15 690±320	1 699 500±300
86	222	Em	17 530±60	1 708 210±70
88	222	Ra	15 365±21	1 708 660±60
89	222	Ac	17 750±90	1 705 660±100
87	223	Fr	19 802±42	1 713 380±70
88	223	Ra	18 565±41	1 713 750±70
89	223	Ac	19 119±40	1 712 450±70
90	223	Th	20 890±170	1 710 010±180
88	224	Ra	20 216±16	1 720 280±60
89	224	Ac	21 690±60	1 718 130±70
90	224	Th	21 379±46	1 717 630±70
88	225	Ra	23 518±37	1 725 280±70
89	225	Ac	23 143±35	1 724 840±70
90	225	Th	23 660±60	1 723 580±80
88	226	Ra	25 360±60	1 731 640±80
89	226	Ac	26 180±110	1 730 090±110
90	226	Th	24 890±23	1 730 500±60
91	226	Pa	27 800±110	1 727 010±110
88	227	Ra	29 220±47	1 736 110±70
89	227	Ac	27 814±41	1 736 630±70
90	227	Th	27 768±41	1 735 900±70
91	227	Pa	28 854±41	1 734 100±70
92	227	U	30 920±220	1 731 390±210
88	228	Ra	31 228±42	1 742 310±70
89	228	Ac	31 169±42	1 741 580±70
90	228	Th	28 749±16	1 743 050±60
91	228	Pa	31 000±50	1 740 180±80
92	228	U	31 278±47	1 739 130±70
90	229	Th	31 629±40	1 748 440±70

Table IV. (continued)

Atomic number Z	Mass number A	Symbol	Mass excess (microunit)	Binding energy (keV)
91	229	Pa	31 952±48	1 747 360±70
92	229	U	33 200±60	1 745 410±80
90	230	Th	33 080±60	1 755 160±80
91	230	Pa	34 366±24	1 753 180±60
92	230	U	33 926±24	1 752 810±60
89	231	Ac	38 600±120	1 758 870±130
90	231	Th	36 350±42	1 760 190±70
91	231	Pa	35 936±42	1 759 790±70
92	231	U	36 330±60	1 758 640±90
93	231	Np	38 330±60	1 756 000±80
90	232	Th	38 211±42	1 766 530±70
91	232	Pa	38 611±27	1 765 370±70
92	232	U	37 167±17	1 765 930±60
94	232	Pu	41 080±70	1 760 730±90
90	233	Th	41 428±42	1 771 600±70
91	233	Pa	40 108±40	1 772 050±70
92	233	U	39 498±40	1 771 830±70
93	233	Np	40 600±70	1 770 020±90
94	233	Pu	42 690±60	1 767 290±80
90	234	Th	43 570±80	1 677 670±100
91	234	Pa	43 370±80	1 777 080±100
92	234	U	40 900±60	1 778 600±80
93	234	Np	42 830±130	1 776 020±130
94	234	Pu	43 290±60	1 774 800±70
91	235	Pa	45 440±120	1 783 230±120
92	235	U	43 933±43	1 783 840±70
93	235	Np	44 069±44	1 782 930±70
94	235	Pu	45 330±70	1 780 980±90
92	236	U	45 733±40	1 790 240±70
93	236	Np	46 625±19	1 788 630±60
94	236	Pu	46 072±17	1 788 360±60
91	237	Pa	51 050±60	1 794 140±90
92	237	U	48 581±41	1 795 660±70
93	237	Np	48 030±41	1 795 390±70
94	237	Pu	48 277±46	1 794 380±70
95	237	Am	49 780±90	1 792 190±100
92	238	U	50 760±80	1 801 700±100
93	238	Np	50 930±70	1 800 760±80
94	238	Pu	49 520±70	1 801 280±80
96	238	Cm	53 010±70	1 796 470±80
92	239	U	54 320±60	1 806 460±80
93	239	Np	52 938±45	1 806 960±70
94	239	Pu	52 161±44	1 806 900±70
95	239	Am	52 970±60	1 805 360±80
92	240	U	56 700±50	1 812 310±80
93	240	Np	56 180±80	1 812 010±90
94	240	Pu	53 974±40	1 813 280±70
96	240	Cm	55 503±37	1 810 290±70
93	241	Np	58 170±110	1 818 230±130
94	241	Pu	56 711±41	1 818 800±70
95	241	Am	56 689±41	1 818 040±70
96	241	Cm	57 510±70	1 816 500±90

Table IV. (continued)

Atomic number Z	Mass number A	Symbol	Mass excess (microunit)	Binding energy (keV)
94	242	Pu	58 710±80	1 825 010±100
95	242	Am	59 480±70	1 823 520±80
96	242	Cm	58 800±70	1 823 370±80
94	243	Pu	61 990±60	1 830 030±80
95	243	Am	61 382±46	1 829 810±70
96	243	Cm	61 377±44	1 829 040±70
97	243	Bk	62 920±80	1 826 820±90
95	244	Am	64 520±110	1 834 960±120
96	244	Cm	62 910±40	1 835 680±70
98	244	Cf	65 933±43	1 831 300±70
95	245	Am	66 313±42	1 841 360±80
96	245	Cm	65 342±41	1 841 490±70
97	245	Bk	66 240±60	1 839 870±70
98	245	Cf	67 890±70	1 837 550±90
94	246	Pu	70 230±110	1 846 570±120
95	246	Am	69 830±100	1 846 160±110
96	246	Cm	67 370±90	1 847 670±100
98	246	Cf	68 780±70	1 844 790±80
97	247	Bk	70 180±70	1 852 340±90
97	248	Bk	73 050±80	1 857 740±100
98	248	Cf	72 350±50	1 857 610±70
100	248	Fm	77 240±120	1 851 480±130
96	249	Cm	75 800±120	1 864 030±130
97	249	Bk	74 838±43	1 864 140±80
98	249	Cf	74 704±42	1 863 490±80
99	249	Es	76 220±80	1 861 290±90
97	250	Bk	78 490±140	1 868 820±140
98	250	Cf	76 550±90	1 859 830±100
100	250	Fm	79 480±80	1 865 540±100
99	251	Es	79 850±90	1 874 050±110
99	252	Es	82 900±100	1 879 280±110
100	252	Fm	82 650±60	1 878 740±80
98	253	Cf	84 980±60	1 886 200±90
99	253	Es	84 685±43	1 885 690±80
99	254	Es	88 110±140	1 890 570±140
100	254	Fm	87 000±90	1 890 820±100
101	255	Md	90 570±110	1 894 780±120

$$1e = (1.000\,043 \pm 0.000\,012)$$

chemical-scale units.

The first relative masses of the nuclides were calculated for the new ^{12}C = 12 scale, based on the latest measurements of the nuclide masses, by Everling, Konig, Mattauch, and Wapstra [21] in 1960. Then in 1961, Konig, Mattauch, and Wapstra compiled a new table for the nuclide masses [22].

The IUPAC Commission on Atomic Weights published in 1961 a new table of atomic weights based on the scale ^{12}C = 12 [23,24]. These data are given in Table III.

The new atomic weights were calculated from the nuclide masses given in the paper by Everling, Konig, Mattauch, and Wapstra [21] and the most reliable values of the relative abundances of the isotopes [25]. The table gives not only the atomic weights, but also the limits of their fluctuations due to changes in the isotopic composition of the elements. In this table the series of atomic weights, particularly for anisotopic elements, are more accurate than the old atomic weights of the elements.

The International Commission on Atomic Weights has proposed to change the name of the table of atomic weights and call it the "Table of Relative Atomic Masses." These proposals are still subject to IUPAC examination and approval.

With improved accuracy of the data on the nuclide masses and the isotope abundance, the accuracy of the values of atomic weights (masses) of the chemical elements will also increase.

At the present time it is already possible to set up a somewhat more accurate table of the nuclide masses (Table IV) compared with the table of [22], on the basis of which the atomic weights were calculated for 1961. The more accurate values of the nuclide masses will be used subsequently to compile the tables of new atomic weights of the elements.

Table IV lists essentially the masses of the nuclides, taken from the last mass listing of Konig, Mattauch, and Wapstra [22], but many values were replaced by the author with data obtained by Demirkhanov, Dorokhov, and Dzkuya [26]. Some values of the masses of the radioactive isotopes are also changed to take account of new data.

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