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A MASS TABLE FOR A CONSISTENT SET OF ATOMS

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Translation from Nuclear Constants 2(46) 31 (1982)

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ABSTRACT

A table of atomic masses is drawn up for a set of atoms characterized by maximum consistency with all experimental data. The following principles are used as a basis for compiling the table: maximum reliability, in the view of the authors, of the experimental data for mass doublets and for energies of nuclear reactions and radioactive decay; use of the least-squares method for processing experimental data; and analysis of the internal consistency of data. The physico-methodological and statistical criteria discussed in the paper were used to select 752 atoms, the masses of which are linked by 2480 experimentally measured ratios, for a consistent set. Apart from masses, mass excesses and binding energies for each atom, the table contains β-decay energies for 474 cases.

In order to ensure the uniformity of measurements in physical studies it is necessary to use data on the masses of atoms and associated quantities which have been evaluated, i.e. correlated to a certain degree of reliability with all the existing experimental data. Among the associated quantities are the mass excess, which is the difference between the mass of an atom and its mass number; the binding energy and the energy of β-decay. It is not possible, working on the basis of purely theoretical assumptions, to calculate the masses of atoms with sufficient accuracy. Nor do semi-empirical equations result for the moment in high enough accuracy. There are no grounds for considering the results of individual studies on an empirical determination of the masses of atoms sufficiently reliable, since there is always a possibility of the systematic error not having been taken into account.

In order to increase reliability we need to follow a combined approach to the whole mass of experimental information available. An approach of this kind is followed in the paper by A. Wapstra and K. Bos [1], who, by analysing and generalizing many primary experimental data, succeeded in drawing up tables for the masses of atoms [2] with an accuracy exceeding that found in individual studies. However, a detailed examination of the principles underlying the mass evaluation of atoms in Ref. [1] shows that the results obtained are of uneven reliability. Moreover, many new data have been published since that time.

In this paper the criteria for drawing up a set of atoms with consistent masses (ACM) are defined on the basis of a given body of experimental information, and the values and errors in ACM masses, and the mass excesses, binding energies and β-decay energies associated with them are rendered more accurate. The data obtained may find extensive application for studies in theoretical and experimental physics and also in the field of nuclear power.

Criteria for the elaboration of a set of atoms with consistent masses and a method of evaluation

A large number of measurements have now been accumulated for mass doublets and energy releases in nuclear reactions and radioactive transformations. Since in experiments nowadays only the difference between the masses (energies) of atoms are determined and not their absolute values, all these results can be divided up into two sets. In the first of these we shall put results which, when taken together, link the mass of each of the atoms in the set in the form of the differences from the masses of at least two other atoms, the experimental information available being self-consistent to within a certain degree of reliability. All other results have to be placed in the second set. In fact, if there is only one measurement of a difference of this kind, there is always a probability, except in the case of mass-spectrometric measurements for stable nuclides, that one may take the energy of transition into an excited state as the energy of transition between the ground states of nuclei. Such cases may occur as a result of insufficiently accurate knowledge of the systems of nuclear transitions. This source of unreliability can be eliminated - or at least allowance can be made for it in the error shown for the mass of an atom - only by intercomparison of data, i.e. only for results of the first set. The criterion selected for this comparison was consistency between evaluated masses and each of the experimental results used to within three adjusted standard deviations of the particular result. This criterion is described more fully below.

It is suggested that ACM should be taken to include only those atoms for which the masses are described by the first set of experimental results. For the formal verification of ACM some basic concepts are required. A comparison is made between any measurement under consideration and the process equation linking the value for a certain linear combination of atomic masses M_i with the process energy Q_j which has a standard deviation $\sigma_j(Q)$:

$$\sum_i \ell_{ij} M_i = Q_j \pm \sigma_j(Q)\,, \tag{1}$$

in which we assume the coefficients ℓ_{ij} to differ from zero by whole numbers and we sum over the atomic masses linked by the given process.

Definition 1. Two process equations are considered to be similar with respect to the pair of atoms i and k if there is a linear combination of these equations which does not contain M_i and M_k simultaneously.

Definition 2. We shall consider as subset pairs similar with respect to the pair of atoms i and k, a subset of process equations, any pair of elements of which is similar with respect to the pair of atoms i and k. Thus, every process equation linking n atoms may be assigned to $n(n - 1)/2$ such subsets.

Definition 3. The atom i is considered independent if there is no similar subset pair which simultaneously includes a full set of equations containing M_i. The atom of the nuclide ^{12}C was taken to be independent since its mass serves as a basis for the scale of atomic mass units (amu).

Definition 4. An atom of the nuclide i is formally included in the ACM as long as at least one of the following conditions is fulfilled:

- It is independent;
- There are at least two equations containing it which are grouped in a pairwise similar subset only in combinations containing independent atoms whose masses are known with an error that is negligible;
- It is stable, and there exist one or more mass spectrometric measurements of its mass relative to a combination of masses of independent atoms.

After examining the entire original set of results and identifying the atoms of nuclides which do not satisfy definition 4, equations containing such atoms are discarded, while the remaining set undergoes the same evaluation again. This process is repeated until a set of equations linking only atoms which satisfy definition 4 is found. It is from this set alone that the mass values are determined and their consistency with each of the equations included in the set is verified. If for any reason it is necessary to omit one or another atom or equation from the evaluation, the remaining set is again analysed according to the method described above. Atoms linked by the final set of results used in the present evaluation are considered to be atoms with standard masses.

From the formal point of view, our verification of ACM is similar to the so-called class of primary data evaluated in Ref. [1]. A considerable amount of primary data has consequently been included in our evaluation exactly as it is given in Ref. [1], and in that sense our tables maintain a degree of continuity with that paper. In addition, we have used data from 164 papers which were either published after the period covered by Ref. [1] or belonged to that period but were not included in that evaluation for one reason or another. Because of the inclusion of new data, and also in cases where there was disagreement with the arguments advanced in Ref. [1], it was necessary to perform an additional matching procedure, the principles of which are described below. As a result of that, some of the data used in Refs [1,2] as primary data were treated in our evaluation as unreliable or as not belonging to the ACM set. However, we felt that some of the data in Ref. [1] regarded as unreliable should be included in the evaluation. Exclusion of some of the data from Refs [1,2] meant that the data referred to but not used had to be included with a lower degree of accuracy, while the incorporation of new data also enabled some of the equations defined in Ref. [1] to be introduced as second- or even higher-order equations since, when combined with the new data, they began to satisfy the requirements for elements of the set of equations for defining ACM masses.

In our study of the new results, we have attempted to stress as far as possible the contribution made by our paper. For example, for some measurements an adjustment was made in respect of a process known from another paper or from an evaluation. When using these data, the authors did not take the absolute values for the process energy, but rather the difference between the measured and calibrated process values. Some of the results could not be utilized because the calibration was performed for atoms not belonging to the ACM.

The same methods were employed to achieve consistency within the set, as in Refs [1,2]: correction of standard deviations of mass spectrometric measurements by means of C_j coefficients and the rejection of unreliable equations. The method of averaging similar equations which was widely used in Ref. [1] was not applied to new data since it has become clear that in many cases it produces an unjustifiably optimistic mean error. The use as in Ref. [1] of the coefficients C_j to correct the standard deviations of mass spectrometric results is an indication of the fact noted in many papers that certain similar data obtained at different facilities deviate significantly from each other for reasons that are not understood. Preference was given in the present evaluation to doublets measured by cycles as this enabled the absence of systematic errors for data obtained at a single facility to be verified by constructing closed circuits. From the methodological point of view, the best of all the analysed data of this kind are probably those of the Sukhumi Physico-Technical Institute (R.A. Demirkhanov Laboratory). No corrective coefficients were assigned to data not included in the Ref. [1] evaluation with the exception of the doublets defining ^{67}Zn, to which the coefficient $C_j = 2.5$ had to be allocated. In addition, it proved necessary to assign a coefficient $C_j = 2.5$ to all the results obtained by the Canadian team (K.S. Sharma, K.S. Kozier et al.). Furthermore, in some cases the mass-doublet weights assigned in Ref. [1] were reviewed.

Criteria of two types were included in the analysis of the reliability of all the results considered. Account was taken of the characteristics of the methodology, the equipment used and (most important of all) the extent to which theoretical and model representations tended to convert the value taken directly from experiments to that required to evaluate the energy of the process being studied. With regard to the last of these, in cases where discrepancies arose between equations describing nuclear processes we decided first and foremost not to use the results of electron capture energy measurements. This explains the substantial discrepancy between the data in this paper and those given in Ref. [2] in the ^{153}Gd region.

Apart from the physico-methodological criteria described above which were applied to individual results, we also applied a statistical criterion which takes advantage of the verification of the ACM set formulated above. The requirement that the discrepancy coefficients

$$(Q_j - \sum_i \ell_{ij} M_i)/C_j \sigma_j(Q) \qquad (2)$$

should not exceed 3 corresponds qualitatively to the requirement that even in relatively small subsets of the set of equations employed (where reasonable values are assigned for masses not defined by the subset in question) the discrepancy distribution should be Gaussian with a single dispersion. Accordingly, the non-fulfilment of this condition can be considered a significant inconsistency in a small subset of this kind. Particular attention was paid in such situations to atoms whose masses are defined by only two equations. Whenever the statistical criterion was not fulfilled in such cases, the atom and both equations defining its mass were quite definitely excluded from the analysis as data whose reliability could not be evaluated. It was for this reason that we omitted the atom ^{60}Co , for example, whose mass was evaluated in Refs [1,2] with the standard deviation at 14 keV (in energy units) on the basis of two measurements the results of which diverged by about 145 keV.

For atoms whose masses were defined by more than two equations, the statistical criterion was applied in practice only in conjunction with physico-methodological criteria, playing an auxiliary role in clarifying cases of conflict. Where there were three or more measurements, it was always possible in practice to identify and discard the most dubious measurement using physico-methodological criteria. Thus, instead of averaging similar but inconsistent equations as was done in Ref. [1], a stricter and more coherent set of conditions for the reliability of the experimental results included in the evaluation was utilized.

It should be stressed that in the matching process constant consideration was given to determining the real source of conflict. Here the statistical criterion described above was applied to subsets of the data set which, in complicated cases, included up to several tens of atoms, and the conflict was by no means always due to those measurements for whose equations there was a large discrepancy.

A detailed description of the results of applying this methodology and a comparison of them with other evaluations are beyond the scope of this paper. Consistency between data was achieved in regions containing nuclides with mass numbers 3, 46–50, 55–67, 82, 87–89, 94, 104–106, 149–153, 159, 175, 180–181, 198–200, 205–206, 249.

The set of data compiled by the authors for determining ACM masses encompassed 2480 experimental results linking the atomic masses of 752 nuclides including ^{12}C. A system of normal equations was established from these data by the usual method. The least-squares method was used to determine the masses [3]. Two fundamental constants were utilized in the calculation process: the atomic mass of the nuclide ^{12}C = 12 amu (exactly) and the coefficient for converting energy units to mass units

$$K \pm \sigma(K) = (1073535{\cdot}5 \pm 3.0)\times10^{-9} \text{ amu/meV} \qquad (3)$$

obtained from the value 1/K given in Ref. [4]. The conversion to amu was chosen because the standard deviation σ(K) is comparable with the errors in the most accurate mass spectrometric measurements, the results of which are given in amu.

<u>Calculation method and atomic mass table structure</u>

The mass excesses (i.e. the differences between the mass of the atom and its mass number) were selected as the parameters to be evaluated:

$$\mu = M - A, \qquad (4)$$

where μ is the mass excess, M is the mass of the atom and A is its mass number. Where necessary, the equations were transformed so that they depended on the mass excesses. Clearly, this procedure did not interfere in any way with the standard deviations.

If the equations of the original system (1) transformed into amu and written in terms of the mass excesses μ_i have the form of the sum of all N atoms in the ACM set:

$$\sum_{i=1}^{N} \ell_{ij} \mu_i = z_j \pm \sigma_j(z) \qquad (j = 1, 2, \ldots, J), \qquad (5)$$

where, in constrast to expression (1), zero values are adopted for the missing coefficients ℓ_{ij}, then the system of normal equations is written as:

$$\sum_{k=1}^{N} a_{km} \mu_m = R_k , \qquad (6)$$

where

$$a_{km} = \sum_{j=1}^{J} \ell_{kj} \ell_{mj} / [C_j \sigma_j(z)]^2 ; \tag{7}$$

$$R_k = \sum_{j=1}^{J} \ell_{kj} z_j / [C_j \sigma_j(z)]^2 . \tag{8}$$

To obtain the covariance matrix a_{km}^{-1}, a specially developed inversion algorithm was used, the prototype for which was algorithm 42b in Ref. [5]; this has much in common with the method described in Ref. [6]. The essential difference in our method is the fourfold reduction of the operating field required (based on the fact that the inverted matrix is symmetrical and positively defined), and a further difference being the steps taken to optimize the operating time of the algorithm in the case of vacuum matrices.

The calculations were performed using a 1010B computer equipped with a specialized mathematical software system, the prototype for which is Basic Fortran - 1010B [7]. High-speed floating-point arithmetical subprograms were used in the calculations, these having a higher accuracy than in Ref. [7] with the number representation remaining unchanged. Five bytes were allocated to one real number, four of which (32 binary digits) were used to represent the mantissa. Rounding off by eliminating the least significant, overflow digits and normalizing the result were carried out after each arithmetical operation.

The operating field for the inversion of the matrix of the 751st order for our algorithm has a volume of about 1.4 megabytes, which enables it to be placed on existing magnetic discs with a total capacity of 1.5 megabytes. To reduce the rounding errors, a special arrangement of the variables was used in inverted matrix calculations with the result that the average number of operations per element was cut by a factor of about three.

The system of normal equations was solved by multiplying the covariance matrix a_{km}^{-1} by the column R_k [8]. In the process, fixed point arithmetic was simulated to improve accuracy. Assessment of how accurately the set of solutions obtained corresponded to the minimum value

$$\chi^2 = \frac{1}{J-N} \sum_{j=1}^{J} \Big(\sum_{i=1}^{N} \ell_{ij} \mu_i - z_j \Big)^2 / [C_j \sigma_j(z)]^2 \tag{9}$$

resulted in the following value for the discrepancy factor for the calculated parameters $\delta\mu_i$:

$$\overline{\left[\delta\mu_i / \sigma_i(\mu)\right]} \sim 0,5 \qquad (10)$$

where $\sigma_i(\mu) = \sqrt{a_{ii}^{-1}}$ is the standard deviation of the i-th evaluated parameter. As a further check, the set of equations (1) used to obtain the tables in Ref. [2] was processed by the method described. A comparison of our control results with the tables in Ref. [2] showed that agreement between them is far better than follows from expression (10). Since there were no data on the degree of accuracy of the minimization of χ^2 when the tables in Ref. [2] were being drawn up, we can only conclude that the degree of equivalance between the calculation processes compared is high.

For our set of data, the calculation of χ^2 gave the result:

$$\chi^2 = 0,895, \qquad (11)$$

and the Birge coefficient was consequently not introduced for standard deviations of the mass excesses.

The results of the calculations are given in the table. The ACMs are arranged according to the mass numbers A and, within the limits of constant A, according to the charge Z. The "N" column shows the number of neutrons in a nucleus and the "Z" column shows its charge. The column 'Atom' contains the mass number A and the chemical symbol of the element. The data for the "Atomic Mass" column were obtained in amu by summing A with the calculated mass excesses. In the summation, steps were taken to prevent the loss of the lowest significant figures of the sum. The standard deviation given in brackets in this column corresponds to $\sigma_i(\mu)$ rounded to two figures if these figures represent a number not exceeding 25, or to one figure in other cases. The standard deviations are given everywhere in units of the least significant figures of the relevant result. The "Mass Excess" column contains the results of the matching process, expressed in keV. Since the transformation was achieved using the coefficient in Eq. (3), the standard deviation for mass excesses was calculated from the relationship

$$\sigma_i(\mu/K) = \sigma_i(\mu)/K \sqrt{\left[\sigma(K)/K\right]^2 + \left[\sigma_i(\mu)/\mu_i\right]^2} \qquad (12)$$

In the "Binding Energy" column, the quantity presented is

$$E_{bi}(A, Z) = Z\mu_H + N\mu_n - \mu(A, Z) \tag{13}$$

where the binding energies are expressed in keV, μ_H is the mass excess of the hydrogen atom, and μ_n is the neutron mass excess.

The "Beta-Decay Energy" column gives the value:

$$E_\beta(A,Z) = \mu(A,Z) - \mu(A,Z+1). \tag{14}$$

The positive value $E_\beta(A, Z)$ corresponds to the β^--decay of the atom (A, Z) into the atom (A, Z + 1), and the negative value to the allowed transition of the atom (A, Z +1) to the atom (A, Z). This value could not be calculated unless the atom (A, Z + 1) was included in the ACM set, and in such cases no entry was made in this column. The beta-decay energies are expressed in keV.

The standard deviations for the last two columns were calculated by the method of evaluating standard deviations for random variable functions described, inter alia, in Ref. [8].

If

$$E = E(\mu_1, \mu_2, \dots, \mu_L), \tag{15}$$

the standard deviation is

$$\sigma(E) = \left(\sum_{i=1}^{L} \sum_{j=1}^{L} \frac{\partial E}{\partial \mu_i} \frac{\partial E}{\partial \mu_j} a_{ij}^{-1} \right)^{1/2}. \tag{16}$$

The values $\sigma_i(E/K)$ were obtained from $\sigma_i(E)$ according to an equation similar to Eq. (12).

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EVALUATED MASSES AND ASSOCIATED VALUES FOR A CONSISTENT SET OF ATOMS

N	Z	ATOM	Atomic mass, amu	Mass excesses, keV	Binding energy, keV	Beta-decay energy, keV
1	0	1N0	1,008664912 (19)	8071,38 (3)	0 (0)	782,345 (16)
0	1	1H	1,007825037 (10)	7289,034 (22)	0 (0)	
1	1	2H	2,014101783 (20)	13135,83 (4)	2224,5 (16)	
2	1	3H	3,01604927 (3)	14949,92 (5)	8481,8 (4)	18,604 (10)
1	2	3HE	3,01602930 (3)	14931,32 (5)	7718,1 (3)	
2	2	4HE	4,00260325 (5)	2424,93 (4)	28295,9 (9)	
4	2	6HE	6,0188868 (9)	17593,1 (9)	29270,5 (9)	3506,6 (7)
3	3	6LI	6,0151224 (7)	14086,5 (6)	31994,7 (6)	
4	3	7LI	7,0160038 (8)	14907,5 (8)	39245,1 (8)	-861,89 (7)
3	4	7BE	7,0169290 (8)	15769,4 (8)	37600,8 (8)	
6	2	8HE	8,033922 (7)	31599 (7)	31408 (7)	10653 (7)
5	3	8LI	8,0224864 (9)	20946,1 (8)	41277,9 (8)	16004,4 (8)
4	4	8BE	8,00530513 (11)	4941,74 (10)	56499,9 (18)	-17979,5 (12)
3	5	8B	8,0246068 (13)	22921,2 (12)	37738,1 (12)	-12172 (24)
2	6	8C	8,03767 (3)	35093 (24)	24784 (24)	
6	3	9LI	9,0267893 (21)	24954,3 (20)	45341,1 (20)	13606,5 (19)
5	4	9BE	9,0121823 (4)	11347,8 (4)	58165,2 (4)	
3	6	9C	9,031038 (4)	28912 (4)	39036 (4)	
6	4	10BE	10,0135343 (4)	12607,2 (4)	64977,2 (4)	555,6 (6)
5	5	10B	10,0129378 (5)	12051,6 (5)	64750,4 (5)	
8	3	11LI	11,04395 (13)	40940 (120)	45500 (120)	20760 (120)
7	4	11BE	11,021659 (7)	20176 (6)	65480 (6)	11508 (6)
6	5	11B	11,0093052 (5)	8667,9 (4)	76205,6 (5)	-1982,3 (8)
5	6	11C	11,0114333 (10)	10650,1 (9)	73441,0 (9)	

N	Z	ATOM	Atomic mass, amu		Mass excesses, keV		Binding energy, keV		Beta-decay energy, keV	
8	4	12BE	12,026916	(15)	25072	(14)	68655	(14)	11703	(14)
7	5	12B	12,0143526	(14)	13369,5	(13)	79575,3	(13)	13369,5	(13)
6	6	12C	12,000000	(0)	0	(0)	92162,5	(3)	-17338,0	(10)
5	7	12N	12,0186130	(10)	17338,0	(10)	74042,1	(10)		
7	6	13C	13,003354847	(16)	3125,045	(18)	97108,8	(3)	-2220,22	(18)
6	7	13N	13,00573833	(19)	5345,26	(18)	94106,3	(3)		
8	6	14C	14,003241985	(23)	3019,915	(23)	105285,3	(3)	156,473	(9)
7	7	14N	14,003074006	(22)	2863,441	(22)	104659,5	(3)	-5144,0	(3)
6	8	14O	14,0085962	(3)	8007,4	(3)	98733,2	(4)		
8	7	15N	15,00010896	(4)	101,49	(3)	115492,8	(4)	-2754,0	(7)
7	8	15O	15,0030654	(8)	2855,5	(7)	111956,5	(8)		
9	7	16N	16,0060996	(25)	5681,7	(23)	117983,9	(24)	10418,8	(23)
8	8	16O	15,99491463	(4)	-4737,03	(4)	127620,3	(4)		
9	8	17O	16,9991305	(8)	-809,9	(7)	131764,6	(8)	-2761,6	(8)
8	9	17F	17,00209517	(20)	1951,65	(19)	128220,7	(4)		
10	8	18O	17,9991594	(3)	-783,0	(3)	139809,1	(5)	-1655,6	(6)
9	9	18F	18,0009367	(7)	872,6	(7)	137371,2	(8)	-4447	(4)
8	10	18NE	18,005710	(5)	5319	(4)	132142	(4)		
12	7	19N	19,01696	(9)	15790	(90)	132090	(90)	12460	(90)
11	8	19O	19,003576	(3)	3331	(3)	143766	(3)	4819	(3)
10	9	19F	18,99840323	(14)	-1487,40	(13)	147802,5	(5)		
11	9	20F	19,9999816	(6)	-17,1	(6)	154403,6	(7)	7025,9	(7)
10	10	20NE	19,9924390	(5)	-7043,1	(5)	160647,2	(7)		
13	8	21O	21,00873	(5)	8130	(40)	155110	(40)	8180	(40)
12	9	21F	20,999949	(8)	-47	(7)	162505	(7)	5686	(7)
11	10	21NE	20,9938452	(12)	-5733,2	(11)	167408,7	(12)		

12	10	22NE	21.9913836	(6)	-8026.2	(5)	177773.1	(7)	-2842.1	(5)
11	11	22NA	21.9944347	(7)	-5184.1	(7)	174148.6	(9)	-4789.2	(19)
10	12	22MG	21.9995761	(19)	-394.8	(18)	168577.0	(19)		
12	11	23NA	22.9897689	(8)	-9530.3	(8)	186566.2	(10)	-4058.8	(14)
11	12	23MG	22.9941261	(15)	-5471.5	(14)	181725.1	(16)		
13	11	24NA	23.9909627	(8)	-8418.3	(8)	193525.6	(10)	5513.2	(6)
12	12	24MG	23.9850440	(7)	-13931.5	(6)	198256.5	(9)	-13878	(4)
11	13	24AL	23.999942	(4)	-54	(4)	183597	(4)	-10821	(22)
10	14	24SI	24.011558	(23)	10767	(22)	171994	(22)		
15	10	25NE	24.99769	(10)	-2150	(90)	196110	(90)	7200	(100)
14	11	25NA	24.989954	(7)	-9357	(7)	202536	(7)	3833	(7)
13	12	25MG	24.9858394	(7)	-13190.6	(6)	205586.9	(9)		
15	11	26NA	25.992606	(24)	-6888	(23)	208138	(23)	9324	(23)
14	12	26MG	25.9825958	(7)	-16212.0	(7)	216679.8	(9)	-4004.8	(4)
13	13	26AL	25.9868951	(8)	-12207.3	(7)	211892.6	(10)		
16	11	27NA	26.99396	(8)	-5630	(80)	214950	(80)	8960	(80)
15	12	27MG	26.9843429	(13)	-14584.6	(12)	223123.7	(14)	2610.6	(10)
14	13	27AL	26.9815403	(7)	-17195.3	(6)	224952.0	(9)		
17	11	28NA	27.99879	(13)	-1130	(120)	218520	(120)		
14	14	28SI	27.9769279	(6)	-21491.7	(6)	236537.5	(9)		
18	11	29NA	29.00286	(16)	2660	(150)	222800	(150)	13310	(160)
17	12	29MG	28.98857	(6)	-10650	(50)	235330	(50)	7560	(50)
16	13	29AL	28.980448	(6)	-18213	(5)	242113	(5)	3681	(5)
15	14	29SI	28.9764961	(7)	-21893.9	(6)	245011.1	(10)		
19	11	30NA	30.0090	(3)	8400	(300)	225200	(300)		
16	14	30SI	29.9737713	(7)	-24432.1	(6)	255620.6	(10)	-4227	(3)
15	15	30P	29.978309	(3)	-20205	(3)	250611	(3)		
16	15	31P	30.9737628	(6)	-24440.0	(6)	262917.5	(10)	-5395.1	(16)
15	16	31S	30.9795547	(17)	-19044.8	(16)	256740.1	(18)		
17	15	32P	31.9739073	(8)	-24305.4	(7)	270854.4	(11)	1710.4	(6)
16	16	32S	31.9720711	(5)	-26015.8	(5)	271782.5	(10)	-12687	(6)
15	17	32CL	31.985691	(7)	-13329	(7)	258313	(7)		

N	Z	Atom	Atomic mass, amu		Mass excesses, keV		Binding energy, keV		Beta-decay energy, keV	
17	16	33S	32,9714591	(5)	-26585,9	(5)	280423,9	(10)		
19	15	34P	33,973632	(9)	-24562	(9)	287253	(9)	5370	(9)
18	16	34S	33,9678679	(3)	-29931,1	(3)	291840,5	(9)	-5492,3	(3)
17	17	34Cl	33,9737641	(4)	-24438,8	(4)	285565,8	(10)		
19	16	35S	34,96903255	(21)	-28846,23	(21)	298827,0	(9)	167,49	(18)
18	17	35Cl	34,96885274	(6)	-29013,72	(10)	298212,1	(9)		
20	16	36S	35,9670790	(16)	-30665,9	(15)	308718,1	(18)	-1144,0	(15)
19	17	36Cl	35,96830711	(8)	-29521,98	(11)	306791,8	(10)	709,4	(3)
18	18	36AR	35,9675456	(3)	-30231,3	(3)	306718,8	(10)	-12806	(8)
17	19	36K	35,981293	(9)	-17426	(8)	293131	(8)	-10980	(40)
16	20	36CA	35,99308	(4)	-6450	(40)	281370	(40)		
21	16	37S	36,971133	(17)	-26889	(16)	313013	(16)	4872	(16)
20	17	37Cl	36,96590257	(9)	-31761,81	(12)	317103,0	(10)	-813,9	(5)
19	18	37AR	36,9667765	(6)	-30948,0	(5)	315506,8	(11)	-6148,5	(15)
18	19	37K	36,9733769	(15)	-24799,4	(14)	308575,9	(17)		
20	18	38AR	37,9627321	(8)	-34715,1	(8)	327345,3	(13)	-5912,7	(7)
19	19	38K	37,9690797	(10)	-28802,3	(10)	320650,2	(14)		
22	17	39Cl	38,968006	(20)	-29803	(18)	331287	(18)	3438	(18)
21	18	39AR	38,964315	(5)	-33241	(5)	333942	(5)	565	(5)
20	19	39K	38,9637077	(8)	-33806,3	(8)	333725,5	(13)	-6530,8	(18)
19	20	39CA	38,9707188	(21)	-27275,5	(19)	326412,4	(22)		
22	18	40AR	39,9623829	(7)	-35040,4	(7)	343813,3	(13)	-1505,0	(6)
21	19	40K	39,9639986	(8)	-33535,4	(8)	341526,0	(13)	1311,7	(5)
20	20	40CA	39,9625904	(9)	-34847,1	(8)	342055,4	(13)		

23	18	41AR	40,9645005	(10)	-33067,9	(9)	349912,2	(14)	2492,0	(8)
22	19	41K	40,9618253	(9)	-35559,8	(8)	351621,8	(13)	-421,4	(4)
21	20	41CA	40,9622777	(9)	-35138,4	(8)	350418,0	(13)		
23	19	42K	41,9624015	(13)	-35023,1	(12)	359156,4	(16)	3522,0	(15)
22	20	42CA	41,9586205	(14)	-38545,0	(13)	361896,1	(17)	-6423,6	(4)
21	21	42SC	41,9655165	(15)	-32121,4	(14)	354690,1	(17)		
23	20	43CA	42,9587691	(14)	-38406,7	(13)	369829,1	(17)	-2220,5	(19)
22	21	43SC	42,9611529	(25)	-36186,2	(23)	366826	(3)	-6866	(7)
21	22	43TI	42,968523	(7)	-29320	(7)	359178	(7)		
24	20	44CA	43,9554832	(14)	-41467,5	(13)	380961,3	(17)	-3655,5	(20)
23	21	44SC	43,9594075	(25)	-37812,0	(23)	376523	(3)	-265	(4)
22	22	44TI	43,959692	(3)	-37547	(3)	375476	(3)		
25	20	45CA	44,9561881	(14)	-40810,9	(13)	388376,1	(17)	257,5	(9)
24	21	45SC	44,9559116	(12)	-41068,4	(12)	387851,2	(17)		
26	20	46CA	45,953689	(4)	-43139	(4)	398775	(4)	-1381	(4)
25	21	46SC	45,9551710	(13)	-41757,5	(13)	396611,7	(17)	2367,3	(8)
24	22	46TI	45,9526304	(12)	-44124,9	(11)	398196,7	(16)	-7050,9	(5)
23	23	46V	45,9601997	(13)	-37074,0	(12)	390363,5	(17)		
27	20	47CA	46,954543	(4)	-42344	(4)	406052	(4)	1988	(4)
26	21	47SC	46,9524085	(22)	-44331,6	(21)	407257,2	(24)	600,6	(19)
25	22	47TI	46,9517637	(9)	-44932,2	(9)	407075,4	(15)	-2928,9	(14)
24	23	47V	46,9549081	(16)	-42003,2	(15)	403364,1	(19)		
28	20	48CA	47,952532	(4)	-44216	(4)	415995	(4)	281	(7)
27	21	48SC	47,952231	(7)	-44497	(6)	415494	(6)	3990	(6)
26	22	48TI	47,9479473	(9)	-48487,1	(9)	418701,7	(16)	-4015	(3)
25	23	48V	47,952257	(3)	-44472	(3)	413905	(3)	-1653	(8)
24	24	48CR	47,954032	(8)	-42819	(7)	411469	(8)		
28	21	49SC	48,950022	(4)	-46554	(4)	425623	(4)	2003	(4)
27	22	49TI	48,9478714	(9)	-48557,9	(9)	426843,9	(16)	-601,8	(8)
26	23	49V	48,9485174	(13)	-47956,1	(12)	425459,8	(18)	-2626	(3)
25	24	49CR	48,951337	(3)	-45329,8	(25)	422051	(3)	-7717	(17)
24	25	49MN	48,959621	(19)	-37613	(17)	413552	(17)		

N	Z	ATOM	Atomic mass, amu	Mass excesses, keV	Binding energy, keV	Beta-decay energy, keV
28	22	50TI	49,9447923 (9)	-51426,1 (9)	437783,5 (16)	-2205,5 (13)
27	23	50V	49,9471599 (13)	-49220,6 (12)	434795,6 (18)	1038,3 (9)
26	24	50CR	49,9460453 (14)	-50258,9 (13)	435051,6 (19)	-7632,0 (4)
25	25	50MN	49,9542385 (14)	-42626,9 (13)	426637,3 (19)	
29	22	51TI	50,9466161 (13)	-49727,1 (13)	444155,9 (19)	2473,5 (16)
28	23	51V	50,9439608 (13)	-52200,6 (12)	445847,0 (18)	-751,5 (9)
27	24	51CR	50,9447675 (14)	-51449,1 (13)	444313,2 (19)	-3208,5 (3)
26	25	51MN	50,9482119 (14)	-48240,7 (13)	440322,4 (19)	
29	23	52V	51,9447768 (17)	-51440,5 (16)	453158,3 (21)	3975,9 (15)
28	24	52CR	51,9405086 (13)	-55416,4 (12)	456351,8 (19)	-4711,4 (21)
27	25	52MN	51,9455664 (25)	-50705,0 (23)	450858 (3)	
29	24	53CR	52,9406503 (13)	-55284,4 (12)	464291,2 (19)	-595,6 (9)
28	25	53MN	52,9412897 (14)	-54688,7 (13)	462913,2 (20)	
30	24	54CR	53,9388816 (13)	-56931,8 (12)	474010,0 (19)	
28	26	54FE	53,9396113 (13)	-56252,1 (12)	471765,6 (19)	-8242,0 (5)
27	27	54CO	53,9484594 (14)	-48010,2 (13)	462741,3 (19)	
30	25	55MN	54,9380462 (13)	-57710,1 (12)	482077,3 (19)	-231,5 (6)
29	26	55FE	54,9382947 (13)	-57478,6 (12)	481063,5 (19)	-3450,9 (6)
28	27	55CO	54,9419994 (14)	-54027,6 (13)	476830,2 (19)	
30	26	56FE	55,9349375 (13)	-60605,8 (12)	492262,1 (20)	-4567,5 (19)
29	27	56CO	55,9398409 (24)	-56038,3 (23)	486912 (3)	-2135 (11)
28	28	56NI	55,942133 (12)	-53904 (11)	483995 (11)	
32	25	57MN	56,938284 (4)	-57488 (3)	497998 (4)	2692 (3)
31	26	57FE	56,9353941 (13)	-60180,5 (12)	499908,1 (20)	-836,2 (5)
30	27	57CO	56,9362918 (13)	-59344,2 (13)	498289,5 (20)	

32	26	58FE	57,9332758	(13)	-62153,7	(12)	509952,7	(20)	-2307,5	(12)
31	27	58CO	57,9357530	(17)	-59846,1	(16)	506862,8	(22)	380,9	(12)
30	28	58NI	57,9353442	(14)	-60227,0	(13)	506461,3	(20)		
34	25	59MN	58,94044	(3)	-55480	(30)	512130	(30)	5180	(30)
33	26	59FE	58,9348760	(16)	-60663,1	(15)	516533,5	(22)	1565,5	(11)
32	27	59CO	58,9331954	(13)	-62228,6	(12)	517316,7	(20)	-1073,1	(6)
31	28	59NI	58,9343474	(13)	-61155,5	(13)	515461,2	(20)		
34	26	60FE	59,934074	(4)	-61410	(4)	525352	(4)	239	(4)
33	27	60CO	59,9338177	(13)	-61648,9	(12)	524808,3	(20)	2823,63	(11)
32	28	60NI	59,9307864	(13)	-64472,5	(12)	526849,6	(20)		
33	28	61NI	60,9310560	(13)	-64221,5	(13)	534669,9	(21)	-2238,4	(14)
32	29	61CU	60,9334590	(18)	-61983,1	(16)	531649,2	(23)	-5636	(16)
31	30	61ZN	60,939509	(17)	-56348	(16)	525231	(16)		
34	28	62NI	61,9283439	(13)	-66747,8	(12)	545267,7	(21)	-3949	(5)
33	29	62CU	61,932583	(5)	-62799	(5)	540537	(5)		
36	27	63CO	62,933599	(20)	-61853	(19)	549227	(19)	3662	(19)
35	28	63NI	62,9296672	(13)	-65515,1	(12)	552106,3	(21)	65,89	(20)
34	29	63CU	62,9295965	(13)	-65581,0	(12)	551389,9	(21)	-3367,4	(17)
33	30	63ZN	62,9332115	(21)	-62213,6	(20)	547240	(3)		
36	28	64NI	63,9279653	(14)	-67100,4	(13)	561763,0	(21)	-1674,9	(8)
35	29	64CU	63,9297633	(15)	-65425,6	(14)	559305,8	(22)	578,0	(14)
34	30	64ZN	63,9291428	(17)	-66003,6	(16)	559101,5	(23)		
36	29	65CU	64,9277898	(18)	-67263,9	(17)	569215,6	(24)	-1352,0	(11)
35	30	65ZN	64,9292413	(17)	-65911,9	(16)	567081,2	(24)		
38	28	66NI	65,929122	(21)	-66023	(19)	576829	(19)	236	(19)
37	29	66CU	65,9288684	(20)	-66259,2	(19)	576282	(3)	2642,2	(17)
36	30	66ZN	65,9260319	(14)	-68901,4	(13)	578142,1	(22)		
39	28	67NI	66,931573	(17)	-63740	(16)	582617	(16)	3570	(17)
38	29	67CU	66,927741	(8)	-67310	(8)	585404	(8)	573	(8)
37	30	67ZN	66,9271254	(14)	-67882,8	(13)	585194,9	(22)	-1002,1	(13)
36	31	67GA	66,9282011	(17)	-66880,8	(16)	583410,5	(24)	-4222	(5)
35	32	67GE	66,932733	(5)	-62659	(5)	578406	(5)		

N	Z	ATOM	Atomic mass, amu		Mass excesses, keV		Binding energy, keV		Beta-decay energy, keV	
38	30	68ZN	67.9248421	(15)	-70009.7	(14)	595393.1	(23)		
36	32	68GE	67.928103	(14)	-66972	(13)	590791	(13)		
39	30	69ZN	68.9265482	(16)	-68420.5	(15)	601875.3	(23)	904.7	(25)
38	31	69GA	68.925577	(3)	-69325.1	(24)	601998	(3)	-2225.2	(25)
37	32	69GE	68.927966	(4)	-67100	(3)	598990	(4)	-4020	(30)
36	33	69AS	68.93228	(3)	-63080	(30)	594190	(30)	-6800	(40)
35	34	69SE	68.93957	(4)	-56290	(40)	586610	(40)		
40	30	70ZN	69.925321	(3)	-69564	(3)	611090	(3)	-655.0	(15)
39	31	70GA	69.926024	(3)	-68908.9	(25)	609653	(3)	1654	(3)
38	32	70GE	69.9242485	(17)	-70562.6	(16)	610524.1	(25)		
41	30	71ZN	70.927721	(11)	-67328	(10)	616925	(10)	2814	(10)
40	31	71GA	70.9247002	(23)	-70141.9	(22)	618957	(3)	-235.1	(17)
39	32	71GE	70.9249526	(20)	-69906.8	(18)	617940	(3)	-2012	(4)
38	33	71AS	70.927113	(5)	-67894	(4)	615145	(5)		
42	30	72ZN	71.926855	(7)	-68134	(6)	625803	(6)	457	(6)
41	31	72GA	71.9263646	(25)	-68591.5	(24)	625478	(3)	3993	(3)
40	32	72GE	71.9220779	(18)	-72584.5	(17)	628689	(3)		
38	34	72SE	71.927106	(13)	-67900	(12)	622440	(12)		
41	32	73GE	72.9234615	(17)	-71295.7	(16)	635471.4	(25)	-345	(4)
40	33	73AS	72.923832	(4)	-70951	(4)	634344	(4)	-2740	(10)
39	34	73SE	72.926773	(12)	-68211	(11)	630822	(11)	-4530	(220)
38	35	73BR	72.93164	(24)	-63680	(220)	625510	(220)	-6690	(220)
37	36	73KR	72.93882	(15)	-56980	(140)	618030	(140)		
42	32	74GE	73.9211762	(17)	-73424.5	(16)	645671.5	(25)	-2561.7	(18)
41	33	74AS	73.9239263	(24)	-70862.8	(22)	642327	(3)	1355.9	(25)
40	34	74SE	73.9224707	(21)	-72218.7	(20)	642901	(3)		

42	33	75AS	74,9215892	(15)	-73039,8	(14)	652575,8	(24)	-864,9	(10)
41	34	75SE	74,9225177	(17)	-72174,9	(16)	650929	(3)		
44	32	76GE	75,9213999	(23)	-73216,1	(22)	661606	(3)	-919,7	(24)
43	33	76AS	75,9223872	(16)	-72296,5	(15)	659904	(3)	2968,7	(16)
42	34	76SE	75,9192002	(19)	-75265,2	(18)	662090	(3)		
39	37	76RB	75,9349	(3)	-60600	(300)	645100	(300)		
44	33	77AS	76,920646	(4)	-73919	(3)	669597	(4)	693	(4)
43	34	77SE	76,9199019	(19)	-74611,5	(18)	669508	(3)	-1365	(3)
42	35	77BR	76,921367	(4)	-73247	(3)	667361	(4)	-3010	(30)
41	36	77KR	76,92459	(3)	-70240	(30)	663570	(30)	-5130	(120)
40	37	77RB	76,93010	(13)	-65110	(120)	657660	(120)		
46	32	78GE	77,922852	(6)	-71863	(5)	676396	(6)	964	(10)
45	33	78AS	77,921817	(10)	-72828	(9)	676578	(10)	4209	(9)
44	34	78SE	77,9172984	(20)	-77036,7	(18)	680005	(3)		
42	36	78KR	77,920393	(4)	-74154	(4)	675558	(5)	-7060	(180)
41	37	78RB	77,92798	(19)	-67090	(180)	667710	(180)		
45	34	79SE	78,918491	(4)	-75926	(3)	686965	(4)	157	(4)
44	35	79BR	78,9183219	(24)	-76083,3	(22)	686340	(3)		
46	34	80SE	79,9165035	(25)	-77777,1	(23)	696888	(3)	-1872,9	(19)
45	35	80BR	79,9185141	(24)	-75904,2	(22)	694232	(3)	1992	(6)
44	36	80KR	79,916376	(7)	-77896	(6)	695442	(6)		
46	35	81BR	80,916290	(3)	-77976	(3)	704375	(3)		
48	34	82SE	81,916696	(4)	-77598	(3)	712851	(4)	-100	(4)
47	35	82BR	81,916804	(3)	-77497	(3)	711968	(3)	3093,4	(14)
46	36	82KR	81,913483	(3)	-80591	(3)	714279	(4)		
49	34	83SE	82,919115	(5)	-75344	(5)	718669	(5)	3670	(15)
48	35	83BR	82,915175	(15)	-79015	(14)	721557	(14)	968	(14)
47	36	83KR	82,914135	(3)	-79983	(3)	721743	(4)		
50	34	84SE	83,918462	(16)	-75953	(15)	727349	(15)	1810	(30)
49	35	84BR	83,91652	(3)	-77760	(30)	728380	(30)	4670	(30)
48	36	84KR	83,911507	(3)	-82431	(3)	732263	(3)	-2680	(3)
47	37	84RB	83,914384	(4)	-79752	(3)	728801	(4)	891	(3)
46	38	84SR	83,913427	(4)	-80643	(4)	728910	(4)		

A	Z	ATOM	Atomic mass, amu		Mass excesses, keV		Binding energy, keV		Beta-decay energy, keV	
49	36	85KR	84,912532	(4)	-81477	(3)	739380	(4)	687,3	(20)
48	37	85RB	84,911794	(3)	-82164	(3)	739285	(4)	-1066	(7)
47	38	85SR	84,912938	(7)	-81098	(7)	737436	(7)		
50	36	86KR	85,910615	(5)	-83262	(4)	749236	(5)	-519	(5)
49	37	86RB	85,911172	(3)	-82743	(3)	747935	(4)	1775,2	(19)
48	38	86SR	85,909267	(3)	-84518	(3)	748928	(3)		
51	36	87KR	86,913359	(5)	-80706	(4)	754752	(5)	3897	(4)
50	37	87RB	86,909176	(3)	-84603	(3)	757866	(4)	272,3	(18)
49	38	87SR	86,908883	(3)	-84875	(3)	757356	(3)	-1861,3	(14)
48	39	87Y	86,910881	(3)	-83014	(3)	754713	(4)	-3664	(9)
47	40	87ZR	86,914815	(9)	-79350	(8)	750266	(9)		
52	36	88KR	87,914452	(15)	-79688	(14)	761805	(14)	2913	(14)
51	37	88RB	87,911325	(4)	-82601	(4)	763935	(5)	5316	(3)
50	38	88SR	87,905618	(3)	-87917	(3)	768469	(4)	-3621	(3)
49	39	88Y	87,909505	(5)	-84296	(4)	764066	(5)		
51	38	89SR	88,907450	(4)	-86210	(4)	774834	(5)	1492	(3)
50	39	89Y	88,905848	(3)	-87703	(3)	775544	(4)	-2836,4	(22)
49	40	89ZR	88,908893	(3)	-84866	(3)	771925	(4)	-4243	(19)
48	41	89NB	88,913448	(20)	-80624	(19)	766900	(19)		
51	39	90Y	89,907152	(4)	-86488	(3)	782401	(4)	2283,1	(25)
50	40	90ZR	89,904701	(3)	-88771	(3)	783902	(4)		
51	40	91ZR	90,905639	(3)	-87897	(3)	791099	(4)	-1255	(3)
50	41	91NB	90,906987	(4)	-86642	(4)	789061	(4)	-4440	(13)
49	42	91MO	90,911754	(13)	-82202	(12)	783839	(13)		

53	39	92Y	91,908935	(17)	-84827	(16)	796882	(16)	3634	(16)
52	40	92ZR	91,905035	(3)	-88460,5	(25)	799734	(4)	-2006,3	(17)
51	41	92NB	91,907188	(3)	-86454	(3)	796945	(4)	355	(4)
50	42	92MO	91,906807	(4)	-86809	(4)	796518	(4)		
53	40	93ZR	92,906471	(3)	-87122,3	(25)	806467	(4)	89,8	(16)
52	41	93NB	92,906375	(3)	-87212	(3)	805774	(4)	-408	(3)
51	42	93MO	92,906812	(4)	-86805	(4)	804584	(4)	-3193	(3)
50	43	93TC	92,910240	(5)	-83612	(5)	800609	(5)		
55	39	94Y	93,911595	(6)	-82349	(6)	810548	(6)	4920	(5)
54	40	94ZR	93,906313	(3)	-87270	(3)	814686	(4)	-899,8	(23)
53	41	94NB	93,907279	(3)	-86370	(3)	813004	(4)	2044,5	(23)
52	42	94MO	93,905084	(3)	-88414,7	(25)	814266	(4)		
55	40	95ZR	94,908039	(3)	-85661	(3)	821149	(4)	1125,5	(23)
54	41	95NB	94,9068333	(23)	-86784,9	(22)	821490	(3)	925,6	(5)
53	42	95MO	94,9058397	(23)	-87710,5	(22)	821633	(3)	-1699	(7)
52	43	95TC	94,907664	(8)	-86011	(8)	819151	(8)	-2560	(14)
51	44	95RU	94,910412	(13)	-83451	(12)	815809	(12)		
56	40	96ZR	95,908273	(3)	-85444	(3)	829002	(4)		
54	42	96MO	95,9046772	(23)	-88793,4	(21)	830787	(3)		
52	44	96RU	95,907596	(9)	-86074	(9)	826504	(9)		
57	40	97ZR	96,910949	(3)	-82951	(3)	834581	(4)	2658,1	(19)
56	41	97NB	96,908096	(3)	-85609	(3)	836457	(4)	1933,6	(19)
55	42	97MO	96,9060198	(23)	-87542,7	(21)	837608	(3)	-320	(4)
54	43	97TC	96,906363	(5)	-87223	(5)	836506	(5)	-1108	(10)
53	44	97RU	96,907553	(10)	-86115	(9)	834615	(9)		
56	42	98MO	97,9054067	(23)	-88113,8	(21)	846250	(3)	-1686	(4)
55	43	98TC	97,907217	(5)	-86428	(5)	843782	(5)	1797	(8)
54	44	98RU	97,905287	(7)	-88225	(6)	844797	(7)		
57	42	99MO	98,9077107	(23)	-85967,7	(22)	852176	(3)	1356,9	(10)
56	43	99TC	98,9062540	(24)	-87324,6	(23)	852750	(3)	293,6	(18)
55	44	99RU	98,905939	(3)	-87618,2	(24)	852262	(4)		
58	42	100MO	99,907474	(6)	-86188	(6)	860468	(7)		
56	44	100RU	99,904219	(3)	-89220,0	(24)	861935	(4)		

N	Z	ATOM	Atomic mass, amu		Mass excesses, keV		Binding energy, keV		Beta-decay energy, keV	
59	42	101MO	100,910343	(7)	-83515	(6)	865866	(7)	2811	(24)
58	43	101TC	100,90733	(3)	-86326	(24)	867895	(24)	1625	(24)
57	44	101RU	100,905581	(3)	-87952	(3)	868738	(4)		
58	44	102RU	101,904348	(3)	-89100	(3)	877958	(4)	-2323	(6)
57	45	102RH	101,906841	(7)	-86777	(6)	874853	(7)	1149	(5)
56	46	102PD	101,905608	(7)	-87926	(7)	875219	(7)		
59	44	103RU	102,906322	(3)	-87261	(3)	884190	(4)	762	(3)
58	45	103RH	102,905504	(4)	-88023	(4)	884170	(5)	-544	(8)
57	46	103PD	102,906088	(8)	-87479	(7)	882843	(8)	-2680	(50)
56	47	103AG	102,90896	(5)	-84800	(50)	879380	(50)	-4180	(50)
55	48	103CD	102,913448	(11)	-80624	(10)	874423	(11)		
60	44	104RU	103,905420	(5)	-88102	(5)	893102	(5)	-1150	(6)
59	45	104RH	103,906694	(4)	-86952	(4)	891170	(5)	2452	(5)
58	46	104PD	103,904022	(3)	-89403	(3)	892839	(4)		
61	44	105RU	104,907740	(5)	-85940	(5)	899012	(5)	1918	(4)
60	45	105RH	104,905681	(4)	-87859	(4)	900148	(5)	567	(3)
59	46	105PD	104,905072	(3)	-88426	(3)	899933	(4)	-1346	(9)
58	47	105AG	104,906517	(10)	-87080	(9)	897804	(9)	-2739	(5)
57	48	105CD	104,909457	(11)	-84341	(10)	894283	(10)		
62	44	106RU	105,907315	(10)	-86336	(9)	907479	(10)	39,4	(3)
61	45	106RH	105,907273	(10)	-86375	(9)	906736	(10)	3541	(9)
60	46	106PD	105,903472	(3)	-89916	(3)	909494	(4)	-2974	(4)
59	47	106AG	105,906665	(5)	-86941	(5)	905737	(5)	193	(7)
58	48	106CD	105,906458	(6)	-87135	(5)	905149	(6)		
61	46	107PD	106,905124	(5)	-88377	(5)	916026	(6)	33	(3)
60	47	107AG	106,905089	(4)	-88410	(4)	915277	(5)		

62	46	108PD	107,903893	(3)	-89524	(3)	925245	(4)	-1916	(5)
61	47	108AG	107,905950	(4)	-87608	(4)	922546	(5)	1641	(6)
60	48	108CD	107,904189	(5)	-89248	(5)	923405	(5)		
63	46	109PD	108,905951	(3)	-87607	(3)	931399	(4)	1116,7	(19)
62	47	109AG	108,904752	(3)	-88723,5	(24)	931734	(4)	-183	(3)
61	48	109CD	108,904949	(4)	-88540	(4)	930768	(5)	-2024	(7)
60	49	109IN	108,907122	(8)	-86516	(7)	927962	(8)		
64	46	110PD	109,905171	(7)	-88334	(7)	940197	(8)	-875	(7)
63	47	110AG	109,906111	(3)	-87458,2	(24)	938540	(4)	2894,5	(18)
62	48	110CD	109,9030032	(24)	-90352,7	(22)	940652	(4)		
63	48	111CD	110,9041802	(25)	-89256,3	(24)	947627	(4)	-830	(8)
62	49	111IN	110,905071	(8)	-88426	(8)	946015	(8)	-2478	(10)
61	50	111SN	110,907731	(8)	-85949	(7)	942755	(8)		
66	46	112PD	111,907326	(21)	-86326	(20)	954332	(20)	294	(19)
65	47	112AG	111,90701	(3)	-86620	(25)	953844	(25)	3963	(25)
64	48	112CD	111,9027569	(22)	-90582,1	(21)	957024	(4)	-2575	(7)
63	49	112IN	111,905521	(7)	-88007	(7)	953667	(8)	659	(6)
62	50	112SN	111,904814	(5)	-88666	(5)	953543	(6)		
65	48	113CD	112,9043984	(21)	-89053,0	(20)	963566	(4)	329	(4)
64	49	113IN	112,904045	(3)	-89382	(3)	963113	(4)	-1042	(4)
63	50	113SN	112,905164	(4)	-88340	(4)	961289	(5)	-3890	(30)
62	51	113SB	112,90934	(3)	-84450	(30)	956620	(30)		
66	48	114CD	113,9033571	(19)	-90023,0	(18)	972608	(4)	-1438	(3)
65	49	114IN	113,904901	(3)	-88585	(3)	970387	(4)	1982,2	(25)
64	50	114SN	113,902773	(3)	-90567	(3)	971587	(4)		
67	48	115CD	114,905414	(5)	-88107	(4)	978763	(5)	1447,8	(20)
66	49	115IN	114,903859	(4)	-89555	(4)	979429	(5)	486	(4)
65	50	115SN	114,903338	(3)	-90041	(3)	979132	(4)		
68	48	116CD	115,9047539	(24)	-88721,9	(22)	987449	(4)	-454	(5)
67	49	116IN	115,905241	(4)	-88268	(4)	986213	(5)	3263	(4)
66	50	116SN	115,901738	(3)	-91531	(3)	988694	(4)		

N	Z	ATOM	Atomic mass, amu		Mass excesses, keV		Binding energy, keV		Beta-decay energy, keV	
69	48	117CD	116.907225	(14)	-86420	(13)	993219	(14)	2528	(14)
68	49	117IN	116.904511	(9)	-88949	(8)	994965	(9)	1455	(8)
67	50	117SN	116.902949	(3)	-90404	(3)	995638	(4)		
68	50	118SN	117.901602	(3)	-91658	(3)	1004963	(4)		
69	50	119SN	118.903306	(3)	-90071	(3)	1011448	(4)		
70	50	120SN	119,902195	(3)	-91105	(3)	1020554	(4)	-2681	(7)
69	51	120SB	119,905073	(8)	-88425	(8)	1017090	(8)	951	(20)
68	52	120TE	119,904052	(20)	-89376	(19)	1017259	(19)		
72	49	121IN	120,907862	(24)	-85826	(22)	1024128	(22)	3379	(22)
71	50	121SN	120,904235	(3)	-89205	(3)	1026725	(5)	386,0	(25)
70	51	121SB	120,903821	(3)	-89591	(3)	1026329	(5)	-1066	(14)
69	52	121TE	120,904964	(16)	-88526	(15)	1024481	(15)	-2267	(22)
68	53	121I	120,907398	(21)	-86259	(19)	1021431	(19)		
72	50	122SN	121.903437	(4)	-89949	(4)	1035540	(5)	-1623	(3)
71	51	122SB	121,905179	(4)	-88326	(3)	1033135	(5)	1981	(4)
70	52	122TE	121,903053	(5)	-90307	(4)	1034333	(5)		
74	49	123IN	122,91044	(3)	-83421	(24)	1037866	(24)	4403	(24)
73	50	123SN	122,905718	(4)	-87824	(4)	1041486	(5)	1396	(4)
72	51	123SB	122,904219	(4)	-89220	(3)	1042100	(5)	-52,3	(23)
71	52	123TE	122,904276	(4)	-89167	(4)	1041265	(5)	-1230	(4)
70	53	123I	122,905596	(6)	-87938	(5)	1039253	(6)		
74	50	124SN	123,905268	(5)	-88243	(5)	1049976	(6)	-627	(5)
73	51	124SB	123,905942	(4)	-87616	(3)	1048567	(5)	2904,8	(18)
72	52	124TE	123,902823	(4)	-90520	(4)	1050689	(5)		
70	54	124XE	123,90612	(15)	-87450	(140)	1046050	(140)		

75	50	125SN	124,907779	(6)	-85904	(5)	1055709	(6)	2348	(6)
74	51	125SB	124,905258	(5)	-88253	(4)	1057275	(5)	766,8	(20)
73	52	125TE	124,904434	(4)	-89019	(4)	1057260	(5)	-177,8	(18)
72	53	125I	124,904625	(4)	-88842	(4)	1056300	(5)		
74	52	126TE	125,903310	(4)	-90067	(4)	1066379	(5)	-2156	(5)
73	53	126I	125,905624	(7)	-87911	(6)	1063441	(7)		
75	52	127TE	126,905222	(5)	-88286	(5)	1072669	(6)	696	(4)
74	53	127I	126,904475	(5)	-88981	(4)	1072582	(5)		
76	52	128TE	127,904463	(4)	-88993	(4)	1081447	(5)	-1257	(5)
75	53	128I	127,905813	(5)	-87736	(4)	1079408	(5)	2125	(4)
74	54	128XE	127,9035308	(17)	-89861,2	(16)	1080751	(4)		
78	51	129SB	128,909146	(23)	-84631	(22)	1085939	(22)	2377	(21)
77	52	129TE	128,906595	(5)	-87007	(4)	1087533	(6)	1498	(4)
76	53	129I	128,904986	(5)	-88505	(4)	1088249	(6)	192	(4)
75	54	129XE	128,9047801	(21)	-88697,5	(20)	1087659	(4)		
78	52	130TE	129,906228	(5)	-87349	(5)	1095946	(6)		
76	54	130XE	129,9035095	(17)	-89881,1	(16)	1096914	(4)	-3020	(11)
75	55	130CS	129,906752	(12)	-86861	(11)	1093111	(11)	441	(4)
74	56	130BA	129,906278	(11)	-87302	(11)	1092770	(11)		
79	52	131TE	130,908533	(5)	-85202	(5)	1101871	(6)	2250	(6)
78	53	131I	130,906117	(5)	-87452	(5)	1103338	(6)	970,8	(6)
77	54	131XE	130,905075	(5)	-88423	(5)	1103527	(6)	-353	(6)
76	55	131CS	130,905454	(8)	-88070	(7)	1102391	(8)	-1358	(13)
75	56	131BA	130,906912	(14)	-86712	(13)	1100251	(13)		
78	54	132XE	131,904147	(5)	-89287	(5)	1112463	(6)	-2109	(23)
77	55	132CS	131,906411	(24)	-87178	(23)	1109571	(23)	1278	(24)
76	56	132BA	131,905039	(10)	-88456	(9)	1110067	(10)		
78	55	133CS	132,905427	(8)	-88095	(7)	1118560	(8)	-521	(3)
77	56	133BA	132,905985	(8)	-87575	(8)	1117257	(9)		
80	54	134XE	133,905395	(8)	-88125	(7)	1127443	(8)	-1209	(10)
79	55	134CS	133,906693	(8)	-86915	(7)	1125451	(8)	2058,5	(4)
78	56	134BA	133,904484	(8)	-88974	(7)	1126727	(8)		

N	Z	Atom	Atomic mass, amu		Mass excesses, keV		Binding energy, keV		Beta-decay energy, keV	
82	53	135I	134,91004	(3)	-83800	(30)	1131970	(30)	2710	(30)
81	54	135XE	134,907126	(12)	-86512	(11)	1133902	(12)	1160	(9)
80	55	135CS	134,905881	(8)	-87672	(8)	1134279	(9)	205	(5)
79	56	135BA	134,905661	(7)	-87877	(6)	1133702	(7)		
82	54	136XE	135,907219	(7)	-86426	(7)	1141887	(8)		
80	56	136BA	135,904549	(7)	-88913	(6)	1142809	(7)		
78	58	136CE	135,90713	(5)	-86500	(40)	1138840	(40)		
83	54	137XE	136,911562	(7)	-82380	(7)	1145912	(8)	4188	(9)
82	55	137CS	136,907067	(6)	-86567	(6)	1149317	(7)	1173,5	(9)
81	56	137BA	136,905807	(6)	-87741	(6)	1149709	(7)		
82	56	138BA	137,905227	(6)	-88281	(6)	1158320	(7)	-1747	(5)
81	57	138LA	137,907103	(5)	-86534	(5)	1155791	(6)	1041	(12)
80	58	138CE	137,905985	(13)	-87575	(12)	1156050	(13)		
83	56	139BA	138,908822	(6)	-84933	(6)	1163043	(7)	2308	(5)
82	57	139LA	138,906344	(5)	-87241	(4)	1164569	(6)		
83	57	140LA	139,909468	(5)	-84331	(4)	1169730	(6)	3760,8	(20)
82	58	140CE	139,905431	(4)	-88091	(4)	1172709	(5)	-3387	(6)
81	59	140PR	139,909066	(7)	-84705	(7)	1168540	(8)		
83	58	141CE	140,908268	(4)	-85449	(4)	1178137	(5)	580,1	(15)
82	59	141PR	140,907645	(4)	-86029	(4)	1177935	(5)	-1814	(8)
81	60	141ND	140,909592	(9)	-84215	(9)	1175339	(10)	-3718	(25)
80	61	141PM	140,91358	(3)	-80496	(25)	1170838	(25)	-4554	(24)
79	62	141SM	140,918473	(13)	-75942	(12)	1165501	(13)		

84	58	142CE	141,909237	(5)	-84546	(4)	1185306	(6)	-745	(3)
83	59	142PR	141,910037	(4)	-83801	(4)	1183778	(5)	2159,3	(25)
82	60	142ND	141,907719	(3)	-85960	(3)	1185155	(5)	-4890	(60)
81	61	142PM	141,91297	(6)	-81070	(60)	1179480	(60)	-2080	(60)
80	62	142SM	141,915204	(16)	-78988	(15)	1176618	(16)		
85	58	143CE	142,912378	(5)	-81620	(4)	1190452	(6)	1455	(4)
84	59	143PR	142,910815	(4)	-83076	(3)	1191125	(5)	935,3	(19)
83	60	143ND	142,909811	(3)	-84011	(3)	1191278	(5)	-1038	(4)
82	61	143PM	142,910925	(5)	-82974	(5)	1189458	(6)	-3492	(10)
81	62	143SM	142,914630	(11)	-79522	(10)	1185224	(11)		
86	58	144CE	143,913642	(5)	-80443	(4)	1197345	(6)	318,2	(20)
85	59	144PR	143,913300	(4)	-80761	(4)	1196881	(6)	2996	(3)
84	60	144ND	143,910084	(3)	-83757	(3)	1199095	(5)	-2327	(4)
83	61	144PM	143,912582	(5)	-81430	(5)	1195986	(6)	544	(4)
82	62	144SM	143,911998	(4)	-81974	(4)	1195748	(5)		
85	60	145ND	144,912570	(3)	-81441	(3)	1204851	(5)	-158	(3)
84	61	145PM	144,912740	(5)	-81283	(4)	1203910	(6)	-618	(4)
83	62	145SM	144,913403	(4)	-80665	(4)	1202510	(5)	-2721	(11)
82	63	145EU	144,916324	(13)	-77944	(12)	1199007	(12)		
86	60	146ND	145,913114	(3)	-80935	(3)	1212415	(5)		
84	62	146SM	145,913049	(7)	-80995	(6)	1210911	(7)	-3873	(9)
83	63	146EU	145,917207	(12)	-77122	(11)	1206256	(11)		
87	60	147ND	146,916097	(3)	-78155	(3)	1217708	(5)	895,7	(9)
86	61	147PM	146,915136	(3)	-79051	(3)	1217821	(5)	224,7	(4)
85	62	147SM	146,914895	(3)	-79276	(3)	1217263	(5)	-1722	(3)
84	63	147EU	146,916744	(4)	-77553	(4)	1214758	(5)		
88	60	148ND	147,916889	(4)	-77418	(3)	1225042	(5)	-537	(9)
87	61	148PM	147,917465	(10)	-76882	(9)	1223723	(10)	2464	(9)
86	62	148SM	147,914819	(3)	-79346	(3)	1225405	(5)	-3120	(30)
85	63	148EU	147,91817	(3)	-76220	(30)	1221500	(30)		
89	60	149ND	148,920144	(4)	-74386	(3)	1230081	(5)	1697,7	(23)
88	61	149PM	148,918322	(3)	-76084	(3)	1230996	(5)	1062,6	(10)
87	62	149SM	148,917181	(3)	-77146	(3)	1231276	(5)		
85	64	149GD	148,919336	(5)	-75139	(5)	1227704	(6)	-3696	(11)
84	65	149TB	148,923304	(13)	-71443	(12)	1223226	(12)		

N	Z	ATOM	Atomic mass, amu		Mass excesses, keV		Binding energy, keV		Beta-decay energy, keV	
90	60	150ND	149,920887	(4)	-73693	(4)	1237460	(5)		
88	62	150SM	149,917273	(3)	-77060	(3)	1239262	(5)	-2294	(11)
87	63	150EU	149,919736	(12)	-74766	(11)	1236185	(12)	1009	(4)
86	64	150GD	149,918652	(11)	-75776	(11)	1236412	(11)	-4683	(13)
85	65	150TB	149,923680	(18)	-71092	(17)	1230947	(17)		
90	61	151PM	150,921204	(11)	-73398	(10)	1244454	(11)	1188	(9)
89	62	151SM	150,919929	(3)	-74586	(3)	1244859	(5)	76,2	(6)
88	63	151EU	150,919848	(3)	-74662	(3)	1244153	(5)	-479	(5)
87	64	151GD	150,920361	(6)	-74183	(5)	1242892	(7)	-2558	(4)
86	65	151TB	150,923108	(5)	-71625	(5)	1239551	(6)		
90	62	152SM	151,919729	(3)	-74773	(3)	1253117	(5)	-1876,8	(11)
89	63	152EU	151,921743	(3)	-72896	(3)	1250458	(5)	1820	(3)
88	64	152GD	151,919790	(4)	-74716	(4)	1251495	(5)		
92	61	153PM	152,924112	(17)	-70690	(16)	1257888	(16)	1879	(15)
91	62	153SM	152,922094	(3)	-72569	(3)	1258985	(5)	807	(3)
90	63	153EU	152,921228	(4)	-73376	(4)	1259010	(6)	-485	(4)
89	64	153GD	152,921749	(4)	-72891	(4)	1257742	(5)	-1585	(5)
88	65	153TB	152,923450	(7)	-71306	(6)	1255375	(7)	-2171,4	(17)
87	66	153DY	152,925781	(7)	-69135	(6)	1252421	(8)		
92	62	154SM	153,922205	(3)	-72466	(3)	1266953	(5)		
90	64	154GD	153,920863	(3)	-73717	(3)	1266639	(5)		
93	62	155SM	154,924629	(3)	-70208	(3)	1272766	(5)	1630	(4)
92	63	155EU	154,922880	(5)	-71837	(4)	1273614	(6)	247	(3)
91	64	155GD	154,922615	(3)	-72084	(3)	1273078	(5)		
94	62	156SM	155,925517	(15)	-69381	(14)	1280011	(14)	715	(11)
93	63	156EU	155,924750	(11)	-70095	(10)	1279943	(11)	2453	(9)
92	64	156GD	155,922116	(3)	-72549	(3)	1281614	(5)		
90	66	156DY	155,924271	(8)	-70542	(7)	1278042	(8)		

94	63	157EU	156,925412	(7)	-69479	(6)	1287398	(7)	1[illegible]9	(5)
93	64	157GD	156,923954	(3)	-70837	(3)	1287974	(5)	-[illegible]	(23)
92	65	157TB	156,924015	(4)	-70780	(4)	1287134	(6)	-13[illegible]0	(7)
91	66	157DY	156,925454	(8)	-69439	(7)	1285011	(8)		
94	64	158GD	157,924097	(3)	-70703	(3)	1295911	(5)	-121[illegible]	(18)
93	65	158TB	157,925403	(4)	-69487	(4)	1293913	(5)	936	(4)
92	66	158DY	157,924398	(5)	-70424	(4)	1294067	(6)		
96	63	159EU	158,929078	(9)	-66064	(8)	1300126	(9)	2510	(7)
95	64	159GD	158,926383	(4)	-68574	(3)	1301853	(5)	976.6	(19)
94	65	159TB	158,925335	(4)	-69551	(3)	1302047	(5)	-365,7	(10)
93	66	159DY	158,925728	(4)	-69185	(3)	1300899	(5)		
96	64	160GD	159,927047	(3)	-67956	(3)	1309306	(5)	-101,4	(14)
95	65	160TB	159,927156	(4)	-67854	(3)	1308423	(5)	1832,9	(17)
94	66	160DY	159,925188	(4)	-69687	(3)	1309473	(5)		
96	65	161TB	160,927558	(4)	-67480	(3)	1316119	(5)	590,3	(16)
95	66	161DY	160,926924	(4)	-68070	(3)	1315927	(5)		
96	66	162DY	161,926790	(4)	-68195	(4)	1324124	(5)		
94	68	162ER	161,928772	(4)	-66349	(3)	1320713	(5)		
97	66	163DY	162,928721	(4)	-66396	(4)	1330396	(5)	-2,6	(21)
96	67	163HO	162,928724	(4)	-66393	(4)	1329611	(6)	-1211	(5)
95	68	163ER	162,930025	(6)	-65182	(6)	1327617	(7)		
98	66	164DY	163,929167	(4)	-65981	(4)	1338052	(6)	-1029	(3)
97	67	164HO	163,930272	(5)	-64951	(4)	1336241	(6)	1003	(4)
96	68	164ER	163,929195	(3)	-65955	(3)	1336462	(5)		
99	66	165DY	164,931697	(4)	-63625	(4)	1343768	(6)	1286	(4)
98	67	165HO	164,930316	(3)	-64911	(3)	1344271	(5)	-377,2	(23)
97	68	165ER	164,930721	(3)	-64534	(3)	1343112	(5)		
99	67	166HO	165,932279	(3)	-63082	(3)	1350514	(5)	1854,7	(17)
98	68	166ER	165,9302880	(25)	-64936,8	(23)	1351586	(5)	-3047	(11)
97	69	166TM	165,933559	(12)	-61890	(11)	1347757	(12)	-293	(3)
96	70	166YB	165,933873	(8)	-61597	(8)	1346682	(9)		

N	Z	ATOM	Atomic mass, amu		Mass excesses, keV		Binding energy, keV		Beta-decay energy, keV	
99	68	167ER	166,9320436	(25)	-63301,5	(23)	1358022	(5)	-749,0	(16)
98	69	167TM	166.932848	(3)	-62553	(3)	1356491	(5)	-1954	(4)
97	70	167YB	166,934945	(5)	-60598	(5)	1353755	(6)		
100	68	168ER	167,9323658	(25)	-63001,3	(23)	1365794	(5)	-1679,7	(19)
99	69	168TM	167.934169	(3)	-61322	(3)	1363332	(5)	258	(4)
98	70	168YB	167.933892	(4)	-61580	(4)	1362807	(6)		
101	68	169ER	168,9345862	(25)	-60933,1	(23)	1371797	(5)	351,2	(15)
100	69	169TM	168,934209	(3)	-61284,3	(24)	1371366	(5)	-409	(4)
99	70	169YB	168.935185	(4)	-60376	(4)	1369675	(6)		
102	68	170ER	169,935460	(3)	-60119	(3)	1379054	(5)	-313,7	(19)
101	69	170TM	169,935797	(3)	-59805,5	(24)	1377958	(5)	967,8	(9)
100	70	170YB	169.9347576	(25)	-60773,4	(23)	1378144	(5)		
103	68	171ER	170.938025	(3)	-57729	(3)	1384736	(5)	1490,3	(12)
102	69	171TM	170.936426	(3)	-59219,7	(24)	1385444	(5)	96,7	(10)
101	70	171YB	170,9363218	(24)	-59316,3	(23)	1384758	(5)	-1480,7	(22)
100	71	171LU	170,937911	(3)	-57836	(3)	1382495	(5)		
102	70	172YB	171,9363768	(24)	-59265,2	(22)	1392778	(5)	-2524	(3)
101	71	172LU	171.939087	(4)	-56741	(4)	1389472	(6)		
104	69	173TM	172.939594	(6)	-56268	(5)	1398635	(7)	1293	(5)
103	70	173YB	172,9382061	(24)	-57561,1	(22)	1399146	(5)	-675	(3)
102	71	173LU	172.938931	(4)	-56886	(3)	1397688	(6)		
104	70	174YB	173.9388571	(24)	-56954,7	(22)	1406611	(5)	-1378	(3)
103	71	174LU	173.940337	(4)	-55576	(3)	1404450	(6)	266	(5)
102	72	174HF	173,940052	(4)	-55842	(4)	1403933	(6)		

105	70	175YB	174,9412713	(24)	-54705,9	(22)	1412433	(5)	467,0 (15)
104	71	175LU	174,9407699	(22)	-55172,9	(20)	1412118	(5)	-694 (4)
103	72	175HF	174,941515	(4)	-54479	(4)	1410642	(6)	
106	70	176YB	175,942561	(3)	-53504	(3)	1419303	(5)	-110,2 (20)
105	71	176LU	175,9426796	(20)	53394,0	(18)	1418410	(5)	1186,5 (21)
104	72	176HF	175,941406	(3)	-54580,5	(24)	1418814	(5)	
106	71	177LU	176,9437519	(19)	-52395,2	(18)	1425483	(5)	497,0 (10)
105	72	177HF	176,9432183	(17)	-52892,2	(16)	1425197	(5)	
106	72	178HF	177,9436967	(17)	-52446,6	(16)	1432823	(5)	
107	72	179HF	178,9458133	(15)	-50475,0	(14)	1438923	(5)	-110 (5)
106	73	179TA	178,945932	(6)	-50365	(5)	1438030	(7)	
108	72	180HF	179,9465467	(15)	-49791,8	(14)	1446311	(5)	-858 (5)
107	73	180TA	179,947468	(6)	-48934	(5)	1444671	(7)	711 (6)
106	74	180W	179,946704	(5)	-49645	(4)	1444600	(6)	
109	72	181HF	180,9490972	(17)	-47416,0	(16)	1452007	(5)	1027,4 (25)
108	73	181TA	180,947994	(3)	-48443,4	(25)	1452252	(5)	-186 (7)
107	74	181W	180,948194	(7)	-48257	(7)	1451283	(8)	
109	73	182TA	181,950150	(3)	-46434,9	(25)	1458315	(5)	1813,4 (19)
108	74	182W	181,948204	(3)	-48248	(3)	1459346	(5)	
109	74	183W	182,950222	(3)	-46368,0	(25)	1465537	(5)	
110	74	184W	183,950931	(3)	-45708,3	(25)	1472949	(5)	
108,	76	184OS	183,952491	(3)	-44255	(3)	1469930	(5)	
111	74	185W	184,953418	(3)	-43391,0	(25)	1478703	(5)	432,6 (9)
110	75	185RE	184,952954	(3)	-43824	(3)	1478353	(5)	-1015,0 (7)
109	76	185OS	184,954043	(3)	-42809	(3)	1476556	(5)	
112	74	186W	185,954358	(3)	-42515	(3)	1485898	(5)	-584,9 (22)
111	75	186RE	185,954986	(3)	-41930	(3)	1484531	(5)	1074,7 (17)
110	76	186OS	185,953833	(3)	-43005	(3)	1484823	(5)	

A	Z	Atom	Atomic mass, amu		Mass excesses, keV		Binding energy, keV		Beta-decay energy, keV	
113	74	187W	186,957155	(3)	-39910	(3)	1491364	(5)	1312,3	(17)
112	75	187RE	186,955746	(3)	-41222,4	(25)	1491894	(5)	2,64	(4)
111	76	187OS	186,955743	(3)	-41225,1	(25)	1491115	(5)		
113	75	188RE	187,958108	(3)	-39023	(3)	1497766	(5)	2119,7	(9)
112	76	188OS	187,955832	(3)	-41142	(3)	1499104	(5)	-2786	(10)
111	77	188IR	187,958823	(11)	-38356	(10)	1495535	(11)	-531	(9)
110	78	188PT	187,959393	(6)	-37826	(6)	1494222	(8)		
114	75	189RE	188,959221	(10)	-37986	(9)	1504800	(10)	1008	(9)
113	76	189OS	188,958139	(3)	-38993	(3)	1505026	(5)	-514	(6)
112	77	189IR	188,958691	(7)	-38480	(7)	1503730	(8)	-1989	(13)
111	78	189PT	188,960827	(13)	-36490	(12)	1500958	(13)		
114	76	190OS	189,958438	(3)	-38715	(3)	1512819	(5)		
112	78	190PT	189,959930	(7)	-37325	(6)	1509864	(8)		
115	76	191OS	190,960921	(3)	-36402	(3)	1518578	(6)	306	(3)
114	77	191IR	190,960592	(4)	-36708	(4)	1518101	(6)	-1019	(5)
113	78	191PT	190,961686	(6)	-35690	(5)	1516300	(7)		
116	76	192OS	191,961474	(4)	-35887	(3)	1526134	(6)	-1051	(4)
115	77	192IR	191,962602	(4)	-34836	(4)	1524300	(6)	1456	(3)
114	78	192PT	191,961039	(4)	-36292	(4)	1524974	(6)		
117	76	193OS	192,964146	(4)	-33398	(4)	1531716	(6)	1125	(4)
116	77	193IR	192,962939	(3)	-34523	(3)	1532058	(6)	-56,7	(22)
115	78	193PT	192,963000	(4)	-34466	(3)	1531219	(6)		
117	77	194IR	193,965094	(3)	-32515	(3)	1538122	(6)	2247,1	(18)
116	78	194PT	193,962681	(3)	-34762	(3)	1539587	(6)		

117	78	195PT	194,9647946	(17)	-32793,8	(16)	1545690	(5)		
118	78	196PT	195,9649562	(14)	-32643,4	(13)	1553611	(5)	-1507	(3)
117	79	196AU	195,966574	(4)	-31136	(4)	1551321	(6)	686	(3)
116	80	196HG	195,965838	(4)	-31822	(3)	1551224	(6)		
119	78	197PT	196,9673449	(14)	-30418,3	(13)	1559457	(5)	718,8	(6)
118	79	197AU	196,9665732	(12)	-31137,1	(11)	1559394	(5)		
120	78	198PT	197,967898	(4)	-29903	(3)	1567013	(6)	-325	(3)
119	79	198AU	197,9682469	(12)	-29578,1	(11)	1565906	(5)	1372,4	(6)
118	80	198HG	197,9667736	(11)	-30950,5	(11)	1566496	(5)		
121	78	199PT	198,970582	(20)	-27403	(19)	1572585	(19)	1688	(19)
120	79	199AU	198,9687701	(12)	-29090,7	(11)	1573490	(5)	452,5	(7)
119	80	199HG	198,9682844	(10)	-29543,1	(9)	1573160	(5)		
120	80	200HG	199,9683307	(10)	-29500,0	(9)	1581188	(5)		
121	80	201HG	200,9703073	(10)	-27658,8	(9)	1587418	(5)	-482	(15)
120	81	201TL	200,970824	(16)	-27177	(15)	1586154	(16)	-1860	(40)
119	82	201PB	200,97282	(4)	-25320	(30)	1583510	(40)		
122	80	202HG	201,9706469	(11)	-27342,5	(10)	1595173	(5)	-1363	(17)
121	81	202TL	201,972110	(18)	-25980	(17)	1593029	(18)	-46	(18)
120	82	202PB	201,972159	(11)	-25934	(10)	1592201	(11)		
123	80	203HG	202,972874	(3)	-25268	(3)	1601171	(6)	492,7	(19)
122	81	203TL	202,972345	(3)	-25761	(3)	1600881	(6)	-975	(9)
121	82	203PB	202,973391	(10)	-24786	(10)	1599124	(11)		
124	80	204HG	203,9734968	(13)	-24687,8	(12)	1608662	(5)	-342	(3)
123	81	204TL	203,973864	(3)	-24346	(3)	1607537	(6)	763,39	(20)
122	82	204PB	203,973045	(3)	-25109	(3)	1607518	(6)		
124	81	205TL	204,974422	(4)	-23826	(4)	1615089	(6)	-56,7	(20)
123	82	205PB	204,974483	(4)	-23769	(3)	1614250	(6)	-2707	(7)
122	83	205BI	204,977389	(8)	-21062	(8)	1610760	(9)	-3490	(30)
121	84	205PO	204,98114	(4)	-17570	(30)	1606480	(30)		

A	Z	ATOM	Atomic mass, amu		Mass excesses, keV		Binding energy, keV		Beta-decay energy, keV	
125	81	206TL	205,976105	(4)	-22258	(4)	1621592	(6)	1527,6	(17)
124	82	206PB	205,974465	(4)	-23786	(3)	1622338	(6)	-3761	(11)
123	83	206BI	205,978503	(12)	-20025	(11)	1617794	(12)		
126	81	207TL	206,977418	(6)	-21035	(6)	1628441	(8)	1419	(6)
125	82	207PB	206,975894	(4)	-22455	(4)	1629078	(6)	-2405	(7)
124	83	207BI	206,978476	(9)	-20050	(8)	1625891	(10)	-2908	(9)
123	84	207PO	206,981598	(11)	-17142	(10)	1622200	(11)		
127	81	208TL	207,982007	(5)	-16761	(5)	1632238	(7)	4991	(4)
126	82	208PB	207,976649	(4)	-21751	(4)	1636446	(6)		
127	82	209PB	208,981090	(4)	-17615	(4)	1640381	(6)	644,4	(12)
126	83	209BI	208,980398	(4)	-18259	(4)	1640243	(6)		
124	85	209AT	208,986173	(9)	-12880	(8)	1633299	(10)	-3890	(30)
123	86	209RN	208,99035	(4)	-8990	(30)	1628620	(30)		
128	82	210PB	209,984188	(4)	-14729	(3)	1645566	(6)	63,0	(5)
127	83	210BI	209,984121	(4)	-14792	(3)	1644847	(6)	1161,5	(10)
126	84	210PO	209,982874	(4)	-15953	(3)	1645226	(6)		
129	82	211PB	210,988739	(4)	-10490	(4)	1649399	(7)	1369	(6)
128	83	211BI	210,987269	(6)	-11859	(6)	1649986	(8)		
130	82	212PB	211,991888	(6)	-7557	(5)	1654537	(8)	572	(4)
129	83	212BI	211,991274	(5)	-8128	(5)	1654326	(7)	2244	(4)
128	84	212PO	211,988865	(4)	-10373	(4)	1655788	(6)		
130	83	213BI	212,994380	(12)	-5235	(11)	1659504	(12)	1420	(10)
129	84	213PO	212,992856	(7)	-6654	(6)	1660141	(8)		

132	82	214PB	213.999803	(3)	-183	(3)	1663306	(6)	1019	(12)
131	83	214BI	213.998709	(13)	-1203	(12)	1663543	(13)	3267	(12)
130	84	214PO	213.995201	(4)	-4470	(3)	1666028	(6)		
131	84	215PO	214.999422	(4)	-539	(4)	1670168	(7)		
132	84	216PO	216.001905	(6)	1775	(5)	1675926	(8)	-469	(5)
131	85	216AT	216.002408	(6)	2243	(6)	1674675	(8)		
132	85	217AT	217.004713	(12)	4390	(11)	1680600	(12)		
134	84	218PO	218.008971	(3)	8357	(3)	1685487	(6)		
132	86	218RN	218.005605	(4)	5221	(4)	1687058	(7)		
133	86	219RN	219.009482	(4)	8833	(4)	1691518	(7)		
134	86	220RN	220.011384	(6)	10605	(5)	1697817	(8)	-872	(6)
133	87	220FR	220.012321	(8)	11477	(7)	1696162	(9)		
134	87	221FR	221.014249	(12)	13273	(11)	1702437	(12)		
136	86	222RN	222.017576	(3)	16372	(3)	1708193	(6)		
134	88	222RA	222.015372	(5)	14319	(5)	1708681	(7)		
135	88	223RA	223.018504	(4)	17237	(4)	1713835	(7)		
136	88	224RA	224.020202	(6)	18819	(5)	1720324	(8)	-1407	(6)
135	89	224AC	224.021713	(8)	20226	(7)	1718135	(9)		
137	88	225RA	225.023606	(4)	21989	(4)	1725225	(7)	355	(12)
136	89	225AC	225.023225	(12)	21634	(11)	1724798	(13)		
138	88	226RA	226.025408	(3)	23668	(3)	1731618	(6)	-635.6	(25)
137	89	226AC	226.026090	(4)	24303	(3)	1730200	(7)	1108	(5)
136	90	226TH	226.024901	(5)	23195	(5)	1730525	(7)		
138	89	227AC	227.027753	(3)	25852	(3)	1736723	(6)	43.4	(20)
137	90	227TH	227.027706	(4)	25808	(4)	1735984	(7)		
140	88	228RA	228.031070	(5)	28942	(5)	1742486	(7)	45.6	(10)
139	89	228AC	228.031021	(5)	28896	(5)	1741750	(7)	2132	(7)
138	90	228TH	228.028732	(6)	26764	(5)	1743100	(8)	-2113	(7)
137	91	228PA	228.031000	(9)	28877	(8)	1740204	(10)		

N	Z	Atom	Atomic mass, amu		Mass excesses, keV		Binding energy, keV		Beta-decay energy, keV	
139	90	229TH	229,031758	(4)	29582	(3)	1748352	(7)		
140	90	230TH	230,033133	(3)	30863	(3)	1755143	(6)	-1304,5	(20)
139	91	230PA	230,034533	(4)	32168	(3)	1753056	(7)	555	(5)
138	92	230U	230,033938	(6)	31613	(5)	1752829	(8)		
141	90	231TH	231,036300	(3)	33814	(3)	1760264	(6)	389,0	(18)
140	91	231PA	231,035883	(3)	33425	(3)	1759871	(6)		
142	90	232TH	232,0380548	(25)	35448,1	(23)	1766701	(6)		
140	92	232U	232,037147	(6)	34602	(5)	1765982	(8)		
143	90	233TH	233,0415814	(25)	38733,1	(23)	1771487	(6)	1244,9	(21)
142	91	233PA	233,040245	(3)	37488,2	(24)	1771950	(6)	572,1	(24)
141	92	233U	233,039631	(3)	36916	(3)	1771740	(7)		
144	90	234TH	234,043599	(5)	40613	(4)	1777679	(7)	262,5	(20)
143	91	234PA	234,043317	(5)	40350	(5)	1777159	(7)	2206	(4)
142	92	234U	234,0409490	(25)	38144,1	(23)	1778583	(6)		
143	92	235U	235,0439266	(25)	40917,7	(23)	1783881	(6)	-123,1	(10)
142	93	235NP	235,044059	(3)	41040,8	(25)	1782975	(6)		
144	92	236U	236,0455644	(24)	42443,3	(22)	1790426	(6)		
145	92	237U	237,048728	(3)	45389,9	(25)	1795551	(6)	519,5	(11)
144	93	237NP	237,0481701	(24)	44870,5	(22)	1795288	(6)	-218	(6)
143	94	237PU	237,048404	(6)	45088	(6)	1794288	(8)		
146	92	238U	238,0507868	(23)	47308,0	(22)	1801705	(6)	-145,7	(13)
145	93	238NP	238,0509433	(24)	47453,7	(22)	1800776	(6)	1291,5	(11)
144	94	238PU	238,0495568	(25)	46162,2	(23)	1801286	(6)		

147	92	239U	239,0542920	(24)	50573,1	(22)	1806511	(6)	1265,3	(24)
146	93	239NP	239,052934	(3)	49308	(3)	1806994	(7)	721,4	(19)
145	94	239PU	239,0521592	(25)	48586,4	(23)	1806933	(6)		
148	92	240U	240,056589	(5)	52713	(5)	1812443	(8)		
146	94	240PU	240,0538101	(24)	50124,2	(23)	1813466	(6)		
147	94	241PU	241,0568482	(24)	52954,2	(22)	1818708	(6)	20,81	(20)
146	95	241AM	241,0568259	(24)	52933,4	(22)	1817946	(6)		
148	94	242PU	242,0587397	(24)	54716,1	(22)	1825017	(6)	-750,1	(9)
147	95	242AM	242,0595449	(24)	55466,2	(23)	1823485	(6)	663,3	(12)
146	96	242CM	242,0588329	(25)	54802,9	(23)	1823366	(6)		
149	94	243PU	243,062000	(4)	57753	(3)	1830051	(7)	582	(3)
148	95	243AM	243,061376	(3)	57171	(3)	1829851	(7)	-7,0	(23)
147	96	243CM	243,061383	(3)	57178,5	(25)	1829062	(6)		
150	94	244PU	244,064201	(5)	59803	(5)	1836073	(8)		
148	96	244CM	244,0627491	(24)	58450,9	(23)	1835861	(6)		
150	95	245AM	245,066451	(4)	61899	(4)	1841266	(7)	896,6	(21)
149	96	245CM	245,065488	(3)	61002	(3)	1841380	(7)		
152	94	246PU	246,070174	(21)	65367	(19)	1846652	(20)	377	(10)
151	95	246AM	246,069769	(22)	64990	(21)	1846246	(22)	2373	(21)
150	96	246CM	246,067222	(4)	62617	(3)	1847837	(7)		
151	96	247CM	247,070349	(5)	65531	(5)	1852995	(7)		
152	96	248CM	248,072345	(5)	67390	(5)	1859207	(8)	-708	(21)
151	97	248BK	248,073106	(22)	68098	(21)	1857717	(22)	858	(18)
150	98	248CF	248,072185	(24)	67240	(22)	1857792	(23)		
153	96	249CM	249,075951	(8)	70749	(8)	1863920	(10)	899	(8)
152	97	249BK	249,074986	(4)	69849	(3)	1864037	(7)	126,3	(19)
151	98	249CF	249,074850	(3)	69723	(3)	1863381	(7)		
154	96	250CM	250,078355	(12)	72987	(11)	1869752	(13)	37	(12)
153	97	250BK	250,078315	(6)	72951	(5)	1869006	(8)	1780	(4)