Table of Isotopes (A=263-272)†

CD ROM Edition

Version 1.0
March, 1996

by Richard B. Firestone

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To see brief instructions for Acrobat Reader please click on this green square

To see README for Table of Isotopes please click on this green square

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Throughout the document green indicates hyperlinked objects.

Instructions for using Tool bar (below menu):

click the icon to activate unless otherwise noted

Tool	Function
Bookmarks	Displays bookmarks
	{ ▷ (▽): Click to show (hide) bookmarks. 🗋: Double click to open.
Hand	Scrolls through window
Zoom In	Magnifies page view
Zoom Out	Reduces page view
First Page	Displays first page of document
Previous Page	Displays previous page
Next Page	Displays next page
Last Page	Displays last page of document
Go Back	Displays previous page view
Go Forward	Returns from Go Back
Actual Size	Sets page view to 100%
Fit Page to Window	Displays whole page
Fit Width to Window	Displays width of page
Find	Find words

Instruction for using Status bar:

Control	Function
◁▷	Changes width of bookmark area
1 of 6,253	Displays page number. ***Click to display*** Go to Page dialog box.
100% ▼	Shows current magnification. ***Click to Select*** magnification.

Keyboard shortcuts for Macintosh (or for Windows):

- **Esc key** (same key for Windows)
  result: Interrupts display of page
- Combined key stroke **⌘-.** (Mac only)
  result: Interrupts find process
- When in (Zoom In) or (Zoom Out), click with **Option key** (for windows **Ctrl key**) pressed, reverse the zooming effect

To open the on-line guide type ⌘-? for Mac or function key F1 for Windows.

Table of Isotopes CD- ROM Edition

(Version 1.0, March 1996)

The CD-ROM edition of the Table of Isotopes is an Adobe^{TM} ACROBAT document. On- line help for ACROBAT is provided. The CD-ROM may be navigated by activating bookmarks on the side bar with the mouse. The bookmarks access an extensive index to the book. The index has hypertext links to the main body of the book, and additional links, within the book, provide easy access to related material. All hypertext links are indicated by green text.

Bookmark and Index Summary

Chart of Nuclides — The chart is divided into 7 sections. Each section is comprised of separate parts for ground states and isomers. The isotope boxes on the chart have hypertext links to either an isomer, if an asterisk is present on the lower right of the box, or to the level table for that nucleus.

Summary Schemes — The 271 summary mass- chain decay schemes accessed by this index contain hyptertext links to the level table for each isotope. Additional links on the summary schemes access summary schemes for A $\pm$ 1 and A $\pm$ 4.

Reaction and Decay Daughter Index — Bookmarks are divided into groups of 10 mass chains with secondary bookmarks for every mass number. They access an index containing hypertext links to the summary schemes, level tables, decay scheme drawings, and nuclear band drawings for each mass chain.

Decay Parent Index — Bookmarks are divided into groups of 10 mass chains with secondary bookmarks for every mass number. They access an index containing hypertext links to the decay drawings and radiation tables for all radioactive parents.

Reference Index — Complete reference abstracts can be accessed by this index of hypertext links to first reference key number on each page of the references.

Appendix Index — The appendices to the Table of Isotopes are accessed through this index.

Other Hypertext Links

Level Tables — The isotope name at the beginning of the level table is linked to the corresponding decay drawing. References are linked to the complete reference abstracts.

Radiation Tables — The radiation table titles are linked to the corresponding decay scheme drawings.

Decay Drawings — The parent isotopes are linked to the corresponding radiation tables. Daughter isotopes are linked to the following band drawing, if one exists, or to the level tables.

Band Drawings — The isotope names are linked to the level tables.

Preface

It has been 60 years since Giorgio Fea published the first compilation of known radionuclides called the *Tabelle Riassuntive E Bibliografia delle Trasmutazioni Artificiali*[1] in Nuovo Cimento. Glenn Seaborg and colleagues published the *Table of Radionuclides*[2] in 1940, and later editions[3,4,5,6], renamed the *Table of Isotopes*, in 1944, 1948, 1953, and 1958. Remarkable historical events paralleled the publication of those editions as the *Table of Isotopes* helped pave our entry into the nuclear age. Some contents of the book were even deleted from publication for several years until the discovery of plutonium could be declassified. Data grew at a remarkable rate despite the prediction of an editor, in 1941, that "the rate at which such radioactivities are discovered may be reduced very considerably and the table would itself become stable." It didn't stabilize and, when Mike Lederer took the helm for the 6th (1967) and 7th (1978) editions[7,8], data compilation was evolving into a specialized discipline. The enormous growth of nuclear data required the development of special expertise to sort through the information, evaluate it, and publish it in a convenient form. Mike Lederer pioneered the use of computers to facilitate the publication of the *Table of Isotopes*. He was one of the first to use word processing techniques, and the 7th edition of the *Table of Isotopes* was an early example of "desktop publishing." However, Mike made one mistake in the last edition. He stated that "the 7th edition of the *Table of Isotopes* will be the last in the series."

While the 7th edition of the *Table of Isotopes* was being prepared, Bruce Ewbank and his colleagues at Oak Ridge National Laboratory were developing the first comprehensive nuclear structure database, the Evaluated Nuclear Structure Data File (ENSDF), with supporting software for producing the *Nuclear Data Sheets*. The Berkeley and Oak Ridge efforts were joined together with groups at Idaho Falls and U. Pennsylvania, under the direction of the National Nuclear Data Center at Brookhaven National Laboratory, to form the U.S. Nuclear Data Network (USNDN). Brookhaven had led similar efforts to advance the compilation of neutron cross section data. Under Sol Pearlstein's direction an international network of nuclear data evaluators was established under the auspices of the IAEA. Nuclear structure and decay data continued expanding at an enormous rate, and it was a challenge even for the large data community to process this information into the ENSDF file and publish it in the

Nuclear Data Sheets. The editors, Murray Martin and Jagdish Tuli, deserve considerable credit for maintaining the quality of ENSDF and guiding the evaluators through the evaluation and review process. Few other scientific fields have developed such an extensive and efficient data program. In 1986, Edgardo Browne and I were able to use the ENSDF database to prepare the *Table of Radioactive Isotopes*[9], a new book emphasizing radioactive decay data. That effort merged the strengths of an international evaluation program with the publication tradition of the *Table of Isotopes*. In 1991 the National Academy of Sciences Panel on Basic Nuclear Data Compilations, chaired by Jolie Cizewski, requested that we prepare an 8th edition of the *Table of Isotopes.*

I owe an enormous debt of gratitude to my predecessors at Berkeley who began the *Table of Isotopes* and taught me the importance of quality in both the content and presentation of this book. In particular Virginia Shirley, my editor, represented the soul of this effort for over 25 years. Her editing standards were extremely high and accounted for the scarcity of mistakes in the 6th and 7th editions and in the *Table of Radioactive Isotopes.* Virginia passed away shortly before we completed this book and is sorely missed. I regret that she did not see the final product but, as I completed the final editing, I could sense that she was looking over my shoulder to make sure that we did it right.

Nearly 24,000 references are cited in this edition, and this book would not be possible without the research efforts of thousands of scientists. There have been over 100 nuclear data evaluators whose efforts have directly or indirectly contributed to the book. Some of them are listed on the summary mass chain decay schemes, but many more participated in numerous previous compilations over the past 60 years. Special thanks go to Mulki Bhat for rallying evaluators to update their mass chains in time for this edition. Georges Audi made a special effort to complete his mass evaluation in time for this book. Peter Ekström provided a great deal of advice and criticism throughout the project. Balraj Singh also contributed significantly to the development of this edition and evaluated most of the superdeformed band data. Darleane Hoffman, Glenn Seaborg, and Sigurd Hofmann helped to review and supply up-to-date heavy-element data. Peter Endt, Ron Tilley and Jean Blachot updated and reviewed much of the data for A<45. Dick Helmer provided prepublication data for the appendix on γ-ray energy and intensity standards. Many evaluators reviewed their contributions to this edition and provided us with additional, updated data.

This book would not be possible without the broad support of my colleagues at the Lawrence Berkeley Laboratory. James Symons, director of the Nuclear Science Division, provided advice, support, and encouragement. Jørgen Randrup helped develop and present the original proposals for the 8th edition, Darleane Hoffman continued those efforts, and Janis Dairiki saw to it that we were provided with the critical resources and support necessary to complete this project. Many LBNL scientists provided useful suggestions and reviewed various parts of the book. Special thanks go to the Information and Computer Science Division, under the direction of Stu Loken, for helping us solve many computer and software problems. Particular thanks go to Eric Beals, Marty Gelbaum, Cindy Hertzer, and Lam Wong who kept us up and running. Finally, I gratefully acknowledge the support and encouragement of the U.S. Department of Energy and, in particular, Stan Whetstone and Dick Meyer.

The 8th edition of the *Table of Isotopes* is not the end of this series, but instead the beginning of a new era. Our technology now allows us to update the book automatically from the underlying databases. We have developed this CD-ROM edition of the book to provide considerably more data in a compact format. With space for nearly 100,000 pages of information, we have solved the problem of an ever-expanding database. We look forward to publishing the *Table of Isotopes* in this CD-ROM format on a much more frequent schedule than was possible for the book. This time we can state that the 8th edition of the *Table of Isotopes* will *not* be the last in this series! We look forward with enthusiasm to preparing the next edition.

Richard B. Firestone

Berkeley, California
August, 1995

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2. J.J. Livingood and G.T. Seaborg, *Reviews of Modern Physics* **12**, 30 (1940).
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Introduction to the CD-ROM

I. General Information

The 8th edition of the *Table of Isotopes* contains nuclear structure and decay data for over 3100 isotopes and isomers with $1 \leq A \leq 272$. The information in this edition was based primarily on evaluation efforts by the members of the U.S. Nuclear Data Network and the International Atomic Energy Agency's Nuclear Structure and Decay Data Working Group. The detailed evaluations for light mass nuclei ($A \leq 44$) were published in *Nuclear Physics A*, and those for heavier nuclei ($45 \leq A \leq 266$) were published in *Nuclear Data Sheets*. These data are also available in the Evaluated Nuclear Structure Data File (ENSDF)[1], maintained by the National Nuclear Data Center at Brookhaven National Laboratory. We have used the ENSDF file as the starting point for this edition of the *Table of Isotopes*. In most instances, the most recently published evaluation was used but, for some mass chains, we used an updated, prepublication version. Some of the data have been selectively updated by the author from recent literature and/or extensively edited to provide uniform and concise presentation. For more detailed information, the reader is encouraged to consult the ENSDF file or the primary evaluation publications (referenced on the mass chain summary drawings), and the source references given in the tabular data.

In addition to the ENSDF file, data from several other compilations have been incorporated. Nuclear mass and Q-value data were taken from the Audi *et al.* 1993 mass table[2], neutron cross-section data are from Mughabghab *et al.*[3], most spontaneous fission probabilities are from Hoffman *et al.*[4] Nuclear moment data have been updated, when necessary, from Raghavan[5], and information on fission isomers and superdeformed nuclear band structure has been expanded to include information from Firestone and Singh[6]. The evaluations for $267 \leq A \leq 272$ were prepared by the author because, at this time, none existed in the ENSDF file.

This edition provides greater coverage of nuclear structure properties than previous editions. Adopted data for all known nuclear levels and their de-excitation modes are given. Complete decay data tables are also presented, as in the previous edition but, here, data evaluated from various literature sources have been combined in a single data set. The reaction level schemes of the 7th edition have been superseded by the more extensive level tables. In place of reaction level schemes, we have introduced high-spin nuclear band drawings, emphasizing information of particular importance in high-spin physics. The appendices from the 7th edition have been updated and expanded in this edition, and several new appendices have been added.

II. Organization of the 8th Edition CD-ROM

The 8th edition CD-ROM is an Adobe Acrobat document. The data are organized by mass number (A) and sub-ordered by atomic number (Z). For each mass chain there is an abbreviated summary decay scheme drawing (skeleton scheme) summarizing the ground state and isomeric state(s) half-lives, spin and parity assignments and ground state decay branchings, decay energies, and the proton and neutron separation energies for all known isotopes and isomers of that mass. The isotopes covered include those whose existence has been determined only in nuclear reactions, but whose decay is, as yet, unobserved. Isomers are defined as excited states with half-lives either greater than 1 ms, comparable to the ground-state half-life, or of particular historical interest (e.g., shape isomers).

The skeleton scheme is followed by the tabular listings for all isotopes, ordered by increasing atomic number (Z). The decay scheme and band structure drawings for each isotope, also ordered by increasing atomic number (Z), follow the tables. The tables contain general nuclear properties including natural isotopic abundance, mass excess, decay Q-values, proton and neutron separation energies, and neutron capture cross sections. These are followed by an alphabetically coded list of the decay modes and reactions known or expected to populate the isotope, with their associated 6-character reference codes from the Nuclear Science Reference file[7] (NSR). The table continues with an energy-ordered list of level data and γ-ray deexcitation information, adopted from decay and reaction measurements. Adopted level data include spin and parity, isospin, half-life, decay modes and branching intensities, dipole and quadrupole moments, and cross-indexing to the populating reactions and decays in which the level is observed. The data listed for the γ rays include energy, relative photon intensity normalized to 100 for the most intense photon branch from a given level, multipolarity, and mixing ratio. Radioactive decay data tables for the isotope and its isomers follow each adopted levels table. These provide tables of transition energies, relative intensities, multipolarities, mixing ratios, and absolute intensity normalizations for emitted γ rays, and tables of energies, relative intensities and absolute intensity normalizations for α, p, n, or other particles emitted in decay.

Decay scheme drawings are presented separtately for each decay mode feeding each daughter isotope. Such drawings show each parent's level energy, spin, parity, half-life, and decay energy. Beta or alpha decay feedings to daughter levels are shown with their associated reduced transition probabilities (log*ft* or HF). All γ rays from the levels populated by decay are shown with their energies, multipolarities, and relative branching intensities from the decay table. Additional γ rays deexciting the decay levels from the adopted levels table which were not observed in decay are shown in red on the drawings. Levels identified as having associated collective or high-spin structure are shown in nuclear band drawings. There, bands are drawn side by side and given a short band name if available. In-band γ rays, with their energies rounded to the nearest keV, and transitions to adjacent bands (arrow only) are shown. The existence of additional transition(s) that are not shown is indicated by an arrowhead on the level.

III. General Features of the 8th Edition

A. Uncertainties:

Uncertainties are indicated by smaller italic numbers following any value. They represent the uncertainty in the least significant digit(s). For example, 37.2 *22* stands for 37.2±2.2, 15.7^{17}_{5} for 15.7+1.7–0.5, and 4.3 *2* $\times10^{-4}$ for (4.3±0.2)$\times10^{-4}$. Some numbers are indicated as approximate (≈0.15) or as a limit (>10, <0.06). Data from ENSDF for which limits were expressed as ≤ or ≥ have had those limits converted to < or >, respectively, except for quantized values such as spin. Values derived from systematics are indicated either in parentheses, e.g., (123), or as 123 *syst*; calculated values are shown, e.g., as 1.5 *calc*.

B. Energies:

All energies are given in keV. Level energies are shown in boldface type, and transition energies in boldface italic type. Level energies are quoted relative to a constant offset (**x, y, z, ..**) as **x** or **0+y, 1576.5+z,** etc., when their relationship to the ground state is unknown. Some γ-ray energies are given as ***X*** or ***>0*** when the transition is known to exist but its energy is not known. Systematic level energies are given in parentheses. Ground state energies are normally written as **0**, not **0.0**.

C. Reference Codes:

Standard reference codes from the Nuclear Science Reference file[7] (NSR), maintained by the National Nuclear Data Center at Brookhaven National Laboratory, are used. These codes follow the general form YYAu%% where the first two characters indicate the reference year, the second two characters are the first two letters of the first author's last name, and the last two characters are arbitrary sequence characters. If the last two characters are numeric, the reference is from a primary source (except for some pre-1969 publications) and, if they are alphabetic, the reference is from a secondary source such as a report, conference proceedings, or private communication. The reference codes are translated into short citations at the end of the main tables. In a few cases, reference codes were unavailable from NSR at the time of publication, so temporary alphabetic sequence numbers were assigned irrespective of whether the source was a primary or secondary one.

D. Masses:

Mass excesses, decay Q-values, and proton or neutron separation energies shown in the tables and figures are from the evaluation of Audi and Wapstra[2]. Values extrapolated from systematics are indicated by enclosing them in parentheses and rounding them based on the systematic uncertainty. Isotopes whose masses have not yet been tabulated are displayed on the summary mass chain schemes at their approximate masses estimated from the calculations of Möller, Myers, Swiatecki, and Treiner[8]. These values are presented on the decay scheme drawings in parentheses.

E. Data evaluation:

Data were generally taken directly from the ENSDF file with only minor adjustments to achieve uniform presentation. Updating was primarily limited to the addition of newly discovered isotopes, more complete nuclear band data, and the addition of missing or incomplete nuclear moments from the compilation of Raghavan[5]. Decay energies and proton/neutron separation energies were updated to values provided by Audi and Wapstra[2]. Log*ft* values were recalculated, rounded to the nearest 0.1 unit, and compared with the ENSDF file values for inconsistencies. Decay parent information was compared with relevant adopted daughter level information, and discrepancies were reconciled. Cross-indexing of levels to populating reactions and decays was taken from ENSDF, when available; otherwise, it was assigned on the basis of energy differences, level spins and parities, de-exciting transition energies and multipolarities, reaction ℓ-transfer values, and band assignments. Transition final level assignments are not generally available in ENSDF, so they were deduced from the transition energy with the requirement that transition multipolarity be consistent with initial and final level spin and parity values.

Adopted levels in the tabular data have been extended to include all levels in the decay scheme drawings whether or not the evaluator adopted them. Adopted γ-ray intensities have been renormalized, when necessary, to give 100 for the most intense photon branch from each level. Systematic multipolarities generally are not shown unless they have been used to infer the mixing ratio.

F. Mass-chain Reference:

The mass-chain evaluation citations are given in a box on the summary mass-chain decay scheme. The most recent primary reference and subsequent update (if any) are indicated. If a revision date is indicated, an unpublished evaluation which is either a continuous evaluation or a prepublication mass-chain evaluation has been used. The reader is encouraged to refer to the original *Nuclear Physics A* or *Nuclear Data Sheets* publication or the ENSDF file for more detailed information. The evaluator(s) of the most recent evaluation are indicated on the mass-chain skeleton scheme and may also be contacted for additional information. In many instances we have updated selected portions of the mass chains beyond the date indicated on the summary mass-chain decay scheme. This will be evident from the post-evaluation date references included in the tabular data.

IV. Detailed Description of the Tables and Drawings

A. Mass-chain Decay Schemes:

The ground-state of each nucleus is represented by a heavy line whose vertical position represents the mass of the nucleus relative to the lightest (most beta-stable) isobar. The square-root energy scale is plotted to the left of the scheme. Isomeric states are represented by heavy lines plotted above the ground state. The positions of these lines only approximate the actual energy to allow room for labels. Dashed lines represent probable isotopes or isomers. Proton or neutron separation energies are plotted as dashed lines near their actual energies. Beta-delayed particle emission is indicated by light lines if only a few discrete levels are populated by the beta decay, or by a cross-hatched band, plotted near the energy region of delayed particle emission, when many levels are populated. The mass, atomic number, and isotope symbol appear below each ground-state line.

Alpha-decay parents are shown at the top of the mass-chain decay scheme, directly above their respective daughters. Their vertical positions are unrelated to the energy scale. Half-lives are printed in large type next to the isotope or isomer lines. Spin and parity assignments are printed above the lines on the left side. Energies of isomeric states are printed above the right hand side of the line. Decay of an isotope is indicated by an arrow, labeled with the decay mode. When several decay processes compete, percentage branchings are given when known.

Q-values for β^-, EC (EC+β^+), α, p, and bb decay modes are given for each isotope; Q_a values are also given for α-decay parents. Q_{EC} is given for all EC+β^+ processes. All Q-values represent the actual mass difference (in units of keV) between neutral atoms, and they are taken from Audi and Wapstra[2]. They are derived from a least-squares fit to measured Q-values for decay and nuclear reactions and data on mass doublets. Systematic values are indicated in parentheses; they have been interpolated or extrapolated from the least-squares fit. The values are rounded, based on experimental or systematic uncertainties, to $<$25 units in the most significant digit(s). (Systematic uncertainties were also derived from the least-squares fit, but they are not shown here.)

B. Tabulated Data:

General Isotopic Information:

Each block of data for an isotope is headed by the isotope label. Immediately below the label are quantities of general interest described as follows.

%: *Natural isotopic abundance* (atom percent basis) for elements as they occur on earth. The values are those adopted by the International Union of Pure and Applied Chemistry[9].

Δ: *Mass excess* (≡ M–A) on the unified mass scale ($\Delta^{12}C \equiv 0$), in units of keV. All values refer to masses of neutral atoms. Systematic values are given in parentheses.

S_n: *Neutron separation energy* ($M_N - M_{N-1} - M_n$) in units of keV. Systematic values are given in parentheses.

S_p: *Proton separation energy* ($M_Z - M_{Z-1} - M_p$) in units of keV. Systematic values are given in parentheses.

Q_x: *Decay energy* for decay mode x = β^-, EC (EC+β^+), α, or p decay in units of keV. Systematic values are given in parentheses.

: *Neutron cross sections*: these include values for σ_γ ($\equiv\sigma(n,\gamma)$, the neutron capture cross section), σ_α (n capture cross section for alpha particle emission), σ_p (n capture cross section for proton emission), σ_{abs}("free" neutron scattering cross section) and σ_f (capture cross section for fission). Cross sections σ are those for thermal neutrons, σ^o for 2200 m/sec neutrons, and σ^r for reactor neutrons. Designation of "from" or "to" is followed by the energy of the capture or product nuclear state.

Populating reactions and decay modes:

A list of reactions and decay modes known to populate this isotope. The reaction list is obtained primarily from the compiled datasets, and the decay modes have been supplemented to include populating decays where explicit feeding of specific final levels is not known. A complete list of reference codes used by the evaluator follows each populating reaction or decay mode. Decay modes, sometimes without references, have been added here and the reader is referred to the parent isotope tables for references. When more than one level from a given parent may populate the isotope, the decay modes specify the identifying half-life; if those parent levels have identical half-lives, the decay modes are identified by the parent level energy or spin and parity values. Each entry on this list is preceded by a character which is used to cross-reference this entry to each level populated by the specified reaction or decay.

Adopted level data:
The following information about adopted levels is presented.

E: *Energy* in keV. If followed by +x, +y, +z, or some other alphabetic constant, the energy is relative to an unknown excitation energy. Levels whose energy is followed by (?) have questionable existence, and levels with energy in parentheses are systematic.

J^π: *Nuclear spin* (angular momentum) in units of $\hbar$ and *parity*. Isospin *T* or T_z may also be given. Multiple possible values may be indicated. Spins and/or parities in parentheses are based on less definite information. If the values are separated by "and", then the level is presumed to be a doublet. In cases, where the spin is presented as J+*x* and *x* is a definite spin value, x is the increment in spin relative to some unknown spin value J.

$t_{1/2}$: *Level half-life* (mean-life $\times$ ln2). Conventional units are employed: y=year, d=day, h=hour, m=minute, s=second, ms=millisecond (10^{-3} s), μ s=microsecond (10^{-6} s), ns=nanosecond (10^{-9} s), ps=picosecond (10^{-12} s), fs=femtosecond (10^{-15} s), and as=attosecond (10^{-18} s). In some instances level width Γ or partial width Γ_x (where x=n, p, γ, . . . is the partial decay mode) is given (in eV, keV, or MeV).

Cross-Reference codes:
Character list indexing the level to the reactions and decay modes which populate it.

Decay modes:
Percentage branchings are given for modes denoted by the following symbols:

β^-	negatron (electron) emission
β^+	positron emission
EC	orbital electron capture

α	alpha-particle emission
IT	isomeric transition (γ ray or conversion electron emission from an excited state)
SF	spontaneous fission
p	proton emission
n	neutron emission
$\beta^-\beta^-$	double negatron emission
ECEC	double orbital electron capture
ECx	electron capture delayed emission of x=p, α, SF(often denoted as ECDF), . . .
β^-x	negatron delayed emission of x=n, 2n, α, . . .
^{14}C	emission of ^{14}C nucleus
^{20}Ne	emission of ^{20}Ne nucleus

In general, decay modes are shown when they have been observed or inferred from experiment or when they are expected to be significant (>0.1 %) based on theory. If the percentage is given as "=?", this indicates that the percentage is unknown, and not that the decay mode is uncertain. If the percentage branching is from theory or systematics, the value is indicated as *syst.* When β^+ emission is energetically possible, it is always accompanied by EC decay. In these tables the undivided percentage branching for both modes %EC+%β^+ is given when both modes are possible.

Nuclear moments:

The magnetic dipole (μ) and electric quadrupole moment (Q) are taken from the compilation of Raghavan[5] unless the evaluator incorporated a newer value. If several values have been measured, the first value listed in Raghavan's table is the recommended value and that one is reported here. If the measurement led to two possible interpretations, both values are presented separated by the word "or". In cases where the spin is unknown, the "g-factor", *g,* may be shown instead; the magnetic dipole moment $\mu = gJ$.

Adopted γ-ray data:

The following information on adopted γ rays depopulating the level are presented.

E: *Energy* of the deexciting transition in keV, preceded by γ_{abc} where abc=energy of the level populated by that transition. Transitions with (?) following their energies have uncertain placements.

$\dagger_{\gamma}$, $\dagger_{e}$,$\dagger_{e+\gamma}$: *Relative intensity* of photon, conversion electron, or total transition, respectively. Photon intensities are given whenever available, and electron intensities are typically given only for E0 transitions. The transition intensities are usually normalized to 100 for the most intense γ ray emitted from the level.

Multipolarity and mixing ratio (δ)**:** The transition multipolarities and mixing ratio are given when available. If the mixing ratio is inferred from systematic multipolarities, the multipolarities are given in square brackets. The multipolarities are shown as magnetic (Mλ) or electric (Eλ) 2^{λ}-multipole transitions, and as dipole (D, λ=1), quadrupole (Q, λ=2), and octupole (O, λ =3) transitions. Multipolarities in parentheses are determined from weaker evidence, and values reported as M1(+E2) generally infer that the contribution of the second multipolarity is minor. Multipolarities separated by commas represent the list of plausible values not excluded by experiment, and one or more values in the list may be negligible or nonexistent. In some cases, when more than one mixing ratio (δ) may be inferred from the data, multiple values are separated by the word “or”. The sign of the mixing ratio (δ) is given explicitly when known, and follows the phase convention of Krane and Steffen[10]. For transitions of the general form E(M)λ_1+M(E)λ_2 ($\lambda_2=\lambda_1+1$), the ratio of the two multipolarity component intensities is δ^2=M(E)λ_2/E(M)λ_1 The percentage of the second (λ_2) component, as expressed in earlier editions of the *Table of Isotopes*, is %E(M)$\lambda_2=100\times\delta^2/(1+\delta^2)$.

Quantities for Superdeformation: The following quantities are provided for superdeformed band levels only:

Rotational Frequency

$$\hbar\omega = [E_\gamma((J+2)\rightarrow J)+E_\gamma(J\rightarrow(J-2))]/4 \text{ MeV}$$

Kinetic Moment of Inertia

$$I^{(1)}(J) = (2J-1)\hbar^2/[E_\gamma(J\rightarrow(J-2))] \text{ MeV}^{-1}$$

Dynamic Moment of Inertia

$$I^{(2)}(J) = 4\hbar^2/[E_\gamma((J+2)\rightarrow J)-E_\gamma(J\rightarrow(J-2))] \text{ MeV}^{-1}$$

Decay γ-ray data:

Tables of γ-ray energies and intensities from decay are headed by the generic title "*γ (daughter) from parent($t_{1/2}$) xx decay <for I_γ% multiply by yy>*" where *xx* is the mode of decay and *yy* is the factor required to normalize the γ-ray intensity to units of "per 100 decays of the parent". In some cases the decay is indicated as *from multiple parents* when the data are from a mixed source. The title is followed by an energy-ordered list of transitions, their intensities and their multipolarities and mixing ratios. See the discussion under adopted γ-ray data for a discussion of these quantities. Unplaced γ-ray transitions, not shown in the adopted γ-ray tables, are indicated by (u), following the energy. The γ-ray list typically includes measured values for transitions observed in decay experiments whose energies may vary from their adopted values in the level table. Additional transitions observed in reaction experiments and included in the adopted levels table are excluded from this list. A complete list of γ rays expected from decay can be inferred from the decay scheme drawings (see discussion below).

Decay particle data:
Tables of particle emission energies and intensities from decay are headed by the generic title "*x from parent($t_{1/2}$) x decay <for I_x% multiply by yy>*" where *x*= α*,p, n,….* is the emitted particle and *yy* is the normalization factor defined as for decay γ rays (see above). Particles are listed in energy order and preceded by x_{abc} where abc is the energy of the level populated in the daughter.

C. Decay-scheme drawings:

Nuclear levels populated by radioactive decay are shown on a detailed decay scheme drawing. A decay scheme for each parent decay mode summarizes the daughter level structure as observed in the decay of that parent isotope or isomeric state. All levels populated in radioactive decay, the adopted transitions from these levels, and additional adopted levels fed by the adopted transitions but not observed in decay, are shown on the decay scheme. If the decay scheme is sufficiently complex, it is drawn in several parts divided into regions of level excitation energy populated by the parent. In each part, the lower energy levels are omitted from the drawing unless they are fed from above. The following is a description of those properties shown on decay scheme drawings.

Levels are represented as horizontal lines and *transitions* by vertical arrows. Heavy lines denote ground states and isomeric states. Uncertain levels or transitions are indicated by dashed lines. The levels are plotted on a linear energy scale as close to their relative energies as possible; however, a minimum separation is imposed to facilitate legibility. The inner scale of the level drawing has a finer minimum level separation while the outer scale is coarser to allow room for labels. A group of unresolved levels, such as might be populated in delayed particle emission, may be presented as a broad band of lines.

Level energies (keV), in bold type, are located near the right end of a level. These energies are taken from the adopted levels tables.

Spins, parities, and isospin assignments, also in bold type, are located near the left end of a level. These values are from the adopted levels tables.

Half-lives, from the adopted levels tables, are located near the level at various positions as determined by layout considerations. Ground state and isomeric state half-lives are given in larger type than other half-lives.

Relative intensities of γ rays are located immediately above the transition arrow.

γ-ray energies (keV), in bold type, follow the intensities. An asterisk following the energy denotes a multiply placed γ ray.

Multipolarity of the γ ray follows the energy on the label. The intensity, energy, and multipolarity are from the adopted γ-ray tables.

Particle emission from excited states is indicated by a decay arrow on the left or right side of the level and labeled by the particle decay mode. When delayed particle emission is known to populate specific levels in the particle decay daughter, the relevant levels for that nucleus and the associated particle transitions to those levels are shown in greater detail. Particle decay branchings may be shown on the particle transition lines and final state feedings may be shown on horizontal feeding arrows pointing to the final states.

Parent isotopes are located in the upper corners of the decay scheme: β^- parents to the left, and α or EC+β^+ parents to the right. The parent half-life, energy, spin and parity assignment, decay mode, and decay Q-value are given. A vertical decay arrow points from the parent line to horizontal transition feeding lines (if any) pointing to levels populated in the daughter. If the parent is drawn to scale, a half-bullet on the parent decay arrow marks the energy (Q-value) of the parent on the same internal scale as the levels. Otherwise, a scale break (≈) is drawn through the decay arrow.

Level feedings from α or β decay are usually given on the transition feeding lines in transitions per 100 decays (%) of the parent. In some cases, relative intensities are given, and these are indicated by a † preceding the value. *Log ft values* for β decay are given in italics to the right of the intensity. For unique-forbidden transitions, the uniqueness order is given as a superscript to the *log ft.* *α-decay hindrance factors* are also given in italics following the α intensity; these values are typically the evaluator's values without revision following the incorporation of the 1993 mass table. In some cases, the transition feeding line is shown bracketed to more than one final level indicating the feeding is the sum to both levels. Dotted transition feeding lines indicate that the population of this level is uncertain.

D. Nuclear structure drawings:

Decay schemes for families of levels with common collective properties, high-spin structures, or structures of importance in high-spin physics have been drawn. For each nucleus the bands or structures are plotted side by side, with levels drawn at a position nearly proportional to the energy, and labeled by spin and parity on the left and energy on the right. In-band transition arrows are plotted in a compact semi-stack plot with energies, rounded to the nearest keV, drawn at the end of the arrow. Transitions between adjacent bands are indicated by diagonal arrows but are unlabeled. The existence of other transitions that could not be drawn is indicated by an arrowhead drawn to the right of the level near the energy. Due to layout considerations, some bands may be plotted at a false position relative to other bands. A band label is drawn beneath each band when that band has been given a definitive name in the literature. Among the common band names used here are:

GS band	The band built on the ground state

Yrast band	Sequence of levels corresponding to the lowest energy for each spin
β band	The band built on the first excited 0^+ state
γ band	The band built on the first excited 2^+ state
Octupole band	The band based on an octupole vibration
$K[Nn_Z\Lambda]$	Nilsson configuration
$\pi h_{11/2}$ or $\nu h_{11/2}$	Band based on configuration derived from the proton (π) or neutron (ν) shell model configuration $h_{11/2}$
SD band	Superdeformed band
α=+1/2, α=–1/2	Favored or unfavored signature band
3 QP	Three quasiparticle band

Sometimes the band label is a compound of more than one of the above forms indicating specific multiparticle configurations or core-particle excitations. Since band labels are somewhat subjective, and labeling has evolved over time, these labels should be considered only as rough descriptions of the more complex nuclear physics underlying their descriptions.

References

1) *Evaluated Nuclear Structure Data File* (ENSDF), an electronic data base containing evaluated nuclear structure and radioactive decay data. The file is maintained by the National Nuclear Data Center (NNDC), Brookhaven National Laboratory, on behalf of the International Network for Nuclear Structure and Decay Data Evaluation.
2) G. Audi and A.H. Wapstra, *Nucl. Phys.* **A565**, 1 (1993); private communication (1993).
3) *Neutron Cross Sections*, S.F. Mughabghab, M. Divadeenam, and N.E. Holden, Academic Press, New York (1981).
4) D.C. Hoffman, T.M. Hamilton, and M.R. Lane, *Spontaneous Fission*, LBL-33001 (1992).
5) P. Raghavan, *At. Data Nucl. Data Tables* **42**, 189 (1989).
6) R.B. Firestone and B. Singh, *Table of Superdeformed Nuclear Bands and Fission Isomers*, LBL-35916 (1994).

7) *Nuclear Science Reference File* (NSR), an electronic database containing nuclear structure references with keyword abstracts. The file is maintained by the National Nuclear Data Center (NNDC), Brookhaven National Laboratory, on behalf of the International Network for Nuclear Structure and Decay Data Evaluation.
8) P. Möller, W.D. Myers, W.J. Swiatecki, and J. Treiner, *At. Data Nucl. Data Tables* **39**, 225 (1988).
9) P. De Bièvre and P.D.P. Taylor, *Int. J. Mass Spectrom. Ion Phys.* **123**, 149 (1993).
10) K.S. Krane and R.M. Steffen, *Phys. Rev.* **C2**, 724 (1970).

Reaction and Decay Daughter Index

A=263 Summary Scheme

^{263}Ha

Level Table

^{263}Sg

Level Table
^{267}Hs(60 ms) α Decay

^{263}Ns

Level Table

^{263}Hs

Level Table
^{267}110(~3 μs) α Decay

A=264 Summary Scheme

^{264}Ns

Level Table
^{268}Mt(0.07 s) α Decay

^{264}Hs

Level Table

A=265 Summary Scheme

^{265}Sg

Level Table

^{265}Hs

Level Table

A=266 Summary Scheme

^{266}Sg

Level Table

^{266}Mt

Level Table

A=267 Summary Scheme

^{267}Hs

Level Table

^{267}110

Level Table

A=268 Summary Scheme

^{268}Mt

Level Table
^{272}111(1.5 ms) α Decay

A=269 Summary Scheme

^{269}110

Level Table

A=271 Summary Scheme

^{271}110

Level Table

A=272 Summary Scheme

^{272}111

Level Table

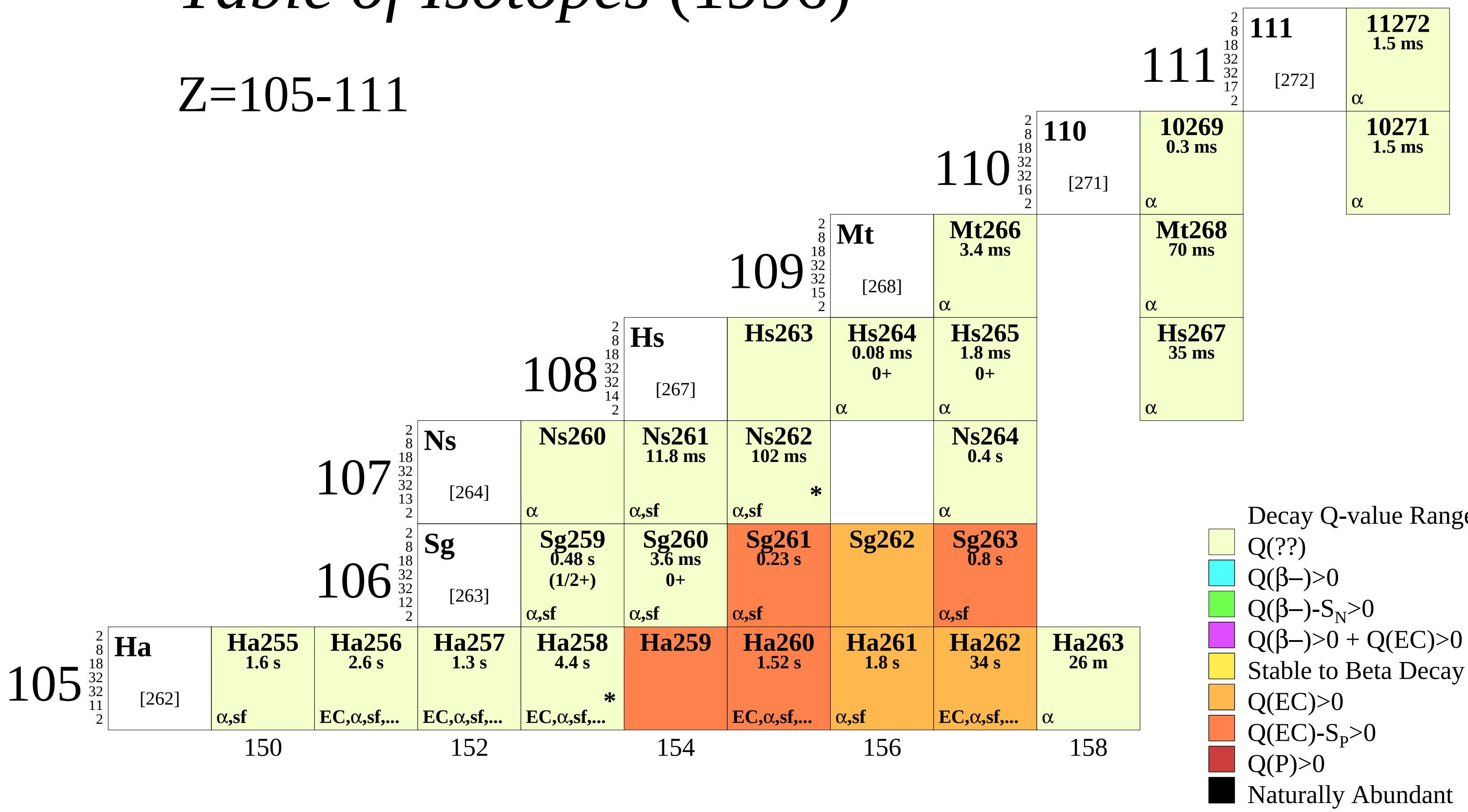
Decay Parent Index

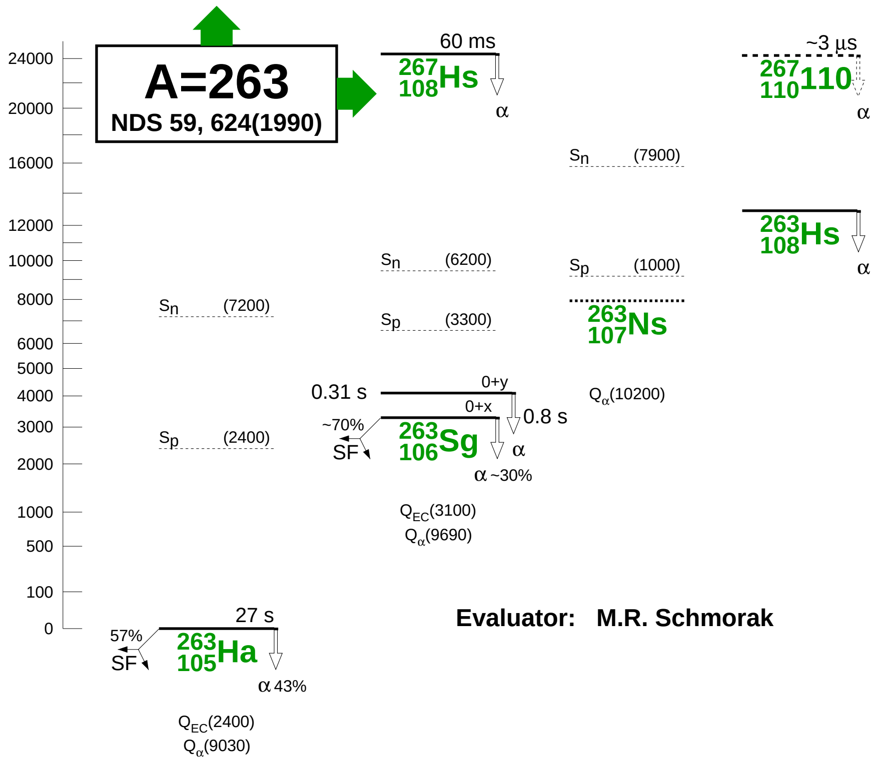
List of First Reference in Each Page

Appendix Index

Table of Isotopes (1996)

Z=105-111




A=263
NDS 59, 624(1990)
24000
20000
16000
12000
10000
8000
6000
5000
4000
3000
2000
1000
500
100
0
60 ms
267 108 Hs
α
~3 µs
267 110 110
α
Sn (7900)
263 108 Hs
α
Sn (6200)
Sp (1000)
Sn (7200)
Sp (3300)
263 107 Ns
Qα(10200)
0.31 s
0+y
0+x
0.8 s
~70%
SF
263 106 Sg
α
α ~30%
Sp (2400)
QEC(3100)
Qα(9690)
27 s
57%
SF
263 105 Ha
α 43%
QEC(2400)
Qα(9030)
Evaluator: M.R. Schmorak

$^{263}_{105}$Ha

Δ: (107390) **S_n:** (7200) **S_p:** (2400)
Q_{EC}: (2400) **Q_α:** (9030)

Populating Reactions and Decay Modes

^{249}Bk(^{18}O,4n) (87GrZN, 92Kr01)

Levels:
0, 27^{+10}_{-7} s, %SF=57 *15*, %α=43 *15*

α from ^{263}Ha (27 s) α decay **<** *for Iα% multiply by 0.43 15* **>**

α_{550}*8355* *27* (†≈100).

$^{263}_{106}$Sg

Δ: (110500) **S_n:** (6200) **S_p:** (3300)
Q_{EC}: (3100) **Q_α:** (9690)

Populating Reactions and Decay Modes

A ^{267}Hs α decay (95HoHB)
B ^{249}Cf(^{18}O,4n) (74Gh04, 76BeZY, 79Dr07)

Levels:
0+x, 0.8 *2* s, *[B]*, %SF≈70, %α≈30
0+y, 0.31^{+16}_{-8} s, *[A]*, %α=?
54+y *30*, *[A]*
135+y *30*, *[A]*

α from ^{263}Sg (0.31 s) α decay :

α_0 ***9248*** *20* .

α from ^{263}Sg (0.8 s) α decay **<** *for Iα% multiply by ≈0.30* **>**

α_{300} ***9250*** *40* (†≈10),
α_{493} ***9060*** *40* (†≈90).

$^{263}_{107}Ns$

Δ: (114900) **S_n:** (7900) **S_p:** (1000)
Q_{EC}: (4400) **Q_α:** (10200)

$^{263}_{108}$Hs

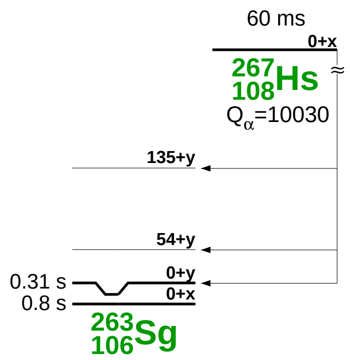
Populating Reactions and Decay Modes

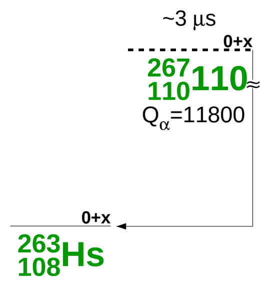
A ^{267}110 α decay (95GhZZ)

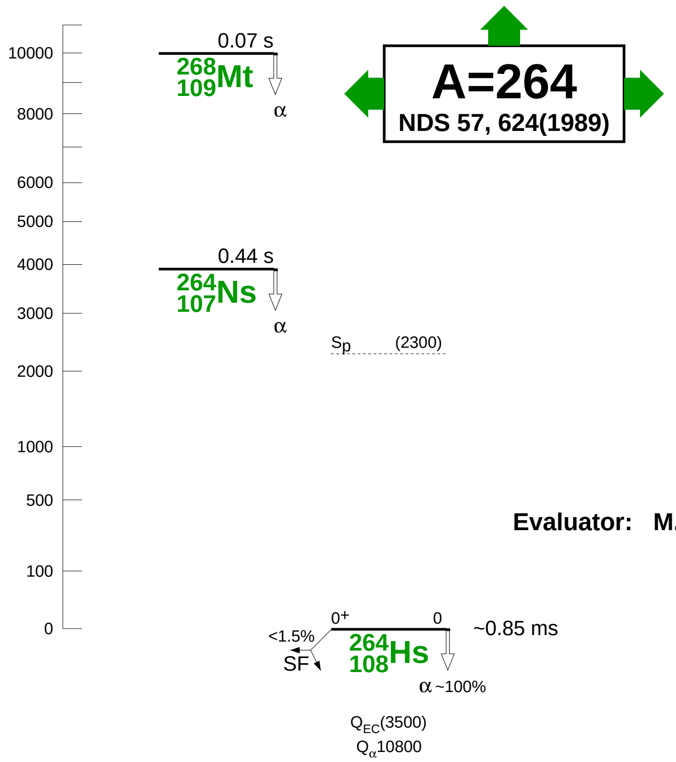
B ^{209}Bi(^{55}Mn,n) (84DeZO, 84Og02, 84Og03)

Levels:

0+x, *[A]*


60 ms
0+x
267
108
Hs
≈
Qα=10030
135+y
54+y
0.31 s
0+y
0.8 s
0+x
263
106
Sg


~3 µs
0+x
267 110 110
Qα=11800
0+x
263 108 Hs



Evaluator: M.R. Schmorak

$^{264}_{107}Ns$

Δ: (116400) **S_n:** (6600) **S_p:** (1400)
Q_{EC}: (5300) **Q_α:** (10100)

Populating Reactions and Decay Modes

^{268}Mt α decay (95HoHB)

Levels:

0+x, 0.44^{+60}_{-16} s, %α=?

145+x *30*

α from ^{264}Ns (0.44 s) α decay

α_{333} ***9619*** *20* ,
α_{479} ***9475*** *20* .

$^{264}_{108}$Hs

Δ: 119800 *300*   **S_p:** (2300)

Q_{EC}: (3500) **Q_α:** 10800 *300*

Populating Reactions and Decay Modes

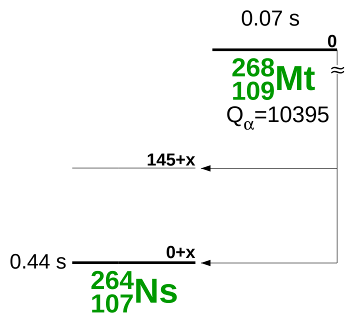
^{207}Pb(^{58}Fe,n) (84Og02, 84Og03, 86Mu10, 87Mu15, 95HoHB)

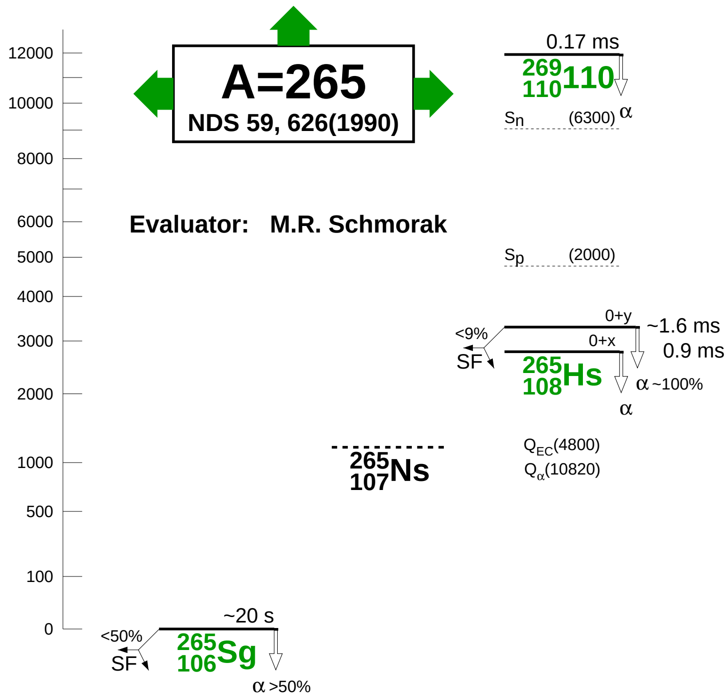
Levels:

0, 0^+, ≈ 0.85 ms, %α≈100, %SF<1.5

α from ^{264}Hs (≈0.85 s) α decay **<** *for Iα% multiply by ≈1.0* **>**

α_0 ***10430*** *20* (†100).


0.07 s
0
268 109 Mt
Qα=10395
145+x
0.44 s
0+x
264 107 Ns


A=265
NDS 59, 626(1990)
Evaluator: M.R. Schmorak
12000
10000
8000
6000
5000
4000
3000
2000
1000
500
100
0
0.17 ms
269
110
110
α
Sn (6300)
Sp (2000)
0+y
~1.6 ms
<9%
SF
0+x
0.9 ms
265
108
Hs
α ~100%
α
265
107
Ns
QEC(4800)
Qα(10820)
~20 s
<50%
SF
265
106
Sg
α >50%

$^{265}_{106}$Sg

Δ: (113100) **S_n:** (6100) **S_p:** (3800)
Q_{EC}: (2400) **Q_α:** (9200)

Populating Reactions and Decay Modes

^{248}Cm(^{22}Ne,5n) (95SeAA)

Levels:
0+x, [20 s calc], %α>50, %SF<50

α from ^{265}Sg (20 s) α decay **<** *for Iα% multiply by >0.50* **>**

$\alpha_?$≈***8800*** (†≈100).

$^{265}_{108}$Hs

Δ: (121600) **S_n:** (6300) **S_p:** (2000)
Q_{EC}: (4800) **Q_α:** (10820)

Populating Reactions and Decay Modes

A ^{269}110 α decay (95HoHA)
B ^{208}Pb(^{58}Fe,n) (84DeZO, 84Og02, 84Og03, 87Mu15)

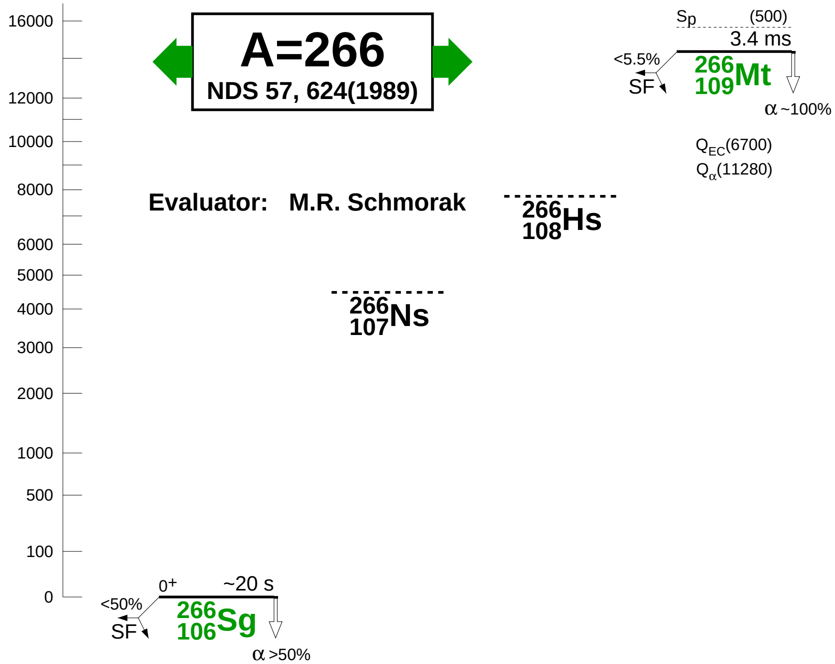
Levels:
0+x, 0.9^{+9}_{-3} ms, *[A]*, %α=?
0+y, ≈ 1.6 ms, *[B]*, %α≈100, %SF<9

α from ^{265}Hs (≈1.6 ms) α decay **<** *for Iα% multiply by ≈1.0* **>**

α_{300} ***10310*** *20* (†≈100).

α from ^{265}Hs (0.9 ms) α decay

$\alpha_{?}$ ***10570*** *20* .


A=266
NDS 57, 624(1989)
Evaluator: M.R. Schmorak
16000
12000
10000
8000
6000
5000
4000
3000
2000
1000
500
100
0
Sp (500)
3.4 ms
<5.5%
SF
266 109 Mt
α ~100%
QEC(6700)
Qα(11280)
266 108 Hs
266 107 Ns
0+
~20 s
<50%
SF
266 106 Sg
α >50%

$^{266}_{106}$Sg

Δ: (114000) **S_n:** (7100) **S_p:** (4000)
Q_{EC}: (1000) **Q_α:** (9100)

Populating Reactions and Decay Modes

^{248}Cm(^{22}Ne,4n) (95SeAA)

Levels:

0, 0^+, [20 s calc], %α>50, %SF<50

α from ^{266}Sg (20 s) α decay **<** *for Iα% multiply by >0.50* **>**

α_0 ***8630*** *50* (†≈100).

$^{266}_{109}Mt$

Δ: (128400) **S_p:** (500)

Q_{EC}: (6700) **Q_α:** (11280)

Populating Reactions and Decay Modes

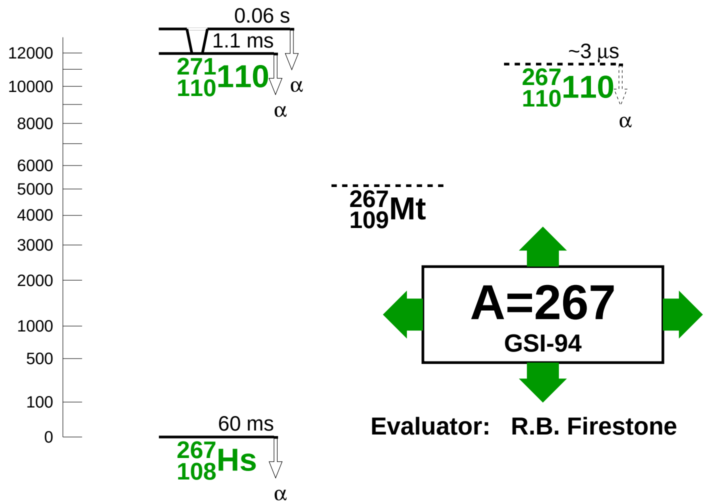
^{209}Bi(^{58}Fe,n) (82Mu15, 84Mu07, 84Og03, 88Mu15, 89Mu16)

Levels:

0, 3.4^{+61}_{-13} ms, %α≈100, %SF<5.5

α from ^{266}Mt (3.4 ms) α decay **<** *for Iα% multiply by ≈1.0* **>**

α_{120} ***11000*** *30* (†≈100).


12000
10000
8000
6000
5000
4000
3000
2000
1000
500
100
0
0.06 s
1.1 ms
271 110 110
α
α
~3 µs
267 110 110
α
267 109 Mt
A=267
GSI-94
Evaluator: R.B. Firestone
60 ms
267 108 Hs
α

$^{267}_{108}$Hs

Populating Reactions and Decay Modes

A ^{271}110 α decay (1.1 ms) (95HoHB)

B ^{271}110 α decay (0.06 s) (95HoHB)

Levels:

0+x, 60^{+30}_{-15} ms, *[A]*, %α=?

58+x *30*, *[A]*

α from ^{267}Hs (60 ms) α decay :

α_{0+y} ***9882*** *20* ,
α_{54+y} ***9829*** *20* ,
α_{135+y} ***9749*** *20* .

$^{267}_{110}110$

Populating Reactions and Decay Modes

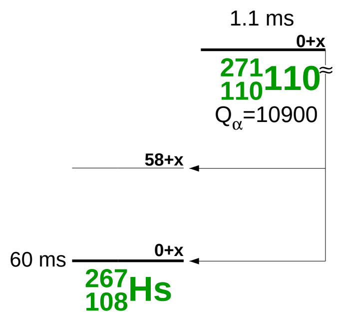
$^{209}Bi(^{59}Co,n)$ (95GhAA)

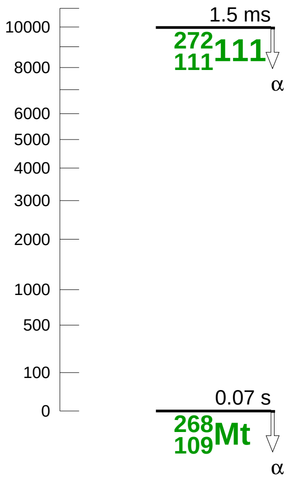
Levels:

0+x (?), ≈ 3 μs, %α=?

α from $^{267}110$ (≈3 μs) α decay :

$\boldsymbol{\alpha_{0+x}}$***11600*** .


1.1 ms
0+x
271 110 110
Qα=10900
58+x
60 ms
0+x
267 108 Hs



A=268

GSI-94

Evaluator: R.B. Firestone

$^{268}_{109}$Mt

Populating Reactions and Decay Modes

^{272}111 α decay (95HoHB)

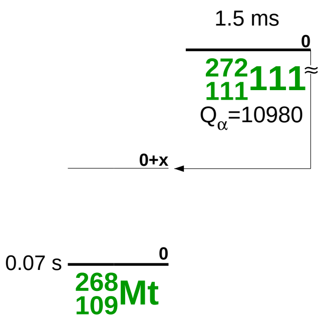
Levels:

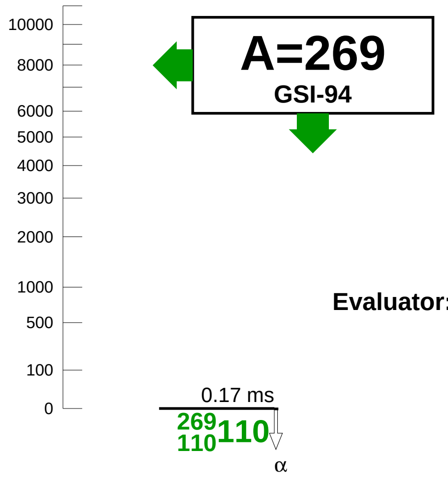
0, 0.07^{+10}_{-3} s, %α=?

0+x

α from ^{268}Mt (0.07 s) α decay :

α_{0+x} ***10240*** *20* ,
α_{145+x} ***10097*** *20* .


1.5 ms
0
272 111 111
≈
Qα=10980
0+x
0.07 s
0
268 109 Mt



Evaluator: R.B. Firestone

$^{269}_{110}110$

Populating Reactions and Decay Modes

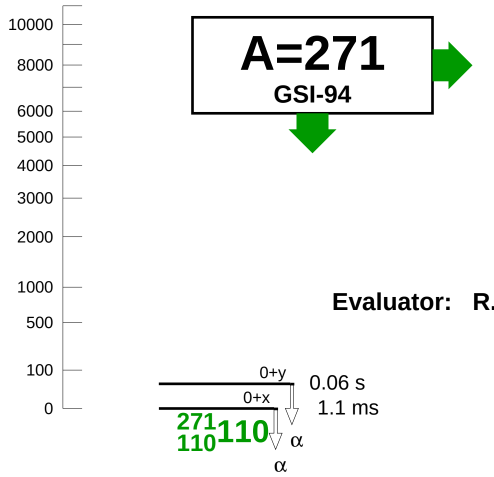
$^{208}Pb(^{62}Ni,n)$ (95HoHA)

Levels:

0, 0.17^{+16}_{-6} ms, %α=?

α from $^{269}110$ (0.17 ms) α decay :

$\alpha_{?}$***11112*** *20* .



Evaluator: R.B. Firestone

$^{271}_{110}110$

Populating Reactions and Decay Modes

^{208}Pb(^{64}Ni,n) (95HoHB)

Levels:

0+x, 1.1^{+6}_{-3} ms, %α=?

0+y, 0.06^{+27}_{-3} s, %α=?

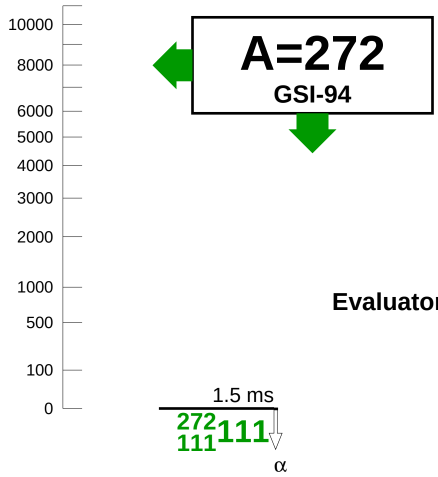
α from ^{271}110 (0.06 s) α decay :

$\boldsymbol{\alpha_{?}}$ ***10709*** *20* .

α from ^{271}110 (1.1 ms) α decay :

$\boldsymbol{\alpha_{0+x}}$ ***10738*** *20* ,

$\boldsymbol{\alpha_{58+x}}$ ***10681*** *20* .



Evaluator: R.B. Firestone

$^{272}_{111}111$

Populating Reactions and Decay Modes

$^{209}Bi(^{64}Ni,n)$ (95HoHB)

Levels:

0, 1.5^{+20}_{-5} ms, %α=?

α from $^{272}111$ (1.5 ms) α decay :

α_{0+x} ***10820*** *20* .

Reference Codes

The six-character reference codes in the tabular level data are taken almost exclusively from the Nuclear Structure Reference (NSR) file, maintained at the National Nuclear Data Center, Brookhaven National Laboratory. The first two characters indicate the publication year, the second two characters are the first two letters in the first author's last name, and the last two characters are an arbitrary sequence code. The references not taken from the NSR file are followed by an asterisk; these are unavailable in NSR at present.

74Gh04 *Element 106*

A. Ghiorso, J. M. Nitschke, J. R. Alonso, C. T. Alonso, M. Nurmia, G. T. Seaborg, E. K. Hulet, R. W. Lougheed, Phys. Rev. Lett. 33, 1490 (1974).

Radioactivity: ^{263}106; measured Eα, $T_{1/2}$.

76BeZY *X-Ray Identification and Decay Properties of Isotopes of Lawrencium*

C. E. Bemis, Jr., D. C. Hensley, P. F. Dittner, R. L. Hahn, R. J. Silva, J. R. Tarrant, L. D. Hunt, ORNL-5111, p. 58 (1976).

Radioactivity: ^{257}, ^{258}Lr, ^{255}, ^{256}Lr [from ^{249}Cf(^{11}B,4n), (^{10}B,4n)]; measured Eα, Iα, $T_{1/2}$.

79Dr07 *Spontaneous Fission of the Heavy Isotopes of Nielsbohrium (Z = 105) and Element 106*

V. A. Druin, B. Bochev, Y. V. Lobanov, R. N. Sagaidak, Y. P. Kharitonov, S. P. Tretyakova, G. G. Gulbekyan, G. V. Buklanov, E. A. Erin, V. N. Kosyakov, A. G. Rykov, Yad. Fiz. 29, 1149 (1979); Sov. J. Nucl. Phys. 29, 591 (1979).

Radioactivity: ^{262}105 (SF), ^{263}106 (SF) [from ^{249}Bk(^{18}O, 5n), ^{249}Cf(^{18}O,4n)]; measured $T_{1/2}$; deduced dependence $T_{1/2}$ (SF) on neutron number.

82Mu15 *Observation of One Correlated α-Decay in the Reaction ^{58}Fe on ^{209}Bi → ^{267}109*

G. Munzenberg, P. Armbruster, F. P. Hessberger, S. Hofmann, K. Poppensieker, W. Reisdorf, J. H. R. Schneider, W. F. W. Schneider, K. -H. Schmidt, C. -C. Sahm, D. Vermeulen, Z. Phys. A309, 89 (1982).

Radioactivity: ^{266}109 [from ^{209}Bi(^{58}Fe,n), E=4.95-5.15 MeV/nucleon]; measured Eα, time correlated α-spectra; deduced α-decay chain correlation followed by ^{258}104 fission. Evaporation residue implantation technique.

Nuclear Reactions: ^{209}Bi(^{58}Fe,n), E=4.95-5.15 MeV/nucleon; measured Eα, time correlated α-spectra; deduced evidence for ^{266}109. Evaporation residue implantation technique.

84DeZO *Experiments on the Synthesis of Element 108*

A. G. Demin, M. Yussonua, Yu. P. Kharitonov, S. P. Tretyakova, V. K. Utenkov, I. V. Shirokovsky, O. Constantinescu, Yu. S. Korotkin, H. Bruchertseifer, V. G. Subbotin, Kh. Esteves, A. V. Rykhlyuk, V. M. Plotko, Yu. Ts. Oganesyan, JINR-P7-84-233 (1984).

Nuclear Reactions: ^{209}Bi, ^{208}Pb(^{55}Mn,X), (^{58}Fe, X), E not given; measured cold fusion product yields; deduced evidence for ^{255}104, ^{257}104.

Radioactivity: ^{263}108, ^{265}108(α) [from ^{209}Bi, ^{208}Pb(^{55}Mn,X)]; measured α-decay probability; deduced stability against SF-decay.

84Mu07 *Evidence for Element 109 from One Correlated Decay Sequence following the Fusion of ^{58}Fe with ^{209}Bi*

G. Munzenberg, W. Reisdorf, S. Hofmann, Y. K. Agarwal, F. P. Hessberger, K. Poppensieker, J. R. H. Schneider, W. F. W. Schneider, K. -H. Schmidt, H. -J. Schott, P. Armbruster, C. -C. Sahm, D. Vermeulen, Z. Phys. A315, 145 (1984).

Radioactivity: ^{266}109(SF) [from ^{209}Bi(^{58}Fe,X), E=5.15 MeV/nucleon]; measured Eα, Iα, αα-coin, SF-decay.

Nuclear Reactions: ^{209}Bi(^{58}Fe,X), E=4.95, 5.05, 5.15 MeV/ nucleon; measured σ(fragment) vs mass, Eα, Iα, SF-decay; deduced evidence for compound nucleus ^{266}109.

84Og02 *On the Stability of the Nuclei of Element 108 with A = 263-265*

Yu. Ts. Oganessian, A. G. Demin, M. Hussonnois, S. P. Tretyakova, Yu. P. Kharitonov, V. K. Utyonkov, I. V. Shirokovsky, O. Constantinescu, H. Bruchertseifer, Yu. S. Korotkin, Z. Phys. A319, 215 (1984).

Nuclear Reactions: ^{208}Pb(^{50}Ti,xn)^{257}104/^{256}104/ ^{255}104, E=5.45 MeV/nucleon; ^{208}Pb(^{54}Cr, xn)^{261}106/^{260}106/^{259}106, E=5.5 MeV/ nucleon; ^{208}Pb(^{58}Fe,xn)^{265}108/^{264}108, E=5.5 MeV/nucleon; ^{207}Pb(^{58}Fe,xn)^{264}108, E=5.5 MeV/nucleon; ^{209}Bi(^{55}Mn,xn), E=5.5 MeV/nucleon; measured evaporation residue production σ. ^{263}108, ^{265}108, ^{264}108 deduced considerable α-decay probability, high stability against SF decay. Activation technique.

84Og03 *Experimental Studies of the Formation and Radioactive Decay of Isotopes with Z = 104-109*

Yu. Ts. Oganessian, M. Hussonnois, A. G. Demin, Yu. P. Kharitonov, H. Bruchertseifer, O. Constantinescu, Yu. S. Korotkin, S. P. Tretyakova, V. K. Utyonkov, I. V. Shirokovsky, J. Estevez, Radiochim. Acta 37, 113 (1984).

Nuclear Reactions: ^{208}Pb(^{50}Ti,γ), (^{50}Ti,n), (^{50}Ti, 2n), (^{50}Ti,3n), E=5.45 MeV/nucleon; ^{208}Pb(^{49}Ti, n), (^{49}Ti,2n), (^{49}Ti,nα), (^{49}Ti, 2np), E=5.53 MeV/nucleon; ^{208}Pb(^{48}Ti,n), (^{48}Ti,np), (^{48}Ti,α), E=5.4 MeV/nucleon; measured α-, fission fragment numbers; deduced residuals production σ. ^{209}Bi(^{50}Ti, n), E=5.3 MeV/nucleon; ^{209}Bi(^{54}Cr,n), E=5.4 MeV/nucleon; ^{208}Pb(^{55}Mn,n), (^{59}Co, n), ^{209}Bi(^{58}Fe,n), ^{208}Pb(^{54}Cr, n), (^{54}Cr,2n), (^{54}Cr,3n), ^{208}Pb(^{58}Fe, n), (^{58}Fe,2n), ^{207}Pb(^{58}Fe,n), ^{209}Bi(^{55}Mn, n), E=5.5 MeV/nucleon; ^{209}Bi(^{55}Mn,np), E=5.55 MeV/nucleon; ^{208}Pb(^{50}Ti,n), (^{50}Ti, 2n), (^{50}Ti,3n), E=5.45 MeV/nucleon; measured Eα, α-, fission fragment numbers, decay $T_{1/2}$; deduced residuals production σ, yields.

Radioactivity: ^{257}104, ^{256}104, ^{255}104, ^{258}105, ^{262}107, ^{266}109, ^{261}, ^{260}, ^{259}106, ^{263}, ^{264}, ^{265}108, ^{254}, ^{256}Lr, ^{252}No [from Pb, ^{209}Bi(^{49}, ^{50}Ti,xn), (^{58}Fe,xn), (^{55}Mn,xn), E 5-5.5 MeV/nucleon]; measured decay characteristics. ^{265}108, ^{264}108, ^{263}108, ^{266}109, ^{261}106, ^{260}106, ^{259}106 deduced α-decay preponderance.

86Mu10 *Evidence for ^{264}108, the Heaviest Known Even-Even Isotope*

G. Munzenberg, P. Armbruster, G. Berthes, H. Folger, F. P. Hessberger, S. Hofmann, K. Poppensieker, W. Reisdorf, B. Quint, K. -H. Schmidt, H. -J. Schott, K. Summerer, I. Zychor, M. E. Leino, U. Gollerthan, E. Hanelt, Z. Phys. A324, 489 (1986).

Radioactivity: ^{264}108(α) [from ^{207}Pb(^{58}Fe,X), E=5.04 MeV/nucleon]; measured Eα, Iα; deduced Qα, $T_{1/2}$, mass excess.

Nuclear Reactions: ^{207}Pb(^{58}Fe,X)^{264}108, E=5.04 MeV/nucleon; measured Eα, Iα following fusion evaporation residue decay; deduced evidence for ^{264}108 production σ lower limit.

87GrZN *Possible Detection of New Isotope 263-105*

K. E. Gregorich, R. Leres, D. Lee, D. C. Hoffman, LBL-22820, p. 54 (1987).

Radioactivity: ^{263}105(α) [from ^{249}Bk(^{18}O,X)]; ^{259}Lr(α) [from ^{263}105(α-decay)]; measured Eα, $T_{1/2}$, $\alpha\alpha$-correlation.

87Mu15 *Observation of the Isotopes $^{264}108$ and $^{265}108$*

G. Munzenberg, P. Armbruster, G. Berthes, H. Folger, F. P. Hessberger, S. Hofmann, J. Keller, K. Poppensieker, A. B. Quint, W. Reisdorf, K. -H. Schmidt, H. -J. Schott, K. Summerer, I. Zychor, M. E. Leino, R. Hingmann, U. Gollerthan, E. Hanelt, Z. Phys. A328, 49 (1987).

Compilation: ^{237}, ^{238}, ^{239}, ^{240}, ^{241}, ^{242}, ^{243}, ^{244}, ^{245}, ^{246}Pu, ^{240}, ^{241}, ^{242}, ^{243}, ^{244}, ^{245}, ^{246}, ^{247}, ^{248}, ^{249}, ^{250}Cm, ^{242}, ^{243}, ^{244}, ^{245}, ^{246}, ^{248}, ^{249}, ^{250}, ^{251}, ^{252}, ^{253}, ^{254}Cf; compiled experimental, theoretical mass differences. ^{245}, ^{246}, ^{247}, ^{248}, ^{249}, ^{250}, ^{251}, ^{252}, ^{254}, ^{255}, ^{256}, ^{257}Fm, ^{251}, ^{252}, ^{253}, ^{254}, ^{255}, ^{256}, ^{257}, ^{259}No, $^{255}104$, $^{256}104$, $^{257}104$, $^{259}104$, $^{261}104$, $^{259}106$, $^{260}106$, $^{261}106$, $^{263}106$, $^{265}108$; compiled partial α-decay $T_{1/2}$, $Q(\alpha)$, experimental, theoretical mass differences.

Radioactivity: $^{264}108$, $^{265}108(\alpha)$ [from ^{207}, ^{208}Pb(^{58}Fe,n), E=5.04 MeV/nucleon]; measured Eα, Iα. $^{265}108$ deduced α-decay $T_{1/2}$, energy. $^{264}108$ deduced α-decay $T_{1/2}$.

Nuclear Reactions: ^{207}, ^{208}Pb(^{58}Fe,n), E=5.04 MeV/nucleon; measured Eα, Iα; deduced evidence for $^{264}108$, $^{265}108$.

88Mu15 *New Results on Element 109*

G. Munzenberg, S. Hofmann, F. P. Hessberger, H. Folger, V. Ninov, K. Poppensieker, A. B. Quint, W. Reisdorf, H. -J. Schott, K. Summerer, P. Armbruster, M. E. Leino, D. Ackermann, U. Gollerthan, E. Hanelt, W. Morawek, Y. Fujita, T. Schwab, A. Turler, Z. Phys. A330, 435 (1988).

Nuclear Reactions: ^{209}Bi(^{56}Fe,X), E=5.17 MeV/nucleon; measured α(evaporation residue)(θ). $^{266}109$ deduced $T_{1/2}$, decay features.

89Mu16 *Heavy Element Production and Limits to Fusion*

G. Munzenberg, Nucl. Phys. A502, 571c (1989).

Nuclear Reactions: ^{209}Bi(^{54}Cr,X), E=4.88 MeV/nucleon; measured α-spectra; deduced $^{261}107$, $^{262}107$ production, decay characteristics. Other data discussed.

92Kr01 *New Nuclide ^{263}Ha*

J. V. Kratz, M. K. Gober, H. P. Zimmermann, M. Schadel, W. Bruchle, E. Schimpf, K. E. Gregorich, A. Turler, N. J. Hannink, K. R. Czerwinski, B. Kadkhodayan, D. M. Lee, M. J. Nurmia, D. C. Hoffman, H. Gaggeler, D. Jost, J. Kovacz, U. W. Scherer, A. Weber, Phys. Rev. C45, 1064 (1992).

Radioactivity: ^{263}104(α), (SF) [from ^{249}Bk(^{18}O, 4n), E=93 MeV]; measured $T_{1/2}$, Eα, Iα, (α)(SF-decay fragment)-, (α,α)-correlations; deduced α/SF branching ratios. Rapid chemical separation.

Nuclear Reactions: ^{249}Bk(^{18}O,4n), E=93 MeV; measured Eα, Iα, $\alpha\alpha$-correlations; deduced evidence for ^{263}104.

95GhAA

Nucl. Phys. A583, 861 (1995) (not abstracted).

95GhZZ

Reference unavailable.

95HoHA

Z. Phys. A350, 277 (1995) (not abstracted).

95HoHB

Z. Phys. A350, 281 (1995) (not abstracted).

95SeAA

Priv. comm. G. T. Seaborg (1995) (not abstracted)

Periodic Table for the *Table of Isotopes* (1995)

Key to Table

Group
Element
K L M N O P Q (electron shells) — E_Z — M.P.°, B.P.°, C.P.°
Ox.States
At.Weight
Abundance%

Group	Element	Symbol	Z	Shells (K L M N O P Q)	M.P.	B.P.	C.P.	Ox. States	At. Weight	Abundance
1 (IA)	Hydrogen	H	1	1	-259.34°	-252.87°	-240.18°	+1-1	1.00794	91.0%
18 (VIIIA)	Helium	He	2	2	-272.2°	-268.93°	-267.96°	0	4.002602	8.9%
1 (IA)	Lithium	Li	3	2 1	180.5°	1342°		+1	6.941	1.86×10^{-7}%
2 (IIA)	Beryllium	Be	4	2 2	1287°	2471°		+2	9.012182	2.38×10^{-9}%
13 (IIIA)	Boron	B	5	2 3	2075°	4000°		+3	10.811	6.9×10^{-8}%
14 (IVA)	Carbon	C	6	2 4	4492t°	3825s°		+2+4-4	12.011	0.033%
15 (VA)	Nitrogen	N	7	2 5	-210.00°	-195.79°	-146.94°	±1±2±3+4+5	14.00674	0.0102%
16 (VIA)	Oxygen	O	8	2 6	-218.79°	-182.95°	-118.56°	-2	15.9994	0.078%
17 (VIIA)	Fluorine	F	9	2 7	-219.62°	-188.12°	-129.02°	-1	18.9984032	2.7×10^{-6}%
18 (VIIIA)	Neon	Ne	10	2 8	-248.59°	-246.08°	-228.7°	0	20.1797	0.0112%
1 (IA)	Sodium	Na	11	2 8 1	97.72°	883°		+1	22.989768	0.000187%
2 (IIA)	Magnesium	Mg	12	2 8 2	650°	1090°		+2	24.3050	0.00350%
13 (IIIA)	Aluminum	Al	13	2 8 3	660.32°	2519°		+3	26.981539	0.000277%
14 (IVA)	Silicon	Si	14	2 8 4	1414°	3265°		+2+4-4	28.0855	0.00326%
15 (VA)	Phosphorus	P	15	2 8 5	44.15°	277°	721°	+3+5-3	30.973762	0.000034%
16 (VIA)	Sulfur	S	16	2 8 6	115.21°	444.60°	1041°	+4+6-2	32.066	0.00168%
17 (VIIA)	Chlorine	Cl	17	2 8 7	-101.5°	-34.04°	143.8°	+1+5+7-1	35.4527	0.000017%
18 (VIIIA)	Argon	Ar	18	2 8 8	-189.35°	-185.85°	-122.28°	0	39.948	0.000329%
1 (IA)	Potassium	K	19	2 8 8 1	63.38°	759°		+1	39.0983	0.0000123%
2 (IIA)	Calcium	Ca	20	2 8 8 2	842°	1484°		+2	40.078	0.000199%
3 (IIIB)	Scandium	Sc	21	2 8 9 2	1541°	2830°		+3	44.955910	1.12×10^{-7}%
4 (IVB)	Titanium	Ti	22	2 8 10 2	1668°	3287°		+2+3+4	47.867	7.8×10^{-6}%
5 (VB)	Vanadium	V	23	2 8 11 2	1910°	3407°		+2+3+4+5	50.9415	9.6×10^{-7}%
6 (VIB)	Chromium	Cr	24	2 8 13 1	1907°	2671°		+2+3+6	51.9961	0.000044%
7 (VIIB)	Manganese	Mn	25	2 8 13 2	1246°	2061°		+2+3+4+7	54.93805	0.000031%
8 (VIII)	Iron	Fe	26	2 8 14 2	1538°	2861°		+2+3	55.845	0.00294%
9 (VIII)	Cobalt	Co	27	2 8 15 2	1495°	2927°		+2+3	58.93320	7.3×10^{-6}%
10 (VIII)	Nickel	Ni	28	2 8 16 2	1455°	2913°		+2+3	58.6934	0.000161%
11 (IB)	Copper	Cu	29	2 8 18 1	1084.62°	2562°		+1+2	63.546	1.70×10^{-6}%
12 (IIB)	Zinc	Zn	30	2 8 18 2	419.53°	907°		+2	65.39	4.11×10^{-6}%
13 (IIIA)	Gallium	Ga	31	2 8 18 3	29.76°	2204°		+3	69.723	1.23×10^{-7}%
14 (IVA)	Germanium	Ge	32	2 8 18 4	938.25°	2833°		+2+4	72.61	3.9×10^{-7}%
15 (VA)	Arsenic	As	33	2 8 18 5	817t°	614s°	1400°	+3+5-3	74.92159	2.1×10^{-8}%
16 (VIA)	Selenium	Se	34	2 8 18 6	221°	685°	1493°	+4+6-2	78.96	2.03×10^{-7}%
17 (VIIA)	Bromine	Br	35	2 8 18 7	-7.2°	58.8°	315°	+1+5-1	79.904	3.8×10^{-8}%
18 (VIIIA)	Krypton	Kr	36	2 8 18 8	-157.36°	-153.22°	-63.74°	0	83.80	1.5×10^{-7}%
1 (IA)	Rubidium	Rb	37	2 8 18 8 1	39.31°	688°		+1	85.4678	2.31×10^{-8}%
2 (IIA)	Strontium	Sr	38	2 8 18 8 2	777°	1382°		+2	87.62	7.7×10^{-8}%
3 (IIIB)	Yttrium	Y	39	2 8 18 9 2	1526°	3336°		+3	88.90585	1.51×10^{-8}%
4 (IVB)	Zirconium	Zr	40	2 8 18 10 2	1855°	4409°		+4	91.224	3.72×10^{-8}%
5 (VB)	Niobium	Nb	41	2 8 18 12 1	2477°	4744°		+3+5	92.90638	2.28×10^{-9}%
6 (VIB)	Molybdenum	Mo	42	2 8 18 13 1	2623°	4639°		+6	95.94	8.3×10^{-9}%
7 (VIIB)	Technetium	Tc	43	2 8 18 13 2	2157°	4265°		+4+6+7	[98]	
8 (VIII)	Ruthenium	Ru	44	2 8 18 15 1	2334°	4150°		+3	101.07	6.1×10^{-9}%
9 (VIII)	Rhodium	Rh	45	2 8 18 16 1	1964°	3695°		+3	102.90550	1.12×10^{-9}%
10 (VIII)	Palladium	Pd	46	2 8 18 18 0	1554.9°	2963°		+2+4	106.42	4.5×10^{-9}%
11 (IB)	Silver	Ag	47	2 8 18 18 1	961.78°	2162°		+1	107.8682	1.58×10^{-9}%
12 (IIB)	Cadmium	Cd	48	2 8 18 18 2	321.07°	767°		+2	112.411	5.3×10^{-9}%
13 (IIIA)	Indium	In	49	2 8 18 18 3	156.60°	2072°		+3	114.818	6.0×10^{-10}%
14 (IVA)	Tin	Sn	50	2 8 18 18 4	231.93°	2602°		+2+4	118.710	1.25×10^{-8}%
15 (VA)	Antimony	Sb	51	2 8 18 18 5	630.63°	1587°		+3+5-3	121.760	1.01×10^{-9}%
16 (VIA)	Tellurium	Te	52	2 8 18 18 6	449.51°	988°		+4+6-2	127.60	1.57×10^{-8}%
17 (VIIA)	Iodine	I	53	2 8 18 18 7	113.7°	184.4°	546°	+1+5+7-1	126.90447	2.9×10^{-9}%
18 (VIIIA)	Xenon	Xe	54	2 8 18 18 8	-111.75°	-108.04°	16.58°	0	131.29	1.5×10^{-8}%
1 (IA)	Cesium	Cs	55	2 8 18 18 8 1	28.44°	671°		+1	132.90543	1.21×10^{-9}%
2 (IIA)	Barium	Ba	56	2 8 18 18 8 2	727°	1897°		+2	137.327	1.46×10^{-8}%
3 (IIIB)	Lanthanum	La†	57	2 8 18 18 9 2	920°	3455°		+3	138.9055	1.45×10^{-9}%
4 (IVB)	Hafnium	Hf	72	2 8 18 32 10 2	2233°	4603°		+4	178.49	5.02×10^{-10}%
5 (VB)	Tantalum	Ta	73	2 8 18 32 11 2	3017°	5458°		+5	180.9479	6.75×10^{-11}%
6 (VIB)	Tungsten	W	74	2 8 18 32 12 2	3422°	5555°		+6	183.84	4.34×10^{-10}%
7 (VIIB)	Rhenium	Re	75	2 8 18 32 13 2	3186°	5596°		+4+6+7	186.207	1.69×10^{-10}%
8 (VIII)	Osmium	Os	76	2 8 18 32 14 2	3033°	5012°		+3+4	190.23	2.20×10^{-9}%
9 (VIII)	Iridium	Ir	77	2 8 18 32 15 2	2446°	4428°		+3+4	192.217	2.16×10^{-9}%
10 (VIII)	Platinum	Pt	78	2 8 18 32 16 2	1768.4°	3825°		+2+4	195.08	4.4×10^{-9}%
11 (IB)	Gold	Au	79	2 8 18 32 18 1	1064.18°	2856°		+1+3	196.96654	6.1×10^{-10}%
12 (IIB)	Mercury	Hg	80	2 8 18 32 18 2	-38.83°	356.73°	1477°	+1+2	200.59	1.11×10^{-9}%
13 (IIIA)	Thallium	Tl	81	2 8 18 32 18 3	304°	1473°		+1+3	204.3833	6.0×10^{-10}%
14 (IVA)	Lead	Pb	82	2 8 18 32 18 4	327.46°	1749°		+2+4	207.2	1.03×10^{-8}%
15 (VA)	Bismuth	Bi	83	2 8 18 32 18 5	271.40°	1564°		+3+5	208.98037	4.7×10^{-10}%
16 (VIA)	Polonium	Po	84	2 8 18 32 18 6	254°			+2+4	[209]	
17 (VIIA)	Astatine	At	85	2 8 18 32 18 7	302°				[210]	
18 (VIIIA)	Radon	Rn	86	2 8 18 32 18 8	-71°	-61.7°	104°	0	[222]	
1 (IA)	Francium	Fr	87	2 8 18 32 18 8 1	27°			+1	[223]	
2 (IIA)	Radium	Ra	88	2 8 18 32 18 8 2	700°			+2	[226]	
3 (IIIB)	Actinium	Ac‡	89	2 8 18 32 18 9 2	1051°	3198°		+3	[227]	
4 (IVB)	Rutherfordium	Rf	104	2 8 18 32 32 10 2				+4	[261]	
5 (VB)	Hahnium	Ha	105	2 8 18 32 32 11 2					[262]	
6 (VIB)	Seaborgium	Sg	106	2 8 18 32 32 12 2					[263]	
7 (VIIB)	Nielsbohrium	Ns	107	2 8 18 32 32 13 2					[264]	
8 (VIII)	Hassium	Hs	108	2 8 18 32 32 14 2					[267]	
9 (VIII)	Meitnerium	Mt	109	2 8 18 32 32 15 2					[268]	
10 (VIII)	Element-110	110	110	2 8 18 32 32 16 2					[271]	
11 (IB)	Element-111	111	111	2 8 18 32 32 17 2					[272]	

† Lanthanides

Element	Symbol	Z	Shells (K L M N O P Q)	M.P.	B.P.	Ox. States	At. Weight	Abundance
Cerium	Ce	58	2 8 18 19 9 2	799°	3424°	+3+4	140.115	3.70×10^{-9}%
Praseodymium	Pr	59	2 8 18 21 8 2	931°	3510°	+3	140.90765	5.44×10^{-10}%
Neodymium	Nd	60	2 8 18 22 8 2	1016°	3066°	+3	144.24	2.70×10^{-9}%
Promethium	Pm	61	2 8 18 23 8 2	1042°	3000°	+3	[145]	
Samarium	Sm	62	2 8 18 24 8 2	1072°	1790°	+2+3	150.36	8.42×10^{-10}%
Europium	Eu	63	2 8 18 25 8 2	822°	1596°	+2+3	151.965	3.17×10^{-10}%
Gadolinium	Gd	64	2 8 18 25 9 2	1314°	3264°	+3	157.25	1.076×10^{-9}%
Terbium	Tb	65	2 8 18 27 8 2	1359°	3221°	+3	158.92534	1.97×10^{-10}%
Dysprosium	Dy	66	2 8 18 28 8 2	1411°	2561°	+3	162.50	1.286×10^{-9}%
Holmium	Ho	67	2 8 18 29 8 2	1472°	2694°	+3	164.93032	2.90×10^{-10}%
Erbium	Er	68	2 8 18 30 8 2	1529°	2862°	+3	167.26	8.18×10^{-10}%
Thulium	Tm	69	2 8 18 31 8 2	1545°	1946°	+3	168.93421	1.23×10^{-10}%
Ytterbium	Yb	70	2 8 18 32 8 2	824°	1194°	+2+3	173.04	8.08×10^{-10}%
Lutetium	Lu	71	2 8 18 32 9 2	1663°	3393°	+3	174.967	1.197×10^{-10}%

‡ Actinides

Element	Symbol	Z	Shells (K L M N O P Q)	M.P.	B.P.	Ox. States	At. Weight	Abundance
Thorium	Th	90	2 8 18 32 18 10 2	1750°	4788°	+4	232.0381	1.09×10^{-10}%
Protactinium	Pa	91	2 8 18 32 20 9 2	1572°		+5+4	231.03588	
Uranium	U	92	2 8 18 32 21 9 2	1135°	4131°	+3+4+5+6	238.0289	2.94×10^{-11}%
Neptunium	Np	93	2 8 18 32 22 9 2	644°		+3+4+5+6	[237]	
Plutonium	Pu	94	2 8 18 32 24 8 2	640°	3228°	+3+4+5+6	[244]	
Americium	Am	95	2 8 18 32 25 8 2	1176°		+3+4+5+6	[243]	
Curium	Cm	96	2 8 18 32 25 9 2	1345°		+3	[247]	
Berkelium	Bk	97	2 8 18 32 27 8 2	1050°		+3+4	[247]	
Californium	Cf	98	2 8 18 32 28 8 2	900°		+3	[251]	
Einsteinium	Es	99	2 8 18 32 29 8 2	860°		+3	[252]	
Fermium	Fm	100	2 8 18 32 30 8 2	1527°		+3	[257]	
Mendelevium	Md	101	2 8 18 32 31 8 2	827°		+2+3	[258]	
Nobelium	No	102	2 8 18 32 32 8 2	827°		+2+3	[259]	
Lawrencium	Lr	103	2 8 18 32 32 9 2	1627°		+3	[260]	

The new IUPAC Group format numbers the groups from 1 to 18. The numbering system used by the Chemical Abstracts Service (CAS) is given in parentheses. For elements that are not naturally abundant, the mass number of the longest-lived isotope is given in brackets. The abundances are based on meteorite and solar wind data. The melting point (M.P.), boiling point (B.P.), and critical point temperatures are given in °Celsius. Sublimation and critical temperatures are indicated by s and t.

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APPENDIX A. PROPERTIES OF THE ELEMENTS

Table 1 lists atomic weights, densities, melting and boiling points, critical points, ionization potentials, specific heats. Data were taken from the 75th edition of the *CRC Handbook of Chemistry and Physics*[1]. Atomic weights apply to elements as they exist naturally on earth, or, in the cases of thorium and protactinium, to the isotopes which have the longest half-lives. Values in parentheses are the mass numbers for the longest lived isotopes of some of the radioactive elements. Specific heats are given for the elements at 25°C. Densities for solids and liquids are given at 25°C, unless otherwise indicated by a superscript temperature (in °C); densities for the gaseous elements are for the liquids at their boiling points.

The solar system elemental abundances (atomic %) in Table 2 are from the compilation of Anders and Grevesse[2], and are based on meteorite and solar wind data. The elemental abundances in the earth's crust and in the sea represent the median values of reported measurements.[1,3,4,5] The concentrations of the less abundant elements may vary with location by several orders of magnitude.

Table 1. Chemical Properties

Z	El	Name	Atomic Weight (a.m.u.)	Density (g/cm^3)	Melting point (°C)	Boiling point (°C)	Critical point (°C)	Ionization potential (eV)	Specific heat (J/g K)
1	H	Hydrogen	1.00794 *7*	0.0708	-259.34	-252.87	-240.18	13.598	14.304
2	He	Helium	4.002602 *2*	0.124901	-272.2	-268.93	-267.96	24.587	5.193
3	Li	Lithium	6.941 *2*	0.534	180.5	1342		5.392	3.582
4	Be	Beryllium	9.012182 *3*	1.85	1287	2471		9.323	1.825
5	B	Boron	10.811 *5*	2.37	2075	4000		8.298	$1.026^{\text{amorphous}}$
6	C	Carbon	12.011 *1*	$2.2670^{15°}$	4492^{t}	3825^{s}		11.260	0.709^{graphite}
7	N	Nitrogen	14.00674 *7*	0.807	-210.00	-195.79	-146.94	14.534	1.040
8	O	Oxygen	15.9994 *3*	1.141	-218.79	-182.95	-118.56	13.618	0.918
9	F	Fluorine	18.9984032 *9*	1.50	-219.62	-188.12	-129.02	17.423	0.824
10	Ne	Neon	20.1797 *6*	1.204	-248.59	-246.08	-228.7	21.565	1.030
11	Na	Sodium	22.989768 *6*	0.97	97.72	883		5.139	1.228
12	Mg	Magnesium	24.3050 *6*	1.74	650	1090		7.646	1.023
13	Al	Aluminum	26.981539 *5*	2.70	660.32	2519		5.986	0.897
14	Si	Silicon	28.0855 *3*	2.3296	1414	3265		8.152	0.705
15	P	Phosphorus	30.973762 *4*	1.82	44.15	277	721	10.487	0.769^{white}
16	S	Sulfur	32.066 *6*	2.067	115.21	444.60	1041	10.360	$0.710^{\text{orthorhombic}}$
17	Cl	Chlorine	35.4527 *9*	1.56	-101.5	-34.04	143.8	12.968	0.479
18	Ar	Argon	39.948 *1*	1.396	-189.35	-185.85	-122.28	15.760	0.520
19	K	Potassium	39.0983 *1*	0.89	63.38	759		4.341	0.757
20	Ca	Calcium	40.078 *4*	1.54	842	1484		6.113	0.647
21	Sc	Scandium	44.955910 *9*	2.99	1541	2830		6.561	0.568
22	Ti	Titanium	47.867 *1*	4.5	1668	3287		6.828	0.523
23	V	Vanadium	50.9415 *1*	6.0	1910	3407		6.746	0.489
24	Cr	Chromium	51.9961 *6*	7.15	1907	2671		6.767	0.449
25	Mn	Manganese	54.93805 *1*	7.3	1246	2061		7.434	0.479
26	Fe	Iron	55.845 *2*	7.875	1538	2861		7.902	0.449
27	Co	Cobalt	58.93320 *1*	8.86	1495	2927		7.881	0.421
28	Ni	Nickel	58.6934 *2*	8.912	1455	2913		7.640	0.444
29	Cu	Copper	63.546 *3*	8.933	1084.62	2562		7.726	0.385

[1] *Handbook of Chemistry and Physics*, 75th edition, D.R. Lide, editor, CRC Press, Boca Raton, FL (1995).

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Z	El	Name	Atomic Weight (a.m.u.)	Density (g/cm^3)	Melting point (°C)	Boiling point (°C)	Critical point (°C)	Ionization potential (eV)	Specific heat (J/g K)
30	Zn	Zinc	65.39 *2*	7.134	419.53	907		9.394	0.388
31	Ga	Gallium	69.723 *1*	5.91	29.76	2204		5.999	0.371
32	Ge	Germanium	72.61 *2*	5.323	938.25	2833		7.900	0.320
33	As	Arsenic	74.92159 *2*	5.776^{26°	817^{t}	614^{s}	1400	9.815	0.329
34	Se	Selenium	78.96 *3*	4.809^{26°	221	685	1493	9.752	0.321
35	Br	Bromine	79.904 *1*	3.11	-7.2	58.8	315	11.814	0.226
36	Kr	Krypton	83.80 *1*	2.418	-157.36	-153.22	-63.74	14.000	0.248
37	Rb	Rubidium	85.4678 *3*	1.53	39.31	688		4.177	0.363
38	Sr	Strontium	87.62 *1*	2.64	777	1382		5.695	0.301
39	Y	Yttrium	88.90585 *2*	4.47	1526	3336		6.217	0.298
40	Zr	Zirconium	91.224 *2*	6.52	1855	4409		6.634	0.278
41	Nb	Niobium	92.90638 *2*	8.57	2477	4744		6.759	0.265
42	Mo	Molybdenum	95.94 *1*	10.2	2623	4639		7.092	0.251
43	Tc	Technetium	[98]	11	2157	4265		7.28	
44	Ru	Ruthenium	101.07 *2*	12.1	2334	4150		7.361	0.238
45	Rh	Rhodium	102.90550 *3*	12.4	1964	3695		7.459	0.243
46	Pd	Palladium	106.42 *1*	12.0	1554.9	2963		8.337	0.244
47	Ag	Silver	107.8682 *2*	10.501	961.78	2162		7.576	0.235
48	Cd	Cadmium	112.411 *8*	8.69	321.07	767		8.994	0.232
49	In	Indium	114.818 *3*	7.31	156.60	2072		5.786	0.233
50	Sn	Tin	118.710 *7*	7.287^{26°	231.93	2602		7.344	0.228^{white}
51	Sb	Antimony	121.760 *1*	6.685^{26°	630.63	1587		8.64	0.207
52	Te	Tellurium	127.60 *3*	6.232	449.51	988		9.010	0.202
53	I	Iodine	126.90447 *3*	4.93^{20°	113.7	184.4	546	10.451	0.145
54	Xe	Xenon	131.29 *2*	2.953	-111.75	-108.04	16.58	12.130	0.158
55	Cs	Cesium	132.90543 *5*	1.93	28.44	671		3.894	0.242
56	Ba	Barium	137.327 *7*	3.62	727	1897		5.212	0.204
57	La	Lanthanum	138.9055 *2*	6.15	920	3455		5.577	0.195
58	Ce	Cerium	140.115 *4*	8.16	799	3424		5.539	0.192
59	Pr	Praseodymium	140.90765 *3*	6.77	931	3510		5.464	0.193
60	Nd	Neodymium	144.24 *3*	7.01	1016	3066		5.525	0.190
61	Pm	Promethium	[145]	7.26	1042	3000		5.55	
62	Sm	Samarium	150.36 *3*	7.52	1072	1790		5.644	0.197
63	Eu	Europium	151.965 *9*	5.24	822	1596		5.670	0.182
64	Gd	Gadolinium	157.25 *3*	7.90	1314	3264		6.150	0.236
65	Tb	Terbium	158.92534 *3*	8.23	1359	3221		5.864	0.182
66	Dy	Dysprosium	162.50 *3*	8.55	1411	2561		5.939	0.173
67	Ho	Holmium	164.93032 *3*	8.80	1472	2694		6.022	0.165
68	Er	Erbium	167.26 *3*	9.07	1529	2862		6.108	0.168
69	Tm	Thulium	168.93421 *3*	9.32	1545	1946		6.184	0.160
70	Yb	Ytterbium	173.04 *3*	6.90	824	1194		6.254	0.155
71	Lu	Lutetium	174.967 *1*	9.84	1663	3393		5.426	0.154
72	Hf	Hafnium	178.49 *2*	13.3	2233	4603		6.825	0.144
73	Ta	Tantalum	180.9479 *1*	16.4	3017	5458		7.89	0.140
74	W	Tungsten	183.84 *1*	19.3	3422	5555		7.98	0.132
75	Re	Rhenium	186.207 *1*	20.8	3186	5596		7.88	0.137
76	Os	Osmium	190.23 *3*	22.5	3033	5012		8.7	0.130
77	Ir	Iridium	192.217 *3*	22.5	2446	4428		9.1	0.131
78	Pt	Platinum	195.08 *3*	21.46	1768.4	3825		9.0	0.133
79	Au	Gold	196.96654 *3*	19.282	1064.18	2856		9.226	0.129
80	Hg	Mercury	200.59 *2*	13.5336	-38.83	356.73	1477	10.438	0.140
81	Tl	Thallium	204.3833 *2*	11.8	304	1473		6.108	0.129
82	Pb	Lead	207.2 *1*	11.342	327.46	1749		7.417	0.129
83	Bi	Bismuth	208.98037 *3*	9.807	271.40	1564		7.289	0.122
84	Po	Polonium	[209]	9.32	254			8.417	
85	At	Astatine	[210]		302				

Z	El	Name	Atomic Weight (a.m.u.)	Density (g/cm^3)	Melting point (°C)	Boiling point (°C)	Critical point (°C)	Ionization potential (eV)	Specific heat (J/g K)
86	Rn	Radon	[222]	4.4	-71	-61.7	104	10.749	0.094
87	Fr	Francium	[223]		27				
88	Ra	Radium	[226]	5	700			5.279	
89	Ac	Actinium	[227]	10.07[a]	1051	3198		5.17	
90	Th	Thorium	232.0381 *1*	11.72	1750	4788		6.08	0.113
91	Pa	Protactinium	231.03588 *2*	15.37[a]	1572			5.89	
92	U	Uranium	238.0289 *1*	≈18.95	1135	4131		6.194	0.116
93	Np	Neptunium	[237]	$20.25^{20°}$	644			6.266	
94	Pu	Plutonium	[244]	19.84	640	3228		6.06	
95	Am	Americium	[243]	$13.69^{20°}$	1176			5.993	
96	Cm	Curium	[247]	13.51[a]	1345			6.02	
97	Bk	Berkelium	[247]	14[b]	1050			6.23	
98	Cf	Californium	[251]		900			6.30	
99	Es	Einsteinium	[252]		860			6.42	
100	Fm	Fermium	[257]		1527			6.50	
101	Md	Mendelevium	[258]		827			6.58	
102	No	Nobelium	[259]		827			6.65	
103	Lr	Lawrencium	[260]		1627				
104	Rf	Rutherfordium	[261]						
105	Ha	Hahnium	[262]						
106	Sg	Seaborgium	[263]						
107	Ns	Nielsbohrium	[264]						
108	Hs	Hassium	[267]						
109	Mt	Meitnerium	[268]						
110	??	Element-110	[271]						
111	??	Element-111	[272]						

[a]Calculated [b]Estimated [t]Critical temperature [s]Sublimation temperature

Table 2. Elemental Abundances

Z	El	Solar System (%)	Abundance in the Earth's	
			Crust (mg/kg)	Sea (mg/L)
1	H	91.0 *23*	1400	1.08×10^{5}
2	He	8.9 *5*	0.008	7×10^{-6}
3	Li	1.86×10^{-7} *17*	20	0.18
4	Be	2.38×10^{-9} *23*	2.8	5.6×10^{-6}
5	B	6.9×10^{-8} *7*	10	4.44
6	C	0.033	200	28
7	N	0.0102	19	0.5
8	O	0.078 *8*	4.61×10^{5}	8.57×10^{5}
9	F	2.7×10^{-6} *4*	585	1.3
10	Ne	0.0112 *16*	0.005	1.2×10^{-4}
11	Na	0.000187 *13*	2.36×10^{4}	1.08×10^{4}
12	Mg	0.00350 *13*	2.33×10^{4}	1290
13	Al	0.000277 *10*	8.23×10^{4}	0.002
14	Si	0.00326 *14*	2.82×10^{5}	2.2
15	P	3.4×10^{-5} *3*	1050	0.06
16	S	0.00168 *22*	350	905
17	Cl	1.7×10^{-5} *3*	145	1.94×10^{4}
18	Ar	0.000329 *20*	3.5	0.45
19	K	1.23×10^{-5} *9*	2.09×10^{4}	399
20	Ca	0.000199 *14*	4.15×10^{4}	412
21	Sc	1.12×10^{-7} *10*	22	6×10^{-7}
22	Ti	7.8×10^{-6} *4*	5650	0.001
23	V	9.6×10^{-7} *5*	120	0.0025
24	Cr	4.4×10^{-5} *3*	102	3×10^{-4}
25	Mn	3.1×10^{-5} *3*	950	2×10^{-4}
26	Fe	0.00294 *8*	5.63×10^{4}	0.002
27	Co	7.3×10^{-6} *5*	25	2×10^{-5}
28	Ni	0.000161 *8*	84	5.6×10^{-4}
29	Cu	1.70×10^{-6} *19*	60	2.5×10^{-4}
30	Zn	4.11×10^{-6} *18*	70	0.0049
31	Ga	1.23×10^{-7} *8*	19	3×10^{-5}
32	Ge	3.9×10^{-7} *4*	1.5	5×10^{-5}
33	As	2.1×10^{-8} *3*	1.8	0.0037
34	Se	2.03×10^{-7} *13*	0.05	2×10^{-4}
35	Br	3.8×10^{-8} *7*	2.4	67.3
36	Kr	1.5×10^{-7} *3*	1×10^{-4}	2.1×10^{-4}
37	Rb	2.31×10^{-8} *15*	90	0.12
38	Sr	7.7×10^{-8} *6*	370	7.9
39	Y	1.51×10^{-8} *9*	33	1.3×10^{-5}
40	Zr	3.72×10^{-8} *24*	165	3×10^{-5}
41	Nb	2.28×10^{-9} *3*	20	1×10^{-5}
42	Mo	8.3×10^{-9} *5*	1.2	0.01
43	Tc			
44	Ru	6.1×10^{-9} *3*	0.001	7×10^{-7}
45	Rh	1.12×10^{-9} *9*	0.001	
46	Pd	4.5×10^{-9} *3*	0.015	
47	Ag	1.58×10^{-9} *5*	0.075	4×10^{-5}
48	Cd	5.3×10^{-9} *3*	0.15	1.1×10^{-4}
49	In	6.0×10^{-10} *4*	0.25	0.02
50	Sn	1.25×10^{-8} *12*	2.3	4×10^{-6}
51	Sb	1.01×10^{-9} *18*	0.2	2.4×10^{-4}
52	Te	1.57×10^{-8} *16*	0.001	
53	I	2.9×10^{-9} *6*	0.45	0.06
54	Xe	1.5×10^{-8} *3*	3×10^{-5}	5×10^{-5}
55	Cs	1.21×10^{-9} *7*	3	3×10^{-4}
56	Ba	1.46×10^{-8} *9*	425	0.013
57	La	1.45×10^{-9} *3*	39	3.4×10^{-6}
58	Ce	3.70×10^{-9} *6*	66.5	1.2×10^{-6}
59	Pr	5.44×10^{-10} *13*	9.2	6.4×10^{-7}
60	Nd	2.70×10^{-9} *4*	41.5	2.8×10^{-6}
61	Pm			
62	Sm	8.42×10^{-10} *11*	7.05	4.5×10^{-7}
63	Eu	3.17×10^{-10} *5*	2.0	1.3×10^{-7}
64	Gd	1.076×10^{-9} *15*	6.2	7×10^{-7}
65	Tb	1.97×10^{-10} *4*	1.2	1.4×10^{-7}
66	Dy	1.286×10^{-9} *18*	5.2	9.1×10^{-7}
67	Ho	2.90×10^{-10} *7*	1.3	2.2×10^{-7}
68	Er	8.18×10^{-10} *11*	3.5	8.7×10^{-7}
69	Tm	1.23×10^{-10} *3*	0.52	1.7×10^{-7}
70	Yb	8.08×10^{-10} *13*	3.2	8.2×10^{-7}
71	Lu	1.197×10^{-10} *16*	0.8	1.5×10^{-7}
72	Hf	5.02×10^{-10} *10*	3.0	7×10^{-6}
73	Ta	6.75×10^{-11} *12*	2.0	2×10^{-6}
74	W	4.34×10^{-10} *22*	1.25	1×10^{-4}
75	Re	1.69×10^{-10} *16*	7×10^{-4}	4×10^{-6}
76	Os	2.20×10^{-9} *14*	0.0015	
77	Ir	2.16×10^{-9} *13*	0.001	
78	Pt	4.4×10^{-9} *3*	0.005	
79	Au	6.1×10^{-10} *9*	0.004	4×10^{-6}
80	Hg	1.11×10^{-9} *13*	0.085	3×10^{-5}
81	Tl	6.0×10^{-10} *6*	0.85	1.9×10^{-5}
82	Pb	1.03×10^{-8} *8*	14	3×10^{-5}
83	Bi	4.7×10^{-10} *4*	0.0085	2×10^{-5}
84	Po		2×10^{-10}	1.5×10^{-14}
85	At			
86	Rn		4×10^{-13}	6×10^{-16}
87	Fr			
88	Ra		9×10^{-7}	8.9×10^{-11}
89	Ac		5.5×10^{-10}	
90	Th	1.09×10^{-10} *6*	9.6	1×10^{-6}
91	Pa		1.4×10^{-6}	5×10^{-11}
92	U	2.94×10^{-11} *25*	2.7	0.0032

APPENDIX B. PHYSICAL CONSTANTS[1,2,3]

Quantity	Symbol, equation	Value	Uncert. (ppm)
speed of light in vacuum[4]	c	$2.997\,924\,58\times10^{10}$ cm s^{-1}	0
Planck constant	h	$6.626\,075\,5(40)\times10^{-27}$ erg s	0.60
Planck constant, reduced	$\hbar = h/2\pi$	$1.054\,572\,66(63)\times10^{-27}$ erg s	0.60
		$= 6.582\,122\,0(20)\times10^{-22}$ MeV s	0.30
electron charge magnitude	e	$4.803\,206\,8(15)\times10^{-10}$ esu	0.30
		$= 1.602\,177\,33(49)\times10^{-19}$ coulomb	0.30
conversion constant	$\hbar c$	197.327 053(59) MeV fm	0.30
conversion constant	$(\hbar c)^2$	0.389 379 66(23) GeV^2 mbarn	0.59
electron mass	m_e	0.510 999 06(15) MeV/c^2 = $9.109\,389\,7(54)\times10^{-28}$ g	0.30, 0.59
proton mass	m_p	938.272 31(28) MeV/c^2 = $1.672\,623\,1(10)\times10^{-24}$ g	0.30, 0.59
neutron mass	m_n	939.565 63(28) MeV/c^2 = $1.674\,928\,6(10)\times10^{-24}$ g	0.30, 0.59
		= 1.008 664 904(14) amu	0.014
deuteron mass	m_d	1875.613 39(57) MeV/c^2	0.30
atomic mass unit (amu)	(mass C^{12} atom)/12 = (1 g)/N_A	931.494 32(28) MeV/c^2 = $1.660\,540\,2(10)\times10^{-24}$ g	0.30, 0.59
electron charge to mass ratio	e/m_e	$5.272\,808\,6(16)\times10^{17}$ esu g^{-1}	0.30
		$= 1.758\,819\,62(53)\times10^{8}$ coulomb g^{-1}	0.30
quantum of magnetic flux	h/e	$4.135\,669\,2(12)\times10^{-15}$ joule s coulomb^{-1}	0.30
Josephson frequency-voltage ratio	$2e/h$	$4.835\,976\,7(14)\times10^{14}$ cycles s^{-1} v^{-1}	0.30
Faraday constant	F	$9.648\,530\,9(29)\times10^{4}$ coulomb mol^{-1}	0.30
fine-structure constant	$\alpha = e^2/\hbar c$	1/137.035 989 5(61)	0.045
classical electron radius	$r_e = e^2/m_e c^2$	2.817 940 92(38) fm	0.13
electron Compton wavelength	$\lambda_e = \hbar/m_e c = r_e\,\alpha^{-1}$	$3.861\,593\,23(35)\times10^{-11}$ cm	0.089
proton Compton wavelength	$\lambda_p = \hbar/m_p c$	$2.103\,089\,37(19)\times10^{-14}$ cm	0.089
neutron Compton wavelength	$\lambda_n = \hbar/m_n c$	$2.100\,194\,45(19)\times10^{-14}$ cm	0.089
Bohr radius ($m_{nucleus} = \infty$)	$\alpha_\infty = \hbar^2/m_e e^2 = r_e\,\alpha^{-2}$	$0.529\,177\,249(24)\times10^{-8}$ cm	0.045
Rydberg energy	$hcR_\infty = m_e e^4/2\hbar^2 = m_e c^2\alpha^2/2$	13.605 698 1(40) eV	0.30
Thomson cross section	$\sigma_T = 8\pi r_e^2/3$	0.665 246 16(18) barn	0.27
Bohr magneton	$\mu_B = e\hbar/2m_e c$	$5.788\,382\,63(52)\times10^{-15}$ MeV gauss^{-1}	0.089
nuclear magneton	$\mu_N = e\hbar/2m_p c$	$3.152\,451\,66(28)\times10^{-18}$ MeV gauss^{-1}	0.089
electron cyclotron frequency/field	$\omega^e_{cycl}/B = e/m_e c$	$1.758\,819\,62(53)\times10^{7}$ radian s^{-1} gauss^{-1}	0.30
proton cyclotron frequency/field	$\omega^p_{cycl}/B = e/m_p c$	$9.578\,830\,9(29)\times10^{3}$ radian s^{-1} gauss^{-1}	0.30
gravitational constant	G_N	$6.672\,59(85)\times10^{-8}$ cm^{3}g^{-1} s^{-2}	128
grav. acceleration, sea level, 45° lat.	g	980.665 cm s^{-2}	0
Fermi coupling constant	$G_F/(\hbar c)^3$	$1.166\,39(2)\times10^{-5}$ GeV^{-2}	20
Avogadro number	N_A	$6.022\,136\,7(36)\times10^{23}$ mol^{-1}	0.59
molar gas constant, ideal gas at STP	R	$8.314\,510(70)\times10^{7}$ erg mol^{-1} K^{-1}	8.4
Boltzmann constant	k	$1.380\,658(12)\times10^{-16}$ erg K^{-1}	8.5
		$= 8.617\,385(73)\times10^{-5}$ eV K^{-1}	8.4
molar volume, ideal gas at STP	$N_A k$(273.15 K)/(atmosphere)	22 414.10(19) cm^3 mol^{-1}	8.4
Stefan-Boltzmann constant	$\sigma = \pi^2 k^4/60\hbar^3 c^2$	$5.670\,51(19)\times10^{-5}$ erg s^{-1} cm^{-2} K^{-4}	34
first radiation constant	$2\pi hc^2$	$3.741\,774\,9(22)\times10^{-5}$ erg cm^2 s^{-1}	0.60
second radiation constant	hc/k	1.438 769(12) cm K	8.4

[1]E.R. Cohen and B.N. Taylor, *Rev. Mod. Phys.* **59**, 1121 (1987).

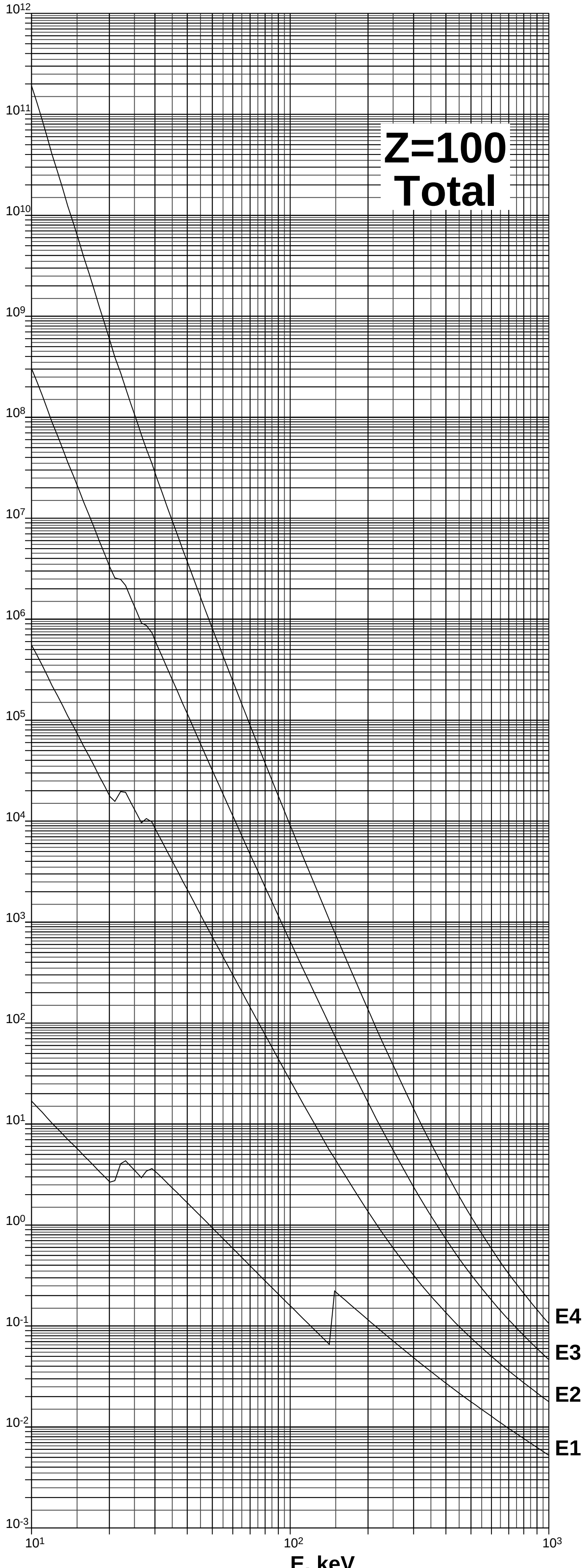
[2]B.N. Taylor and E.R. Cohen, *J. Res. Natl. Inst. Stand. Technol.* **95**, 497 (1990).

[3]E.R. Cohen and B.N. Taylor, *Phys. Today*, **46**(8) Part 2, BG9 (1993).

[4]Defined at the Conférence Générale des Poids et Mesures, October, 1983.

Physical Constants (continued)

Useful constants and conversion factors	
π= 3.141 592 653 589 793 238	1 coulomb = 2.997 924 58$\times10^{9}$ esu
e = 2.718 281 828 459 045 235	1 tesla = 10^{4} gauss
γ = 0.577 215 664 901 532 861	1 atm. = 1.013 25$\times10^{6}$ dyne/cm^{2}
1 in = 2.54 cm	0° C = 273.15 K
1 Å = 10^{-8} cm	1 sidereal year = 3.155 814 98$\times10^{7}$ s
1 fm = 10^{-13} cm	1 tropical year 3.155 692 52$\times10^{7}$ s
1 barn = 10^{-24} cm^{2}	1 light year = 9.460 528$\times10^{17}$ cm
1 newton = 10^{5} dyne	1 parsec = 3.261 633 light year
1 joule = 10^{7} erg	1 astro. unit = 1.495 978 706 6(2)$\times10^{13}$ cm
1 eV = 1.602 177 33(49)$\times10^{-12}$ erg	1 curie = 3.7$\times10^{10}$ disintegration /s
1 eV/c^{2} = 1.782 662 70(54)$\times10^{-33}$ g	1 rad = 100 erg/ g of tissue
1 cal = 4.184 joule	1 roentgen = 1 esu/ 0.001293 g of air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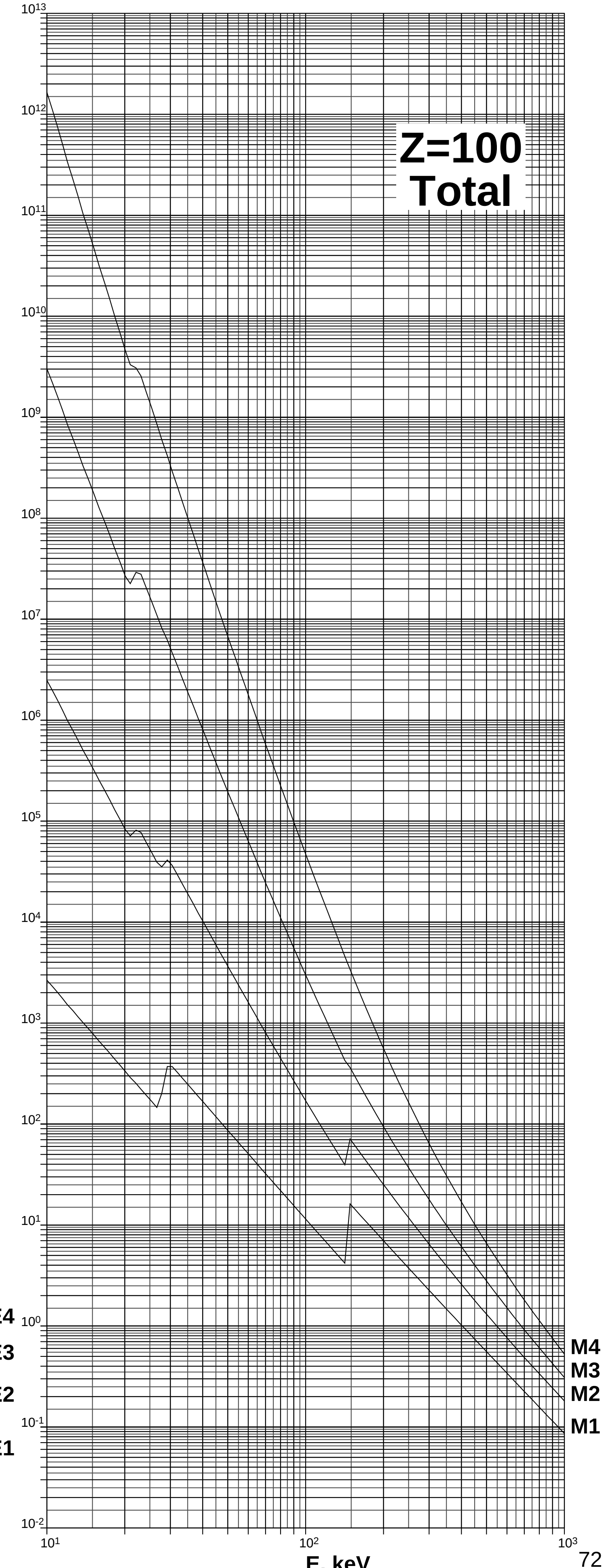
E3
E2
E1
E, keV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M4
M3
M2
M1
E, keV

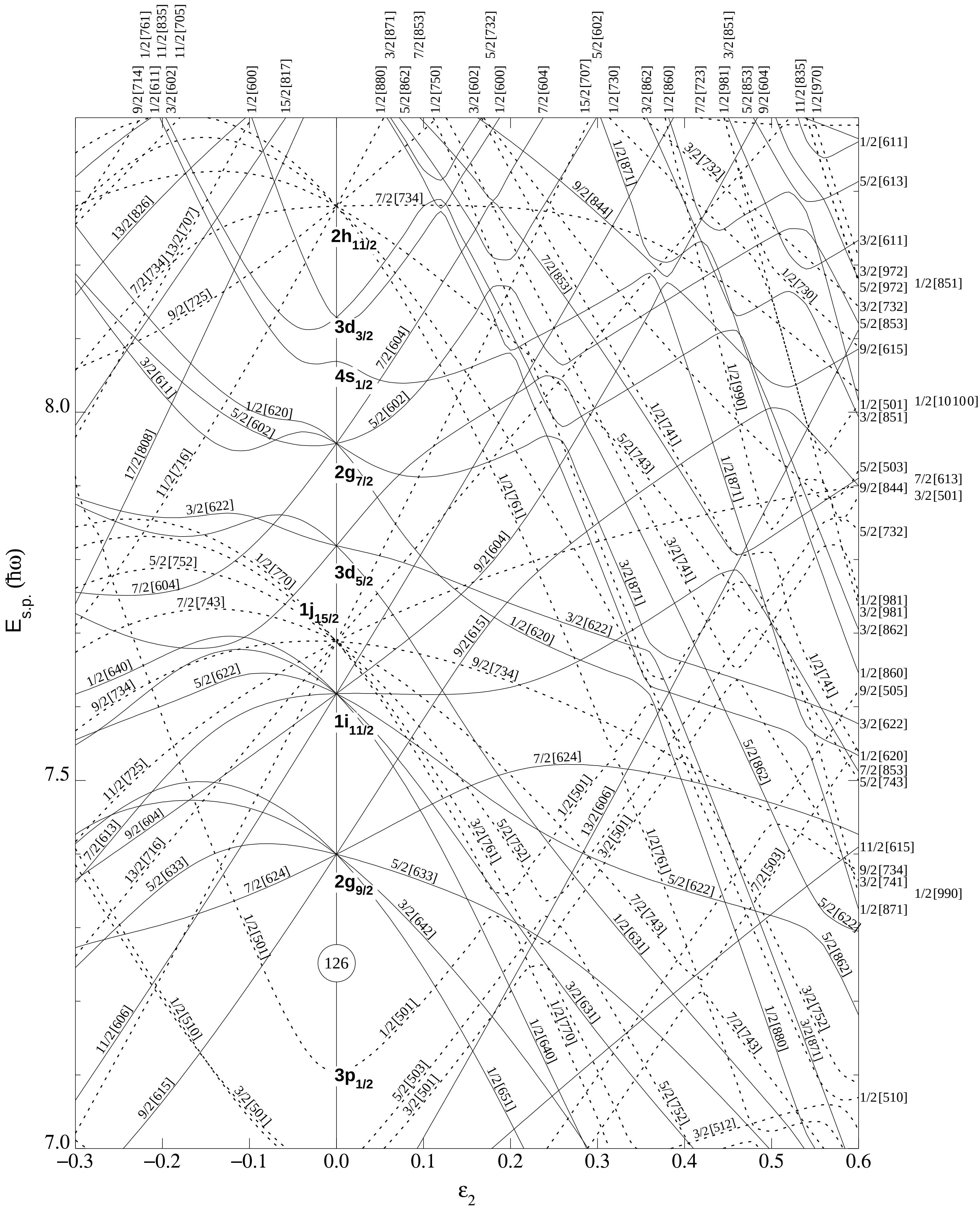

Figure 9. Nilsson diagram for neutrons, N ≥ 126 ($\varepsilon_4 = \varepsilon_2^2/6$).

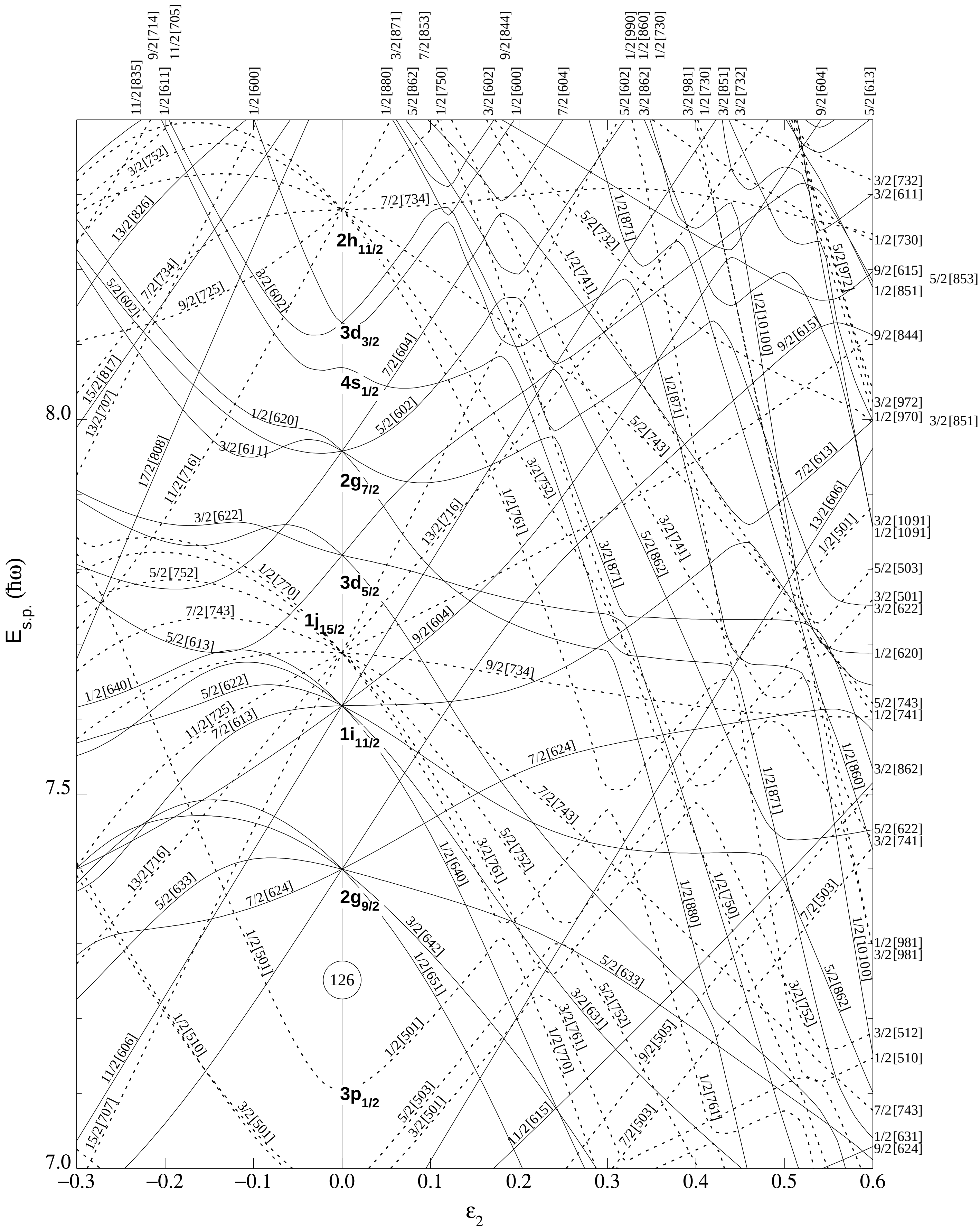

Figure 10. Nilsson diagram for neutrons, N ≥ 126 ($\varepsilon_4 = -\varepsilon_2^2/6$).

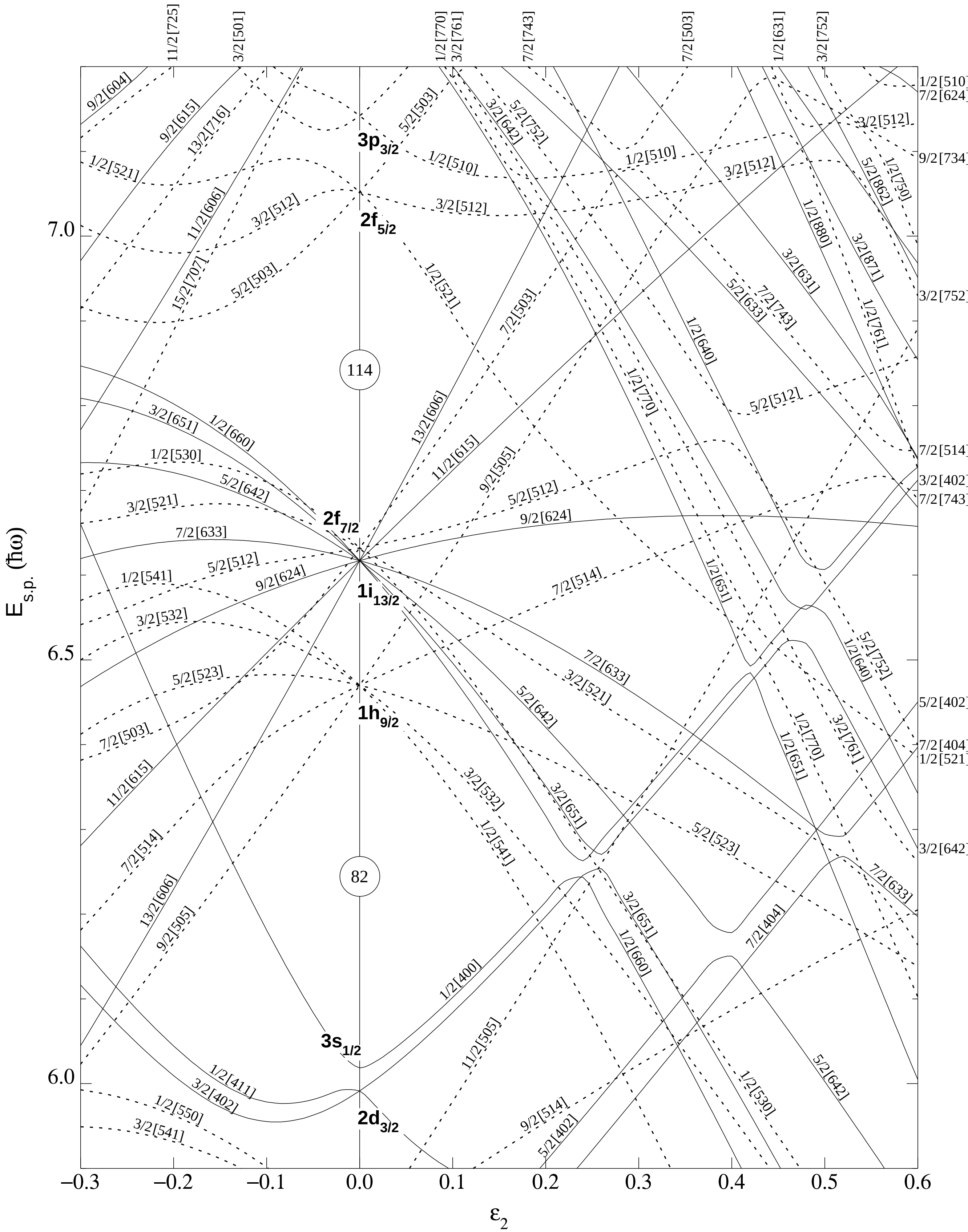

Figure 13. Nilsson diagram for protons, Z ≥ 82 ($\varepsilon_4 = \varepsilon_2^2/6$).

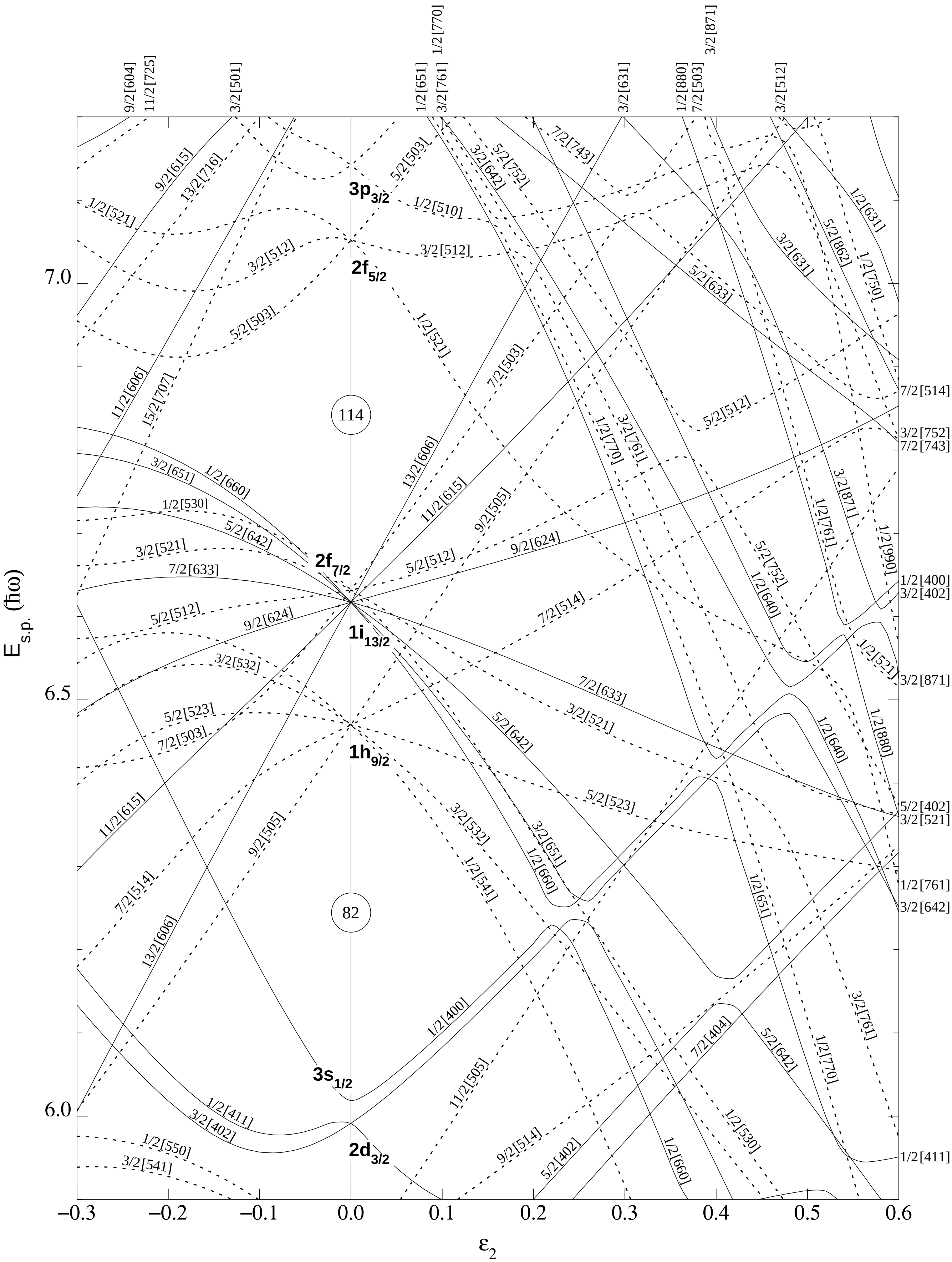

Figure 14. Nilsson diagram for protons, Z ≥ 82 ($\varepsilon_4 = -\varepsilon_2^2/6$).