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UNITED STATES DEPARTMENT OF COMMERCE, Charles Sawyer, Secretary
NATIONAL BUREAU OF STANDARDS, E. U. Condon, Director

NUCLEAR DATA

A Collection of Experimental Values of Half-lives, Radiation Energies,
Relative Isotopic Abundances, Nuclear Moments, and Cross Sections

Compiled by
National Bureau of Standards Nuclear Data Group
Katharine Way, Lilla Fano, Millicent R. Scott, and Karin Thew

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with assistance from
Information Division, Brookhaven National Laboratory
Chemistry Division, University of California Radiation Laboratory
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Foreword

During the last decade identification and description of members of the nuclear population and determination of the characteristics of their society has proceeded at a continually accelerating pace. At the present moment the nuclear population numbers approximately 1,200 and is still growing. Knowledge of individual characteristics and of the laws of social behavior as reported in some 40 journals representing the work of dozens of laboratories is growing at an even more rapid rate.

The nuclear population is now so great and the sources of information so diverse that the active research worker in the field is in serious need of a periodic census to keep abreast of developments and guide his efforts into productive, nonduplicating investigation. In this year of our great decennial census, it seems only fitting that we should also enumerate and carefully describe the nuclear population.

This compilation of nuclear data is such a census. It is not the first. A number of careful compilations have appeared in the past and have proven their value. Although the increase in population and information indicates the desirability of a new count, this new compilation is based upon its predecessors as a firm foundation. But even this new census is not complete and exact. In common with any dynamic society, the nuclear population changes during the compilation. As the complexity of the society becomes more apparent, needs for further information are indicated. Any good census will clearly delineate this need and herein perhaps lies its major scientific value.

It therefore becomes a matter of judgment and arbitrary decision to select a cut-off date and say, "Enough is available to go ahead. We will proceed without awaiting further developments." The cut-off date has been set at January 1, 1950, although where possible some 1950 information has been included. To take account of subsequent developments, the format of the presentation has been selected to allow incorporation of new information which will be issued periodically as supplements.

To make the census useful as a generator of new investigations and as a critique of the validity of existing reports similar information from different sources is presented. This information is often conflicting but no attempt has been made to select "best values." On the contrary, discrepancies are emphasized and pointed up so that they may serve as a stimulus for new work.

The compilers are quite conscious of inconsistencies and possible errors and omissions in the table. Its weaknesses and shortcomings will promptly become evident to many active workers who are urged and invited to contribute to future improvements. The compilers hope that, with criticism, suggestions, and information regarding errors from many sources, they will be able to produce subsequent editions which will better fill the needs of all workers in the nuclear field.

Grateful acknowledgment of the help of many scientists who have already given freely of their time is made below. Direct financial assistance from the Atomic Energy Commission has made possible the great amount of work necessary to bring the compilation to its present state.

WASHINGTON, D. C., May 1950.

E. U. CONDON, *Director*.

Preface

The Nuclear Data Group of the National Bureau of Standards has had the most generous assistance from many groups and individuals in collecting the data presented here, in checking them, and in planning the method of presentation. The Bureau group assumes, of course, the final responsibility for the accuracy of the material and for its editing, but it would like to make grateful acknowledgment of the invaluable assistance which it has received.

Both the Oak Ridge National Laboratory and the Brookhaven National Laboratory supported the nuclear data work from the beginning. A. M. Weinberg at Oak Ridge reorganized the Nuclear Data Committee there and made possible an integration of its current data collection program with the work of compilation undertaken at the Bureau.

Early plans for new nuclear tables were discussed at length with H. H. Goldsmith of the Information Division of the Brookhaven National Laboratory. Dr. Goldsmith immediately listed the interest of Gerhart Friedlander of the Brookhaven Chemistry Division and the group spent a great deal of time in helping to map out the work as a whole and in collecting and viewing the data for a number of elements. Dr. Friedlander continued his help after the untimely death of Dr. Goldsmith and gave a meticulous check to Bureau work on regions of the periodic table with which he is especially familiar.

The Brookhaven Information Division encouraged other work in data collection and analysis by members of the Brookhaven Laboratory with the resultant preparation of reports* by H. L. Poss, D. E. Alburger and E. M. Hafner, and W. F. Hornyak. These reports have been of the greatest help to the compilers of the present table. Ways in which they have been used are discussed in detail in the section of explanation.

Dr. Hornyak gave a good deal of thought to possible ways for presenting all the data for the light nuclei in the present compilation. It was finally decided, however, to limit the material used, at least in this edition, to the radioactivity data and the bare level diagrams. The latter were kindly supplied by Dr. Hornyak from the data available in March 1950. Detailed discussion of the nuclear information furnished by light nuclei reactions has been given in previous summaries* of Lauritsen and Hornyak and will be extended and brought up to date in a forthcoming review paper* by Hornyak, Lauritsen, and Morrison. It is hoped that in the future ways of presenting this material in some convenient tabular form will be devised.

Members of the Nuclear Chemistry Group of the Laboratory for Nuclear Science and Engineering of the Massachusetts Institute of Technology very kindly cross-checked with the Bureau staff the data on the fission products. Professor Coryell of this group, an editor of Volume 9, Division IV, of the National Nuclear Energy Series, which will contain Manhattan Project papers on fission product work, made it possible for the Bureau group to give references to papers in this volume rather than to old and generally unavailable Metallurgical Laboratory reports. Those to whom the Bureau group is particularly indebted in addition to Professor Coryell are Ronald A. Brightsen, and Arthur Y. Sakakura.

Several of the chemists at the University of California Radiation Laboratory went over most of the data on the artificially produced heavy nuclei with a member of the Bureau staff and later sent lists of their most recent results. Special thanks are due to I. Perlman, G. T. Seaborg, E. K. Hyde, A. Ghiorso, and D. H. Templeton.

*Complete reference is given in the list of other compilations.

In its search for the older data the Bureau group has made extensive use of a number of other tables and compilations. These are listed on a separate page at the beginning of the reference section. In the work of collecting nuclear data reported since January 1949, the Bureau staff has had the assistance of two groups, the Nuclear Data Committee of the Oak Ridge National Laboratory already mentioned, which has sent in unclassified or declassified items appearing in AEC reports, and the National Bureau of Standards Nuclear Data Readers who have abstracted papers in the open literature. The members of the first group are Herbert Pomerance, chairman, N. M. Dismuke, F. K. McGowan, O. E. Myers, R. W. Stoughton, and H. Zeldes, all of the Oak Ridge National Laboratory. The members of the second group are U. Fano, National Bureau of Standards; W. Faust, Naval Research Laboratory; R. D. Huntoon, National Bureau of Standards; W. Koski, The Johns Hopkins University; F. N. D. Kurie, Naval Research Laboratory; W. B. Mann, British Embassy; G. G. Manov, Atomic Energy Commission, Isotopes Division; G. Plass, The Johns Hopkins University; J. S. Smart, Naval Ordnance Laboratory; and J. H. Sreb, Naval Research Laboratory.

An advisory panel serving at the request of Dr. Condon has given generous assistance to the Bureau staff on general problems connected with the scope of the work and methods of presentation. Members of the panel are Charles D. Coryell and Martin Deutsch, Massachusetts Institute of Technology; Louis Hempleman, Massachusetts General Hospital; Maria Goeppert Mayer, University of Chicago; Harvey Brooks, Knolls Atomic Power Laboratory; and Eugene P. Wigner, Princeton University.

Other physicists and chemists who have given particular help include G. Scharff-Goldhaber and M. Goldhaber of the University of Illinois, J. J. Howland of Brookhaven National Laboratory, G. E. Boyd and B. H. Ketelle of the Oak Ridge National Laboratory, and J. R. Stehn of the Knolls Atomic Power Laboratory.

The Nuclear Data Group is much indebted to the Bureau librarians for cheerful assistance and to many Bureau colleagues for helpful discussions. In the jobs of compiling and checking it has had important temporary help from Edith Haggstrom Nagel, Irma Wachtel, Miriam Dodson, and Abraham Schwebel.

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EXPLANATION OF TABLE

1. General

In the following table an attempt has been made to list the more recent, measured values of some of the nuclear constants. The philosophy behind the compilation has been that it should be primarily a tool for active workers in the field of nuclear physics rather than a list of "best values." Therefore, several values for each quantity have been included when available, so that the extent of agreement is at once apparent and discrepancies which call for further experiment are emphasized.

Older results are left out when there are a number of newer ones all in fair agreement, but an attempt was made to give enough references in one way or another so that all the older work can easily be found either directly or through the references given in the papers cited.

In general, results are reported as given by the original experimenters. In cases where corrections have been suggested by later writers the corrected value is listed and the reference to the original work is followed by a reference in parentheses to the later paper. As a general rule significant figures have been kept until they are in doubt by ten or more according to the judgment of the experimenter.

Question marks placed after specific values and followed by a reference indicate doubt on the part of the experimenters as to the validity of the result. Question marks in place of charge or mass numbers in the headings for the boxes are used to call attention to the fact that there is very little evidence for the assignment given. When

placed after level values they indicate that the evidence for the level is inconclusive or open to more than one interpretation.

References. The reference keys are usually of the type 48H11. The first two numbers indicate the year of publication of the paper. The following capital letter is the first letter of the surname of the senior author and the following numbers merely serial. When other compilations are given as references, special keys are used consisting entirely of letters after the figures for the year; e. g., 48HL. These special keys are included in the reference list before the usual listings. For example, 48HL is to be found just ahead of 48H1. There is also a list of compilations with their respective keys just ahead of the main reference list.

A number of keys have lower case rather than capital letters for the author's name; e. g., 50k2. These special designations are used for papers to appear in 1950 in Volume 9 of the National Nuclear Energy Series on the fission products. The work they describe was done during the war mainly at the Metallurgical Laboratory at the University of Chicago and until the publication of this volume will have been reported only in project documents which are generally unavailable.

No such special keys have been used for the papers collected in Volumes 14B and 17B of the National Nuclear Energy Series. This is the case because the listings in the Seaborg-Perlman* table made it possible to refer

*Complete reference is given in the list of other compilations.

to papers in both of these volumes in advance of their publication. In such instances the year appearing in the Seaborg-Perlman reference is the year appearing in the key unless the paper in question has also appeared in the Physical Review in which case the year of publication there is used.

Decay Schemes.—Decay schemes have been drawn whenever the data on radioactivity are sufficiently self-consistent. Conventions adopted are:

- Full single arrow slanting to the right for β^- emission ↘
- Full single arrow slanting to the left for β^+ emission ↙
- Dashed single arrow slanting to the left for decay by electron capture ↙
- Full double arrow slanting to the left for α emission ↙
- Wiggly vertical arrow for γ emission ↓

Spin values have been attached to levels when they have been measured directly. Where there is indirect evidence for spin values from studies of angular correlation or gamma ray conversion coefficients, this evidence is noted below the decay scheme.

Very Light Nuclei, $Z=0-10$. The data for the very light nuclei are treated as elsewhere in the table with the exception of data relating to energy levels. Energy level values are listed or shown in diagrams, but the nuclear reaction data which support the level values are not reported in detail. Reference is made instead to summary articles and reviews of Hornyak and Lauritsen (48HL), Lauritsen (48Lau), and Hornyak, Lauritsen, and Morrison (50HLM) which contain comparisons and discussions of the data and pertinent references to the original literature. As mentioned before Dr. W. F. Hornyak has given considerable thought to ways of organizing the data for very light nuclei in tabular form. Some work along lines suggested by him was started, but the job proved to be so big that its completion would have delayed the appearance of this table for some months. It was therefore temporarily abandoned. The energy level values given here are those considered best by Dr. Hornyak in March 1950, and were very kindly communicated by him in advance of their publication elsewhere.

Mass values have not been included. A new set of masses for nuclei through A^{41} is given in the *Isotopic Report* of Mattauch and Flammersfeld* but the details of the calculations have not yet been published. An older set of values is included in Bethe's *Elementary Nuclear Theory*.*

Light Nuclei, $Z=10-20$. Information about the energy levels of nuclei with charge between 10 and 20 has been carefully organized by D. E. Alburger and E. M. Hafner (49AH). Their selection of level values has been used

extensively in the present compilation. Such use is indicated by placing the reference key 49AH on the line marked "Levels." In the $Z=10-20$ region, however, direct reference is made to the original literature on nuclear reactions, either under methods of production or under resonances. Q values and thresholds are given when measured.

Fission Products. The special keys, such as 50k2, which are used for a number of references in this region have been explained in the section headed References.

Under the methods of production the designation "Fission" means that the nucleus in question has been identified as the fission product of some heavy nucleus. No attempt has been made to distinguish between different kinds of fission, since in this compilation methods of production are given primarily to help in making mass assignments. Most of the direct references are to studies of the fission of U^{235} . When the Seaborg-Perlman table lists other modes of fission as methods of production, this fact is noted by including the reference key for that table, 48SP. Reference is also made to papers on the fission of other heavy nuclei which have appeared since the Seaborg-Perlman table was published. Fission yields have not been given. It is now known that the yield depends not only on the identity of the fissioning nucleus but also on its excitation energy. The yield curve for the slow neutron fission of U^{235} is readily available in the Plutonium Project Report, Nuclei Formed in Fission (46PP).

Very Heavy Nuclei. When observed, α activity has been indicated in about the middle of the data box for both β stable and β active nuclei. In cases of β - α branching, percentages given to the left of the α energies are percentages of disintegrations in which the α 's in question have been found; those to the right are percentages of the total number of α particles.

For data on new, artificially produced nuclei of very heavy elements the compilers are much indebted to the Seaborg-Perlman group at the University of California Radiation Laboratory. An effort was made to tabulate all the important results for the naturally occurring radioactivities but it is realized that a complete coverage has not been made of the voluminous literature in this field. It is hoped that those who have made detailed studies will point out important omissions so that a better job can be done in a revised edition. References have been omitted for the well known genetic relationships in the naturally occurring families. Neutron cross sections have been omitted for elements heavier than bismuth.

Isomerism. When an excited state of a particular nucleus has a half-life of more than one second, it is treated as a distinct radioactive species and given a separate box just to the left of the box containing the proper-

*Complete reference is given in the list of other compilations.

ties of the ground state. Both boxes have a common heading zA_N . If both isomers are active the two half-lives are indicated in the usual place and are designated as τ_1 and τ_2 . In cases of triple isomerism the treatment is similar.

When the half-life of an upper state is less than one second, this half-life is indicated on the decay scheme and is listed again in connection with the γ -ray whose delay has been noted.

2. Neutron Cross Sections for Natural Elements

Absorption, scattering, and total cross sections have been measured for a number of elements which in many cases consist of several stable isotopes. Such cross sections are listed in the first box under each element. Even when an element has only one stable isotope, the above cross sections are given first for the sake of uniformity. Cross sections which have been assigned to a certain isotope from activation results or other measurements are always listed under that particular isotope. Therefore in the case of monoisotopic elements, such as Al, both the box for the 'natural element' and the box for Al^{27} should be consulted for complete cross section information.

An attempt has been made to list all measurements of cross sections which have been made as a function of neutron energy and for which cross section graphs are available. It did not seem feasible, however, to list all measured neutron cross section values. A fairly comprehensive job of this kind was done in 1947 and revised in 1948 by K. Way and G. Haines, 48WH. The policy here has been to list those values in 48WH which seem to be the most reliable and to add any more recent results. Occasionally an averaged value from several measurements listed in 48WH is given. The reference key for such a value is (48WH). The cooperation of several experimenters has also made it possible to include a number of values which are still unpublished or are contained only in Atomic Energy Commission reports. More detailed mention of such results is made in the following paragraphs.

σ_c , Coh and σ_s , Bound, Coherent and Bound Scattering Cross Sections. The values listed for these scattering cross sections are all from the recent neutron diffraction work of C. G. Shull and E. O. Wollan of the Oak Ridge National Laboratory, who very kindly supplied a list of their results. The experimental methods used are described in detail in two papers listed under the reference 49S12. Definitions of the terms will be found in the explanations for the abbreviations used in this table as well as in the papers just mentioned. The monochromatic neutrons employed had a wave length of 1.057 Å ($E_n \sim 0.08$ ev) but since these cross sections are believed to be practically independent of neutron energy in the

low energy region, no neutron energy value is associated with them. The values for σ_s bound are not all derived from new work but represent the best values according to Shull and Wollan for these quantities in the light of all results.

σ_a , Absorption Cross Section. For the most part the values given for the absorption cross sections are from the results of oscillator measurements made at the Oak Ridge pile by H. S. Pomerance and co-workers (49P3) and at the Argonne pile by S. P. Harris and his collaborators (49H2). The Oak Ridge workers measured periodic fluctuations in neutron density in the pile shield caused by the oscillating motion of an absorbing sample. The measurements were made relative to gold whose absorption cross section at 0.025 ev was taken as 95 barns. Values at 0.025 ev were calculated assuming a $1/v$ dependence.

The Argonne results are not directly comparable to the Oak Ridge values and strictly speaking should not have been listed under neutron energies of 0.025 ev. They are oscillator values for pile neutrons and consist of the values at 0.025 ev plus a small amount of the resonance integral. The apparatus was calibrated using 710 barns as the absorption value for boron at a neutron energy of 0.025 ev.

σ_s , Scattering Cross Section. The values listed here are those found from direct measurement of this quantity. Additional light on the best value of σ_s will be found from the value for σ_s bound or analysis of the total neutron cross section curves.

σ_t , Total Cross Section. The total (absorption plus scattering) cross section is measured by transmission methods. Since transmission curves are now available for most elements, the values for $E_n = 0.025$ ev have been read off the graphs.

Resonances. Information on neutron resonances is given when available in terms of the Breit-Wigner constants σ_0 , E_0 , and Γ . These symbols are defined in the list of abbreviations. Where assignment of a resonance to a particular isotope has been made this fact is indicated. However, the value of σ_0 given is that found for the natural element.

Fast Neutron σ 's. When available a value of σ_t for some neutron energy of the order of 1 Mev or more is listed chiefly for purposes of orientation. Other values will be found from the graphs listed or in 48WH.

Graphs Available. Cross section graphs have been listed even if two or more happen to cover the same neutron energy region since they often include different results. A new attempt to synthesize all cross section data capable of being plotted has been made by R. K. Adair (50Ad), who very kindly supplied advance copies of his drawings. Since his report is still unpublished the best plan seemed to be to refer to the older papers as well as this forthcoming one.

3. β and γ Stable Nuclei

z_A		
	Relative Abundance in %	Reference
I (Spin in units of $\hbar$)		Reference
μ (Magnetic moment in nuclear magnetons)		Reference
q (Electric quadrupole moment in barns)		Reference
Energy levels in Mev from	β decay	Reaction
Reactions which show resonances in which z_A is the compound nucleus		
σ 's		
Cross sections in barns or millibarns (mb)		Reference
Methods of production when these give information about levels or binding energies		Reference

β and γ Stability. A heavy black line at the top of a box denotes stability against β decay to a different nucleus and against γ decay to a lower state of the same nucleus. Doubtful cases have been marked with dashed lines. In the region of natural α activity assignments of β stability have been made in accordance with the rules which apply in other regions of the periodic table and the most stable charge numbers Z_A . The values for Z_A have been taken from the stability line of the Sullivan chart.* A discussion of other possibilities is given by S. Nordstrom and by Perlman, Ghiorso, and Seaborg in recent papers.**

Relative Abundances. When variations in relative abundances have been observed in materials from different sources, a note of the fact is made and reference given to papers in which measurements of the variations are reported.

Nuclear Moments. For values of the nuclear moments, the present compilers have leaned very heavily on the recent collection of H. L. Poss (49Po). Poss's values of the magnetic and electric quadrupole moments which were calculated from the original data in a uniform way have been given with the reference 49Po whenever available. On the following lines the experimental methods used are listed by means of abbreviations, and literature references to the experimental work are given. In the case of only

one experimental value the experimental reference is given first followed by 49Po in parentheses. Poss's values are based on a proton moment of 2.7934 nuclear magnetons.

Energy Levels An attempt has been made to list under each nucleus the energy levels of that nucleus which can be deduced from the α , β , or γ decay of a parent or from resonances or particle groups in nuclear reactions. In the first case the parent nucleus is given in the usual place for a reference, and further information will be found under that nucleus. In the second case the reaction is given as a reference. Literature references are given just below the list of levels when the nucleus in question is the compound nucleus formed in the reaction and under the methods of production when it is the end product.

Neutron and Charged Particle Cross Sections. Cross sections given in the box for a particular isotope are those which have been definitely assigned to the isotope in question and are isotopic rather than atomic values; i. e., values per atom of the isotope rather than per atom of the natural element. In all cases the nucleus z_A is the target nucleus. Within the parentheses the energy of the bombarding particle and the symbol for the particle appear before the comma, and the symbol for the emitted particle after the comma. Following the parentheses the half-life and chemical symbol of the active product formed, if any, are given. When no active product is indicated, the cross section given has been obtained by an absorption method in which the disappearance of neutrons rather than the appearance of radioactivity is measured. In most cases the reaction will be (n, γ) but other possibilities are not excluded. The entries under σ 's for Ag^{107} may serve for illustrations of the general scheme of abbreviation:

(th n, γ) 2.3^mAg 44 47S33

means that the cross section of Ag^{107} for the production of 2.3^mAg by an (n, γ) reaction with thermal neutrons has been found to be 44 barns by 47S33.

Cross section measurements with slow neutrons are usually made relative to the value for some large absorber whose cross section is known from transmission measurements and which has been found to vary as $1/v$ where v is the neutron velocity. The value found for the neutron distribution used is then converted to a value for monoenergetic neutrons of energy 0.025 ev under the assumption that the new cross section also has a $1/v$ dependence and this converted value is reported as the thermal cross section. Neutron energies for such cross sections are listed as "th" (thermal) rather than as 0.025 ev to call attention to the fact that measurements were not actually made at a specific energy. If a cross section does vary as $1/v$ its average value for any neutron distribution can be found from the relation

$$\bar{\sigma} = \sigma (0.025 \text{ ev}) 2200/\bar{v}$$

where $\bar{v}$ is the average neutron velocity in meters per second in the distribution in question.

*Complete reference is given in the list of other compilations.

**S. Nordstrom, *Zeits. f. Naturforsch.* 5a, 6 (1950). I. Perlman, A. Ghiorso, G. T. Seaborg, *Phys. Rev.* 77, 26 (1950).

The isotopic activation cross sections reported by an experimenter depend upon the values of the half-life and relative abundance used in his calculations. Since most of the activation measurements are good only to about 20 percent, corrections have not been made in this table for more recent values of either secondary quantity. If a correction has been made for a new value of a cross section taken as a standard, a note of this fact is made with the reference.

The next line in the Ag^{107} cross sections

(th n, γ) **30** 48H38

means that a sample of Ag^{107} separated electromagnetically from Ag^{109} has been found to have an absorption cross section of 30 barns for neutrons of 0.025 ev by methods similar to those just described. This result is not in good agreement with the activation value. The discrepancy is probably due to the difficulties of activation measurements.

The next line

($\sim 1\text{Mev}$ n, γ) 2.3^mAg **0.13** 49H5

shows that the Ag^{107} activation cross section for neutrons of ~ 1 Mev energy is 0.13 barns according to 49H5.

The following entry

(16Mev e^- , e^-n) 24.3^mAg **5.4×10^{-4}** 48S3

means that the cross section of Ag^{107} for the production of the 24.3^mAg by means of 16 Mev electrons has been found to be 5.4×10^{-4} barns by 48S3.

Finally, under Graphs Available,

$\sigma(n,\gamma)2.3^m\text{Ag}$ 0.003-6Mev 46L7, 47GIF, 50Ad

is intended to convey the information that the activation cross section for production of 2.3^mAg by an (n, γ) reaction has been measured for various values of the neutron energy from 0.003 Mev to 6 Mev by 46L7. A graph of the results is given in the compilations 47GIF and 50Ad as well as in the original paper.

Only the more recent neutron cross section values are included. Older results are listed in the cross section compilation of K. Way and G. Haines (48WH).

It was originally intended to include all values of charged particle cross sections, since not many of these are known and they have not been collected elsewhere. However, when the compilation was partially completed, it was found that some had been missed, especially those contained in project documents. The difficulty of making the collection complete at that time seemed monumental. It was decided, however, to leave those which had already been listed since they may help to orient readers in the order of magnitude of the results to be expected from possibly unfamiliar types of irradiations and to give a feeling for the relative probability of different types of reactions.

Methods of Production. These are given for stable nuclei only when Q values have been measured. The different Q values for a given reaction found by a particular experimenter are listed on the same line separated by commas.

4. β or γ Active Nuclei

$z\text{An}$				
τ	Half-life			Reference
K capture if observed				Reference
β^+ or β^- percentages of β groups	Maximum energy	Method	Reference	
γ	Energy	Method	Reference	
	Conversion coefficients			
X-rays				Reference
Producing reaction				Reference
	Chemical separation Cross section, yield, or excitation function observed			
	descendant of	Reference		
	predecessor of	Reference		

Degree of Certainty Symbols. Symbols indicating degree of certainty of the mass and charge assignments of radioactive nuclei are not included. The symbols commonly used for this purpose are A, B, C, etc. It was felt that while such symbols may serve a useful purpose on charts or in shorter compilations they are out of place in a table where the information on which they are based is immediately available. Moreover, some symbols have in the past engendered false complacency and discouraged experiments which should have been tried. It seemed safer and more stimulating to let the past work speak for itself and call forth all possible doubt and criticism.

Relative Abundances and Half-lives. In the few cases where β active nuclei are found in nature, their abundances relative to other isotopes of the element to which they belong are given first. In all other cases a list of the measured values of the half-life heads the data. To avoid confusion with other abbreviations, the symbols for the time units (s, m, h, d, y) are used as superscripts throughout the table. Half-lives are generally given in the units which have been most commonly used. However, values exceeding 10^6 or 10^9 have been given in terms of the next larger unit.

K Capture. If there is evidence for decay by K or L electron capture this fact is next indicated. The X-rays observed are listed after the γ -rays so the extent to which they support the indication of K capture is easily ascertained.

β -Rays. Information about β^+ or β^- emission follows. The maximum energy of the β -rays and the method of measurement are given wherever available in the center column. All energies are in Mev as elsewhere in the table. If partial β -ray spectra have been observed, the various endpoint energies and estimated percentages are given. The notation "complex" indicates that the experimenter has found some evidence for more than one β -ray, but has not been able to resolve the β groups; "simple" means that he has looked specifically and found no evidence for more than one group. The appearance of the β symbol without an energy value means that the radiation has been detected but not measured quantitatively.

γ -Rays. The γ -rays are listed with abbreviations for the methods of measurement and values of the conversion coefficients when these have been reported. Annihilation radiation is not specifically noted but should be assumed as present wherever there are positrons. If conversion has been noted but no conversion coefficient measured, this fact is shown either by explicit mention of the presence of e^- or by the fact that the γ -ray energy was found from the measurement of the energy of conversion electrons. The two method abbreviations "sc" and "ac", mean respectively, spectrometer and absorption measurements by means of conversion electrons. Conversion electrons not clearly identified with particular γ -rays are listed separately. X-rays observed are identified according to X-ray terminology (Cs K α , etc.) when the experiment has made this possible. When doubt of identity still exists, some indication of the energy observed is given whenever possible.

Methods of Production. Nuclear reactions which produce a given radioactive nucleus as end product are listed in the lower part of the box, (Sn- γ -n, Sb-d-p, etc.). If isotopically enriched material has been used to establish a particular reaction, this fact is indicated by putting the target mass number after the chemical symbol (Sb ¹²³n- γ).

The policy has been to list those reactions that help to establish the mass of the product nucleus or its neighbors rather than to put down all reactions by which it has ever been produced. For this reason note of production by spallation reactions is generally omitted. The papers on fission which are cited deal chiefly with the slow fission of U²³⁵. When references to production in other fission processes are given in the Seaborg-Perlman table this fact is noted by including the key 48SP. If a mass spectrograph identification of the product of a reaction has been made the symbols "ms" follow the reaction. If the experimenters report that a chemical separation of the product element was made after the nuclear reaction

had taken place, the abbreviation "chem" follows the reaction. In many cases, especially where the work is described in an abstract only, it seems probable that chemistry was done but since no specific mention of the fact was made, "chem" could not be included. The best policy would probably be to put down "chem" only when the chemistry performed is described in some detail but if this policy had been applied to past work, in many cases it would not be apparent that the chemical identity of the product is felt to be well established.

If the cross section or excitation function for any reaction listed has been measured or if the reaction yield is known the abbreviations "s", "f", or "yield" follow "chem". In the case of slow neutron cross sections, the actual values reported will be found under the data on the target nucleus. It was originally intended to include all other cross sections but, as noted elsewhere, this plan was only partially carried out. Reaction energies, Q , or threshold energies when available are also recorded just under the reaction. The maximum energy of the capture γ 's found in (n, γ) reactions is listed as E_γ (max).

No attempt has been made to give references to all the papers in which a particular reaction is reported as Mattauch and Flammersfeld have done. The policy adopted here was to list only the more recent papers reporting the reactions that refer in turn to a large number of previous papers also describing the same reaction. By using these papers as secondary sources it is believed that most of the references for a given reaction can be quickly accumulated.

Genetic Relationships. At the very bottom of the box, information is given about genetic relationships with the help of the abbreviation "p" for predecessor of, and "d" for descendant of. The predecessors or descendants are identified by means of their half-lives and chemical symbols. In the heavy element region where there is possible confusion between α and β decay their probable mass assignments are also given.

5. Abbreviations

All energies are given in Mev unless otherwise stated.

All cross sections are given in barns (10^{-24} cm²) unless otherwise stated.

a	Measurement by absorption method
a $\beta \gamma$	measurement by absorption of β 's in coincidence with γ 's
ac	measurement by absorption of conversion electrons
a coin	measurement by placing absorbers between counters in coincidence
α	(1) alpha particles; (2) total γ -ray conversion coefficient defined as ratio of total number of conversion electrons to number of γ -rays, i. e. N_e/N_γ . If $c = N_e/(N_e + N_\gamma)$, $\alpha = c/(1 - c)$.

$\alpha_{K, L, M}$	γ -ray conversion coefficient for electrons ejected from the K, L, M, shell	μ	magnetic moment in units of nuclear magnetons
B	band spectra method	μs	microseconds
β^-	negative beta particles	n	neutron
β^+	positive beta particles	N	measurement by means of nuclear scattering experiments
cc	measurement by cloud chamber	p	(1) proton; (2) predecessor of
ce	crystal effects	P	polarization of resonance radiation method
chem	chemical separation of product made	pc	measurement by means of proportional counter
d	(1) deuteron; (2) descendant of; (3) days, when used as superscript	q	electric quadrupole moment in units of barns
D	deuterium	Q	reaction energy in Mev
e or e^-	electron	rel	relative
E_0	neutron resonance energy, usually in ev	s	(1) spectrometer measurement by means of secondary electrons; (2) seconds, when used as superscript
E_β, E_γ , etc.	energy of β -ray, energy of γ -ray, etc.	S	measurement by means of atomic spectra
$\bar{E}$	average energy	$s\beta\gamma$	spectrometer measurement of β 's in coincidence with γ 's
ev	electron volts	sc	spectrometer measurement by means of conversion electrons
f	excitation function determined	scin	measurement by means of scintillation counter
γ	gamma rays	σ	cross section in barns
Γ	resonance half-width (the whole width at half-maximum), usually in ev. Breit-Wigner formula: $\sigma = [\sigma_0 \Gamma^2 (E_0/E)^{1/2}] / [4(E_0 - E)^2 + \Gamma^2]$	σ_0	cross section at resonance energy, E_0 . See Γ .
γn	measurement by means of photo neutron detection	σ_a	absorption cross section in barns
h	hours, when used as superscript	σ_{ac}	activation cross section in barns
I	(1) spin in units of $\hbar$; (2) nuclear induction method	σ_{eff}	effective cross section in barns
ic	measurement by ionization chamber	σ_s	scattering cross section in barns
IT	isomeric transition	σ_s bound	bound scattering cross section or $4\pi(p_1 f_1^2 + p_2 f_2^2 + \dots)$ where the f 's are the bound scattering lengths and the p 's are the relative isotopic abundances. See 49S12.
K	electron capture from the K shell	σ_s coh	coherent scattering cross section or $4\pi(p_1 f_1 + p_2 f_2 + \dots)^2$
K/L	α_K/α_L	σ_t	total cross section in barns
kev	thousand electron volts	t	triton
KU	β -ray end point found using Konopinski-Uhlenbeck theory	th	thermal
L/(M+N)	$\alpha_L/(\alpha_M + \alpha_N)$	τ	half-life in units indicated
L capture	electron capture from the L shell	wt	weight
L/M	α_L/α_M	y	years, when used as superscript
m	minutes, when used as superscript	Z	method of zero moments
M	molecular or atomic beam resonance method		
mb	millibarns		
Mev	million electron volts		
Mic	microwave method		
ms	mass spectroscopic identification of mass number		

1. Alphabetical Index to Elements

Element	Symbol	Z	Page	Element	Symbol	Z	Page
Actinium.....	Ac	89	258	Neptunium.....	Np	93	267
Aluminum.....	Al	13	23	Neodymium.....	Nd	60	176
Americium.....	Am	95	271	Neon.....	Ne	10	17
Antimony.....	Sb	51	137	Neutron.....	n	0	1
Argon.....	A	18	32	Nickel.....	Ni	28	56
Arsenic.....	As	33	70	Niobium.....	Nb	41	99
Astatine.....	At	85	249	(Columbium)			
				Nitrogen.....	N	7	11
Barium.....	Ba	56	164	Osmium.....	Os	76	221
Berkelium.....	Bk	97	273	Oxygen.....	O	8	13
Beryllium.....	Be	4	5				
Bismuth.....	Bi	83	241	Palladium.....	Pd	46	116
Boron.....	B	5	7	Phosphorus.....	P	15	26
Bromine.....	Br	35	77	Platinum.....	Pt	78	225
				Plutonium.....	Pu	94	269
Cadmium.....	Cd	48	124	Polonium.....	Po	84	246
Calcium.....	Ca	20	37	Potassium.....	K	19	34
Californium.....	Cf	98	274	Praseodymium.....	Pr	59	174
Carbon.....	C	6	9	Promethium.....	Pm	61	179
Cerium.....	Ce	58	171	Protactinium.....	Pa	91	263
Cesium.....	Cs	55	159				
Chlorine.....	Cl	17	30	Radium.....	Ra	88	256
Chromium.....	Cr	24	47	Rhenium.....	Re	75	218
Cobalt.....	Co	27	53	Rhodium.....	Rh	45	113
Copper.....	Cu	29	58	Rubidium.....	Rb	37	85
Curium.....	Cm	96	272	Ruthenium.....	Ru	44	110
Dysprosium.....	Dy	66	194	Samarium.....	Sm	62	182
				Scandium.....	Sc	21	40
Emanation.....	Em	86	252	Selenium.....	Se	34	73
Erbium.....	Er	68	199	Silicon.....	Si	14	25
Europium.....	Eu	63	185	Silver.....	Ag	47	119
				Sodium.....	Na	11	18
Fluorine.....	F	9	15	Strontium.....	Sr	38	89
Francium.....	Fr	87	254	Sulphur.....	S	16	28
Gadolinium.....	Gd	64	188	Tantalum.....	Ta	73	213
Gallium.....	Ga	31	64	Technetium.....	Tc	43	106
Germanium.....	Ge	32	67	Tellurium.....	Te	52	142
Gold.....	Au	79	227	Terbium.....	Tb	65	191
				Thallium.....	Tl	81	234
Hafnium.....	Hf	72	210	Thorium.....	Th	90	260
Helium.....	He	2	3	Thulium.....	Tm	69	202
Holmium.....	Ho	67	197	Tin.....	Sn	50	133
Hydrogen.....	H	1	2	Titanium.....	Ti	22	43
Indium.....	In	49	128	Uranium.....	U	92	265
Iodine.....	I	53	148				
Iridium.....	Ir	77	223	Vanadium.....	V	23	45
Iron.....	Fe	26	51				
				Wolfram.....	W	74	215
Krypton.....	Kr	36	81	(Tungsten)			
Lanthanum.....	La	57	168	Xenon.....	Xe	54	154
Lead.....	Pb	82	237				
Lithium.....	Li	3	4	Ytterbium.....	Yb	70	204
Lutetium.....	Lu	71	207	Yttrium.....	Y	39	92
Magnesium.....	Mg	12	21	Zinc.....	Zn	30	61
Manganese.....	Mn	25	49	Zirconium.....	Zr	40	96
Mercury.....	Hg	80	231				
Molybdenum.....	Mo	42	102				

2. Atomic Number Index to Elements

Element	Symbol	Z	Page	Element	Symbol	Z	Page
Neutron	n	0	1	Tin	Sn	50	133
Hydrogen	H	1	2	Antimony	Sb	51	137
Helium	He	2	3	Tellurium	Te	52	142
Lithium	Li	3	4	Iodine	I	53	148
Beryllium	Be	4	5	Xenon	Xe	54	154
Boron	B	5	7	Cesium	Cs	55	159
Carbon	C	6	9	Barium	Ba	56	164
Nitrogen	N	7	11	Lanthanum	La	57	168
Oxygen	O	8	13	Cerium	Ce	58	171
Fluorine	F	9	15	Praseodymium	Pr	59	174
Neon	Ne	10	17	Neodymium	Nd	60	176
Sodium	Na	11	18	Promethium	Pm	61	179
Magnesium	Mg	12	21	Samarium	Sm	62	182
Aluminum	Al	13	23	Europium	Eu	63	185
Silicon	Si	14	25	Gadolinium	Gd	64	188
Phosphorus	P	15	26	Terbium	Tb	65	191
Sulphur	S	16	28	Dysprosium	Dy	66	194
Chlorine	Cl	17	30	Holmium	Ho	67	197
Argon	A	18	32	Erbium	Er	68	199
Potassium	K	19	34	Thulium	Tm	69	202
Calcium	Ca	20	37	Ytterbium	Yb	70	204
Scandium	Sc	21	40	Lutetium	Lu	71	207
Titanium	Ti	22	43	Hafnium	Hf	72	210
Vanadium	V	23	45	Tantalum	Ta	73	213
Chromium	Cr	24	47	Wolfram	W	74	215
Manganese	Mn	25	49	Rhenium	Re	75	218
Iron	Fe	26	51	Osmium	Os	76	221
Cobalt	Co	27	53	Iridium	Ir	77	223
Nickel	Ni	28	56	Platinum	Pt	78	225
Copper	Cu	29	58	Gold	Au	79	227
Zinc	Zn	30	61	Mercury	Hg	80	231
Gallium	Ga	31	64	Thallium	Tl	81	234
Germanium	Ge	32	67	Lead	Pb	82	237
Arsenic	As	33	70	Bismuth	Bi	83	241
Selenium	Se	34	73	Polonium	Po	84	246
Bromine	Br	35	77	Astatine	At	85	249
Krypton	Kr	36	81	Emanation	Em	86	252
Rubidium	Rb	37	85	Francium	Fr	87	254
Strontium	Sr	38	89	Radium	Ra	88	256
Yttrium	Y	39	92	Actinium	Ac	89	258
Zirconium	Zr	40	96	Thorium	Th	90	260
Niobium	Nb	41	99	Protactinium	Pa	91	263
Molybdenum	Mo	42	102	Uranium	U	92	265
Technetium	Tc	43	106	Neptunium	Np	93	267
Ruthenium	Ru	44	110	Plutonium	Pu	94	269
Rhodium	Rh	45	113	Americium	Am	95	271
Palladium	Pd	46	116	Curium	Cm	96	272
Silver	Ag	47	119	Berkelium	Bk	97	273
Cadmium	Cd	48	124	Californium	Cf	98	274
Indium	In	49	128				

3. Index for Classical Radioactive Families

THORIUM FAMILY

Name	Z	Isotope	Page	Name	Z	Isotope	Page
Th.....	90	Th ²³²	261	ThA.....	84	Po ²¹⁶	248
MsTh ₁	88	Ra ²²⁸	257	ThB.....	82	Pb ²¹²	240
MsTh ₂	89	Ac ²²⁸	259	ThC.....	83	Bi ²¹²	245
RdTh.....	90	Th ²²⁸	261	ThC'.....	84	Po ²¹²	247
ThX.....	88	Ra ²²⁴	257	ThC''.....	81	Tl ²⁰⁸	236
Tn.....	86	Em ²²⁰	253	ThD.....	82	Pb ²⁰⁸	239

URANIUM FAMILY

UI.....	92	U ²³⁸	266	RaB.....	82	Pb ²¹⁴	240
UX ₁	90	Th ²³⁴	262	RaC.....	83	Bi ²¹⁴	244
UX ₂	91	Pa ²³⁴	264	RaC'.....	84	Po ²¹⁴	248
UZ.....	91	Pa ²³⁴	264	RaC''.....	81	Tl ²¹⁰	236
UII.....	92	U ²³⁴	266	RaD.....	82	Pb ²¹⁰	239
Io.....	90	Th ²³⁰	261	RaE.....	83	Bi ²¹⁰	243
Ra.....	88	Ra ²²⁶	257	RaF.....	84	Po ²¹⁰	247
Rn.....	86	Em ²²²	253	RaG.....	82	Pb ²⁰⁶	238
RaA.....	84	Po ²¹⁸	248				

ACTINIUM FAMILY

AeU.....	92	U ²³⁵	266	An.....	86	Em ²¹⁹	253
UY.....	90	Th ²³¹	261	AeA.....	84	Po ²¹⁵	248
Pa.....	91	Pa ²³¹	263	AeB.....	82	Pb ²¹¹	240
Ae.....	90	Ac ²²⁷	258	AeC.....	83	Bi ²¹¹	244
RdAe.....	90	Th ²²⁷	260	AeC'.....	84	Po ²¹¹	247
AeK.....	87	Fr ²²³	255	AeC''.....	81	Tl ²⁰⁷	235
AeX.....	88	Ra ²²³	256	AeD.....	82	Pb ²⁰⁷	238

0 NEUTRON n

	$\begin{array}{c} \\ 0 \quad 1 \end{array}$	
	τ 10^{-30}^m $9 \cdot 18$ 50S6 50R2 I $1/2$ N 37S9 μ -1.9135 I 49P0 48B29, 47A10, 49R15 β^- 50S6 p 50R2, 50S6 D$\rightarrow\gamma$-p 50HLM	

I HYDROGEN H

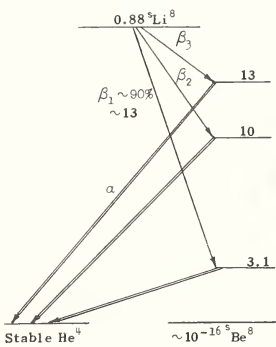
Neutron Cross Sections for Natural Element				I I 0	
σ_s coh	2.0 (-)	49S12	Graphs Available σ_t (H_2 , H_2O , methane, ethane, propane, n-butane, cetane, ethylene, 1,3-butadiene) $0.003-100\text{ev}$ 49M40 $0.03-23\text{Mev}$ 47GIF $0.03-290\text{Mev}$ 50Ad $0.8-1.6\text{Mev}$ 49L20 Other fast n references on graphs and in 48WH	99.9844%	36H3
σ_s bound	80	49S12		1/2 B 30H2, 29M1, 30C1 SH* 27D1	
σ_a	$E_n = 0.025\text{ev}$ 0.32 (48WH) 0.33 48R13 0.25 49H2			2.7926^{**}	49H49
σ_t Value depends on H compound used See graphs List of thermal values for various compounds 48WH Free proton value 20.36 49M4 20.8 (theoretical) 47B28				1.4100** dyne cm/gauss 49T18	
σ_t	$E_n = 1\text{Mev}$ 4.2 49B48 See graphs			1.52100** Bohr magnetons 49G11	
				1.52106** Bohr magnetons 49T1	
				σ 's See natural element	
				* Specific heat measurements ** Diamagnetic correction for atomic hydrogen (41L3) applied	
2 I I				3 I 2	
	0.0156% 0.015	36H3 39S19		τ	12.5 ^y 49J4 12.1 47N1 10.7 47G8
σ_s coh	5.0 (+)	49S12	I 1 R 34M3 OP* 34F2	I 1/2 B 49D31 I 47B31	
σ_s bound	7.4	49S12	μ 0.85761 49P0	μ 2.9795 49P0	
σ_a (D_2O)	$E_n = 0.025\text{ev}$ 0.92mb*	47S38	I 49S37, 49Z2, 47B29, 47R8, 47B30	I 47A9, 47B32	
σ_s (D_2O)	15.3*	46R9	M 39K12	β^- 0.0189 pc 49H1 0.0180-0.0186 pc 49C8 0.0180 a 49Q7 0.0170 cc 49B22	
σ_t (D_2O)	14.6*	See graphs	q 0.00273 M 40K10	$\overline{E}_\beta$ 5.69kev 49J4 5.64 48H51 calorimetric measurements	
* per molecule				No γ	46G14
σ_t	$E_n = 1\text{Mev}$ 3.1 See graphs			D-n- γ He ³ -n-p D-d-p Li-n- α Be-d-t	} 50HLM 48HL, 48Lau 48HL, 48Lau
Graphs Available					
σ_t 0.005-40ev 48R6, 47GIF 0.35-14Mev 47GIF 0.35-290Mev 50Ad					
Other references on graphs and in 48WH			* Ortho-para conversion		

2 HELIUM He

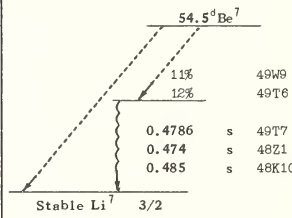
Neutron Cross Sections for Natural Element			3 2 1		4 2 2	
σ_s	$E_n = 0.025\text{ev}$ 1.55	50H5	Atmospheric Value: 1.3x10 ⁻⁴ % 49C9,47F1 1.2x10 ⁻⁴ 48A7		~100% 47F1	
			Wide variations in well and mineral values 49C9,48A7		I 0 B 29M1 N 31B1	
			I 1/2 B 49D24			
			μ (-)2.128 I 49A11 Negative sign not verified			
			σ 's (th n,p)H ³ 5040 49C10 5100 49K17 3700 49B32			
σ_s	Graphs Available	47K13,47G1F				
σ_t	0.6-1.6Mev	49B48				
	0.04-6.4Mev	49B48				
	Only one peak observed	49B48	Graphs Available			
			$\sigma(np)$ 0.001-0.03ev 49K17			
	σ (elastic back scattering)					
	0.5-1.8Mev	40S11				
	0.5-4.3Mev	39S18				
5 2 3			6 2 4			
τ	$\sim 2.4 \times 10^{-21}\text{s}$		τ 0.82 ^s 48K13,49H24			
	Calculated weighted mean from several experiments 50HLM		0.85 48S5			
			0.87 47C15			
			0.89 48H17			
			β^- 3.23 s 50P1			
			3.7 a 48K13			
			3.5 a 49A2,48S5			
			No γ 48K13			
He-d-p	} 50HLM		Li- γ -p			
Li-d- α			Li-n-p			
			Be-n- α			

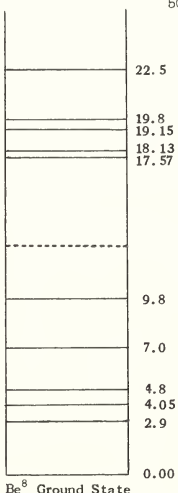
3 LITHIUM Li

Neutron Cross Sections for Natural Element				5 3 2		6 3 3			
σ_s coh	0.4	(-)	49S12	$H^2-He^3-\alpha$ $He-p-p$		7.30%	48W9		
	$E_n = 0.025\text{ev}$					7.40	48I6		
σ_a	67		49P3			7.40-7.46	47H27		
	65		44F13			I	1	M	40K9
								Z	37M6
σ_t	70		44F13			μ	0.8221	M	49S37 (49K31)
	71		46H26						
	$E_n \sim 2.5\text{Mev}$					$\frac{q(Li^6)}{q(Li^7)}$	≤ 0.044	M	49K30
σ_t	2.0		39A5			Levels ?	~ 1.0		50HLM
Other fast n values			48WH				~ 3.0		
							$\sigma's$		
					σ_s coh (+)	~ 6	49S12		
					By calculation from Li and Li ⁷				
Graphs Available				$H^2-He^3-\alpha$ $He-p-p$		Large absorption cross section of element attributed to n, α reaction in this isotope			
σ_t	0.015-5ev	50Ad, 46H26, 47G1F	37LB						
$\sigma(n,\alpha)$	0.04-1.8Mev	50Ad, 47G1F							

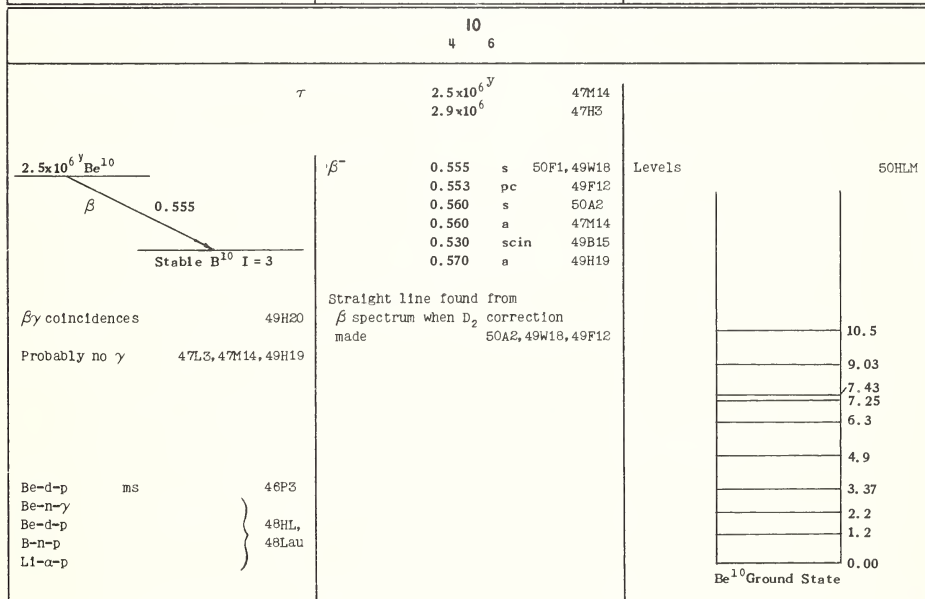
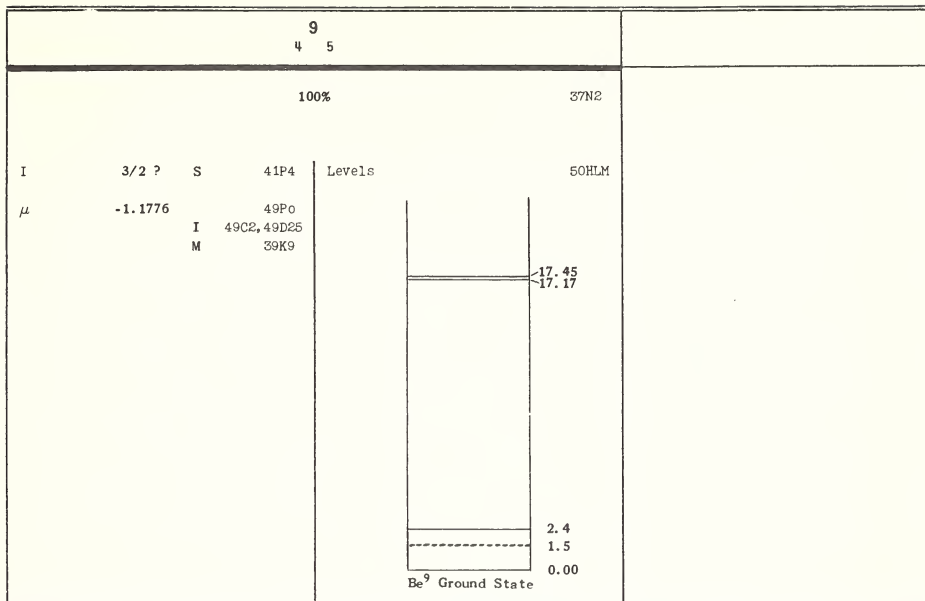
7 3 4				8 3 5			
	92.70%		48W9	τ	0.88 ^s	49B24, 4702, 45H5, 37L1	
	92.60		48I6		0.89	47H6	
	92.54-92.60		47H27	Proposed decay scheme 50H1		Maximum β energy ~ 13 50H1	
I	3/2	B	30H1			β spectrum consistent with proposed decay scheme 50H1	
		S	32G3			$\beta_1^- \sim 90\%$ ~ 13 s 50H1	
		M	40K9			12 a 4702	
		Z	35F3			12 cc 37B1	
μ	3.2567		49P0			$\beta_2^-, \beta_3^- \sim 10\%$ 50H1	
		I	49B7, 49Z2,	$< 5\%$ of transitions to 4.8Mev γ emitting state of Be ⁸ 50H1			
		49S37					
		M	41M8	No γ 37R3, 37B1			
q	$\sim +0.02$		49K29				
Levels	0.477	} 48Lau, 48HL, 50HLM		$\left. \begin{array}{l} \text{Li-d-p} \\ \text{Li-n-}\gamma \\ \text{Be-}\gamma\text{-p} \\ \text{B-n-}\alpha \end{array} \right\} \begin{array}{l} 48HL, \\ 48Lau \end{array}$			
	7.38						
	$\sigma's$						
(th n, γ) 0.88 ^s Li	33mb	47H6					
	1mb	46P12					
σ_s coh	(-)	0.8	49S12				
σ_s bound	~ 2		49S12				

4 BERYLLIUM Be

Neutron Cross Sections for Natural Element			7 4 3		
σ_s coh	7.7	49S12			
σ_s bound	7.5	49S12			
$E_n = 0.025\text{ev}$					
σ_a	0.009	47N5			
	0.0085	47A8			
	0.01	47H3			
	≤ 0.01	48H20			
σ_s	6.9	37G1			
σ_t	ce	See graphs			
Values at other n energies 48WH, 49H16					
Graphs Available			Maximum energy of Li^7 recoils = 57ev 49S38 $\frac{\lambda(\text{Be}^0) - \lambda(\text{Be})}{\lambda(\text{Be})} \sim 3 \times 10^{-4}$ Level 0.43 Li-p- γ Li-d-n Li-p-n B-p- α		
σ_t	0.004-10ev	47GIF, 47F12			
	0.5-4Mev	47A7			
	0.02-1.4Mev	50Ad, 49A8, 47GIF			
	1-300Mev	50Ad			
$\sigma(n, \alpha)$	1.7-4Mev	47A7			

8 4 4					
τ	10^{-16} - 10^{-17} ^S	37B5			
calculated value					
Mass difference in Mev					
$\text{Be}^8 - 2 \text{He}^4$	0.103	48H2			
	0.089	49T16			
Li-p- γ Li-d-n Be-d-t Be-p-d Be- γ -n B-d- α B-n-t Be-p- α C- γ - α					
d 0.86 $^5\text{Li}^8$					

4 BERYLLIUM Be



5 BORON B

Neutron Cross Sections for Natural Element		9 5 4	
σ_a	$E_n = 0.025\text{ev}$ 718 49P3		
σ_t	702 47F13 708 46B31 737 47S36 745 46R8		
σ_s	Ep1-Cd 3.7 44A3 3.9 46D16		
σ_t	$E_n = 1\text{Mev}$ ~ 1.7 See graphs		
Graphs Available			
σ_t	0.01-1000ev 47S36, 47G1F 0.01-100ev 46R8 See also 49H16 0.023-14Mev 50Ad, 47G1F 0.2-3Mev 46B32		
References on graphs and in 48WH			
$\sigma(n, \alpha)$	0.3-3.0Mev 47G1F, 50Ad		

10 5 5			
18.83%		4611	
I	3 Mic 48G20	Levels	50HLM
μ	1.801 I 49P0 M 36M5		8.76 7.47 7.38 7.09 6.76
q	0.06 Mic 49G23		5.1 3.6 2.85 2.14 1.42 1.02 0.713 0.411 0.00
$\sigma's$	(th n,p) <0.2 46B34 (~1Mev n,p) 3mb 47E4 σ_s (Ep1-Cd) 2.6 46D16 Graph Available σ_t 0.2-3Mev 46B32		Large absorption cross section of natural element attributed to n, α reaction in this isotope 37LB
		B ¹⁰ Ground State	

5 BORON B

[illegible]

6 CARBON C

Neutron Cross Sections for Natural Element			10 6 4		11 6 5				
σ_s coh	5.2	49S12	τ	19.1 ^s	49S25	τ	20.35 ^m	41S11	
σ_s bound	5.2	49S12					20.5	48P3, 41S1	
							20.0	44S3	
σ_a	$E_n = 0.025\text{ev}$ ~4.5mb 4.9mb	(48WH) 47A8	β^+	2.2	a	49S25	β^+	0.970 s	44S3
			γ	~1		49S25		0.981 s	41T1
								0.95 cc	40D6
σ_t	$E_n > 1\text{ev}$ 4.70 4.8	49H18 (48WH)					No $\beta\gamma$ coincidences		46S12
							Level	2.0	50HLM
								4.5 ?	
								6.7 ?	
								10.1	
Graphs Available									
σ_t	0.002-4ev	ce 50Ad, 47GIF	$B^{10}\text{-p-n}$	chem	49S25	$B\text{-p-}\gamma$			} 48HL, 48Lau
	0.02-300Mev	50Ad	$C\text{-}\gamma\text{-}2n$?		48P3	$B\text{-d-n}$			
	0.1-6Mev	47GIF				$B\text{-p-n}$			
	0.6-1.6Mev	49L20				$C\text{-n-}2n$			
Fast n graphs in 50Ad and 47GIF based on many others. References on graphs and in 48WH						$N\text{-p-}\alpha$			

12 6 6					
98.892% limestone variations				50N1 41M7	
I	0	B	48J21	Levels	50HLM
					16.71
					16.11
					10.8
					10.3
					9.7
					7.
					5.5
					4.5
					0.00
				C^{12} Ground State	

6 CARBON C

13 6 7					14 6 8				
1.108% limestone variations					50N1 41M7				
I	1/2	B	48J21	Levels	50HLM	5,720 ^y 5,589 6,400 7,200 5,100			
μ	0.7023		49P0 49P8 41H14			I	0	B	48J21
					13.6	β^-	0.155	s	49F2, 48E21
					11.7		0.154	s	47L8
					9.8		0.156	s	48C10
					8.9		0.154	a	47S26
					8.25		0.158	pc	49A3
					7.3	No γ			41R5
					5.4	Level	5.6		50HLM
(th n, γ) 5,720°C	σ 's	~0.1	45L8		3.9		6.1	σ 's	
C-n- γ					3.1	(th n, γ)		< 200	46E8
$E_{\gamma}(\text{max}) = 4.9$			49K32		1.0	B- α -p			} 48HL. 48Lau
					0.00	C-d-p			
						N-n-p			
						O-n- α			
C ¹³ Ground State									
Also 22 levels found between 12.6 and 16.6					39F5, 48HL				

7 NITROGEN N

Neutron Cross Sections for Natural Element			12 7 5			13 7 6				
σ_s coh	4.6	49S12	τ	$12.5 \times 10^{-3} \text{ s}$	49A5	τ	10.1^m	45S3		
σ_s bound	6-10	49S12					10.2	48C1		
							9.93	39W4		
σ_a	$E_n = 0.025 \text{ ev}$		β^+	16.6	a	49A5	β^+	1.24	s	45S3
	1.86	49P3						1.25	s	48C11
	1.45	49H2						1.22	s	41T1
σ_t	12.7	See graph					No γ of 0.28 Mev		46S12	
	$E_n = 10-200 \text{ ev}$						No γ between 0.135 and 0.700 Mev		47L4	
σ_t	9.96	49M40					Level	2.4	50HLM	
								3.5		
							C-p-n			
							B-d-n			
							C-d-n		48HL,	
							C-p- γ		48Lau	
							N-d-t			
							N- γ -n	rel σ	48W13	
							threshold = 10.7		49M17	
							11.1		45B12	
Graphs Available										
σ_t	0.003-2000 ev	49M40	C-p-n		49A5					
	0.3-3.4 Mev	50Ad, 49B50								
	0.03-90 Mev	50Ad								
	0.05-4 Mev	47GIF								
References on graphs and in 48WH										

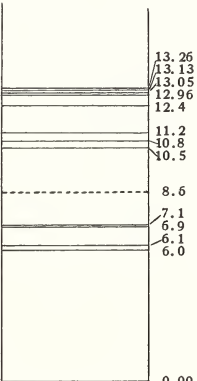
			14			
			7 7			
			99.635%		50N1	
			99.637		31U1	
			99.620		35W1, 34V1	
I	1	B	2801	Levels	50HLM	
		Mic	46D15, 46C10			
μ	0.403	M	39K10 (49P0)			
q	0.02	Mic	48T11, 49T17			
		σ 's				
(th n,p)		1.75	49C10			
		1.60	49B32			
Graphs Available						
$\sigma(n,p)$	0.2-1.7Mev		50A4, 46B35			
$\sigma(n,\alpha)$	1.3-1.7Mev		47G1F			
n,p and n, α resonances			48S34			
				N^{14} Ground State		

7 NITROGEN N

15				16			
7		8		7		9	
0.365% 50N1		Levels		50HLM		τ	7.35 ^S 47B3
0.363 31U1							7.3 46B6
0.380 35W1, 34V1							7.5 46H17
I	1/2 B	39K11, 40W10				$\beta^- \sim 40\%$	3.8 a $\beta\gamma$ 47B3
μ	± 0.280 M	40Z2 (49Po)				$\sim 40\%$	4.3 a $\beta\gamma$ 47B3
						$\sim 2\%$	4.6 cc 47B3
						$\sim 18\%$	10.5 a 47B3
						10	cc 46H17
						γ	6.2 ac 46B10
							6.2 49M49
							photographic plate
							6.7 ac 46B10
							7.0 49M49
							photographic plate
σ^1s							Best estimate of disintegration energy = 10.3 $\pm$ 0.7 47B3
(th n, γ) 7.35 ^S N <0.013mb 45H14							

8 OXYGEN 0

Neutron Cross Sections for Natural Element			14 8 6			15 8 7		
σ_s coh	4.2	49S12	τ	76.5 ^s	49S25	τ	1.97 ^m	49P12
σ_s bound	4.15	49S12					2.1	35M1, 39B5, 48P3, 49S25
							2.2	48W13
σ_a	$E_n = 0.025\text{ev}$ <0.9mb	See D ₂ O	β^+ simple	1.8	a	49S25		
σ_s	4.2	37G1	γ	2.3	a	49S25	β^+	1.683 s 49P12 1.68 a 49S25 1.7 cc 38F1
σ_t	4.2	See graph						
σ_t	$E_n = 15-1000\text{ev}$ 3.73	49M40					Levels ?	4.0 50HLM 7.9
E_o	Resonances 0.440Mev 1.0 1.3 4.0	49A8, 50Ad						
σ_t	Graphs Available 0.003-2000ev 50Ad, 49M40 0.02-6Mev 47GIF 0.1-1.4 Mev 50Ad 1.5-300Mev 50Ad 0.01-0.6Mev 49A8		N-p-n	chem	49S25	C-a-n N-d-n N-p- γ O- γ -n O-n-2n F-n-p4n O- γ -n		50HLM 48P3, 48W13
References on graphs and in 48WH							rel σ	

16 8 8					
			99.759% atmospheric	50N1	
			99.757	44T1	
			99.7	49H3	
I	0	B	29M1	Levels	50HLM
					
(~1Mev n, p)	σ^{ts}	0.014mb	46G31		
			O ¹⁶ Ground State		

8 OXYGEN 0

17 8 9				18 8 10			
0.0374% atmospheric 50N1 0.039 44T1 0.035 49H3				0.2039% atmospheric 50N1 44T1 0.204 44T1 0.195 49H3			
I	1/2 ? Mic	49L21	Levels	50HLM			
(th n,α)		σ's	0.48 46H27 < 0.4 46E9	(th n,γ) 29.4*0 σ's 0.22mb 46S24 0.20mb 46H14			
O ¹⁷ Ground State							

19 8 11			
τ	29.4 ^S 29.5 27.0	44F6 46H17 47B4	
β ₁ ⁻ 30%	4.5	a	47B4
	4.1	a	44F6
β ₂ ⁻ 70%	2.9	a	47B4
γ	1.6	a	44F6
O-n-γ F-n-p		} 50HLM	

19 8 11							
τ	29.4 ^S	44F6					
	29.5	46H17					
	27.0	47B4					
β_1^- 30%	4.5	a	47B4				
	4.1	a	44F6				
β_2^- 70%	2.9	a	47B4				
γ	1.6	a	44F6				
O-n- γ		} 50HLM					
F-n-p							

9 FLUORINE F

Neutron Cross Sections for Natural Element			17 9 8		
σ_s coh	~ 4	49S12	τ	72.0^B	48P3
				74	38D1
σ_s bound	~ 3.5	49S12		66	49B27
	$E_n = 0.025\text{ev}$		β^+	2.1	cc
	≤ 0.01	46M20			36K2
σ_a			No γ		48K13
σ_t	4.0	48R6			
	$E_n = 0.25\text{-}40\text{ev}$				
σ_t	3.3	48R6	Level ?	3.9	50HLM
	$E_n = 1\text{Mev}$				
σ_t	3.7	See graphs			
Graphs Available					
σ_t	0.02-40ev	50Ad, 48R6, 47GIF	N- α -n	}	50HLM
See also		49H16	O-d-n		
	0.02-3Mev	50Ad, 47GIF	O-p- γ		
References on graphs and in 48WE			F- γ -2n		
			F-n-3n		

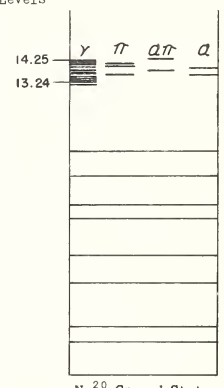
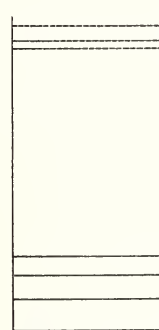
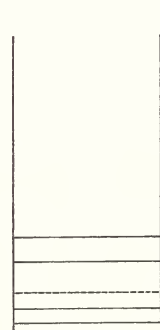
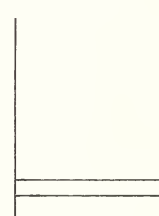
		18			
		9 9			
τ		1.87 ^h		37S1, 48P3, 49B26	
		1.92		44H8	
		1.78		38D1	
β^+ simple	0.64 s	49B26	Levels	50HLM	
	0.7 a	50K14			
	0.72 a	41K1			
80%	0.6 cc	48H19			
20%	0.95 cc	48H19			
No γ		48K13			
γ	1.4 cc	48H19			
K ?		48H19			
O- α -pn	}				11.2
O-p-n					10.3
O-d-n					9.6
O-t-n					9.2
F-n-2n					8.6
F-d-t					8.2
F- γ -n					7.8
Ne-d- α					7.3
Na- γ -an ?					5.9
F- γ -n					0.0
			F ¹⁸ Ground State		
			* 7 levels reported between 10.3		
			and 11.2		50HLM

9 FLUORINE F

				19			
				9	10		
				100%		42A2	
I	1/2	B	29G1	Levels		50HLM	
		S	33C4				
μ	2.6283		49F0				
		I	49Z2, 49FB,				
			49S37				
		M	41M8				
						11.2	
						11.1	
						11.0	
						10.8	
						10.5	

20 9 11		
τ	12^8	35C1
β^-	5.1 a 40C11(46B27) 5.1 cc 39B10	Levels 50HLM
γ	2.2 cc 39B10	
5.1 Mev β in coincidence with γ , $\gamma\gamma$ coincidences also observed 40C11		
F-d-p F-n- γ Na-n- α	} 50HLM	
		F²⁰ Ground State

10 NEON Ne

Neutron Cross Sections for Natural Element	19 10 9	20 10 10
$E_n = 0.025\text{ev}$ σ_t 2.8 41C5 σ_s 2.3 50H5	τ 18.2 ^S 49S25 20.3 39W2 β^+ 2.3 a 39W2, 49S25 2.2 cc 39W2 No γ 39W2 F-p-n 49S25, 39W2	89.99% 49H3 90.51 47D9 Levels 50HLM  Ne ²⁰ Ground State
21 10 11	22 10 12	23 10 13
0.30% 49H3 0.28 47D9 I $\geq 3/2$ S 49K21 μ negative S 49K21 Levels 50HLM  Ne ²¹ Ground State	9.72% 49H3 9.21 47D9 Levels 50HLM  Ne ²² Ground State	τ 40.7 ^S 44H4 40 35A1, 49B27 43 40P4 β^- 4.3 a 40P4 (46B27) Levels 50HLM  Ne ²³ Ground State Ne-d-p Na-n-p Mg-n-a } 50HLM

11 SODIUM Na

Neutron Cross Sections for Natural Element			21 11 10		
σ_s coh	1.5	48S12	τ	$\sim 20^S$	48B22
σ_s bound	3.5	48S12		23	40C3
σ_a	$E_n = 0.025\text{ev}$				
	0.46	49P3			
	0.51	49H2			
	0.41	48W19			
σ_s	4.0	37G1			
Resonances					
E_0					
$\sim 1700\text{ev}$		47L18			
>1000		48H45			
Graphs Available					
σ_t	0.02-14Mev	47G1F		Ne-p-n	40C3
	0.02-1Mev	49A6,50Ad		Ne-d-n	40P4
	many resonances			$Mg^{24}\text{-p-}\alpha$	48B22
Other references on graphs and in				$Ne^{20}\text{-p-}\gamma$	47B18
		48WH		f	

22 11 11					
τ			2.6 ^y	49L12	
			2.8	41S13	
			3.0	37L2	
I	3	M	49D1	β_1^+	0.575 s 46G1
μ	1.7454	M	49D1(49Po)		0.55 s 3901
					0.53 a 37L2(48B27)
			2.6 ^y Na ²² I = 3	β_2^+	$\sim 4 \times 10^{-3}\%$ 4.8 cc 49H34
			2mc ²	γ	1.277 s 49A7
			β_1 0.575		1.30 s 46G1
			γ 1.28		1.3 s 3901
			β_2		
			$\sim 4 \times 10^{-3}\%$		
			~ 1.8		
Levels			Stable Ne ²²		
			$\beta\gamma$ coincidences	46G1,44M3,49A7	
			No K capture	44B8,46G1	
			F- α -n	chem	35F4
				Q = -2.3, -2.64	34B2
			Ne ²¹ -p- γ	f	47B18
			Na-n-2n		47S24
			Mg-d- α	chem	37L2
				f, σ	44B8,46C5
				yield	46C9

11 SODIUM Na

25					
11 14					
τ	62.5 ^s			46B7	
	62.0			48P3	
	60			44R1	
	58			47B4	
β^-	$\sim 45\%$	2.7	a	47B4	
	$\sim 55\%$	3.7	a	47B4	
		3.3	a	44R1	
		2.8	a	46B7	
γ	>0.5		a	47B4	
Mg- γ -p	rel σ			47H4, 49B51	
threshold = 14				48M17	
Mg-n-p	chem			47B4	
Al- γ -ep	rel σ			48P3	

.12 MAGNESIUM Mg

Neutron Cross Sections for Natural Element			23 12 11			
σ_s coh	2.4	49S12	τ	11.9 ^s 11.6	43H2 39W2	
σ_s bound	4.2	49S12	β^+	2.82 cc	39W2	
σ_a	$E_n = 0.025\text{ev}$ 0.06 0.07	49P3 49H2	No γ		39W2	
σ_s	3	(48WH)				
σ_t	3	See graphs				
σ_t	$E_n = 1\text{Mev}$ ~ 3	See graphs				
Graphs Available						
σ_t	0.02-400ev	48R6, 47GIF, 50Ad	Na-p-n		39W2, 44D9	
	0.023-14Mev	47GIF	threshold ~ 4.7		39W2	
	0.5-2Mev	49W21	Mg- γ -n		43H2, 46B7	
	2-90Mev	50Ad	threshold = 16.2		49M17	
Other references on graphs and in			relo		48W13	
48WH						
24 12 12			25 12 13			
78.98%	49H32		10.05%	49H32	10.97%	49H32
78.60	48W9		10.11	48W9	11.29	48W9
			I	5/2 S	49C18	
			μ	-0.96 S	49C18	
Levels	49AH		Levels	49AH	Levels	49AH
1.38	Mg-p-p, Mg-n-n, Na ²⁴		0.6	Mg-d-p	0.44	Na-a-p
4.14	Mg-p-p, Na ²⁴		0.8	Al-d-a	1.91	Na-a-p, Mg-d-p
5.51	Mg-p-p		1.0	Mg-d-p, Na ²⁵	2.85	Na-a-p, Mg-d-p
			1.58	Al-d-a	4.0	Na-a-p
Mg-p-p	49R12, 43D3, 41W12, 48F13		2.54	Al-d-a	5.0	Na-a-p
Mg-n-n	48L8					
25 levels between 11.72Mev and (11.72 $\pm$ 1.85) Mev from resonances in Na-p- γ 41B3, 47T19, 39C8, 38G2					σ 's	
					(th n, γ) 9.58 ^m Mg	0.05 47S33
					($\sim$ 1Mev n, γ) 9.58 ^m Mg	0.6mb 49H5
Al-p-a	Q = 1.32	48E7	Mg-d-p		Na-a-p	
			Q = 5.08, 4.52, 4.10	50P2	Q = 1.72, 1.28, -0.19, -1.13	49M54
			Q = 5.03, 4.45, 4.05	49A14	Q = 1.91, -0.2	34K3 (37LB)
			Al-d-a		Q = -0.4, -2.1, -3.1	36M2 (37LB)
			Q = 6.52, 5.71, 4.94, 3.98	49P21	Mg-d-p	41P5

12 MAGNESIUM Mg

27					
12 15					
τ	9.58 ^m		43E7		
	10.0		39C3		
	10.2		35H2		
Decay scheme	48B3	β_1^- 20% ~ 0.9 s 48B3 β_2^- 80% 1.80 s 48B3 1.74 a 40M9 1.77 cc 43E7 γ_1 1.01 s 48B3 1.02 s 41I1 1.05 cc 43E7 γ_2 0.84 s 48B3, 41I1 γ_3 0.64 s 41I1 $\gamma_3/\gamma_2 < 6\%$ 48B3 $\gamma\gamma$ coincidences 48B3 $\beta\gamma$ coincidences 47B4			
Mg-d-p	f	35H2			
	Q = 4.21	49A14			
Mg-n- γ	σ	47S33			
Al-n-p	chem	35A1			
threshold ~ 2.5		50G2			
	σ	46G31, 50G2			

13 ALUMINUM Al

Neutron Cross Sections for Natural Element				25 13 12	
σ_s coh	1.5	49S12	Graphs Available σ_t 0.025-1000ev 47GIF, 50Ad 0.01-1.0Mev 47S35, 50Ad 0.001-10Mev 47GIF 0.5-4Mev 47A7 Other references on graphs and in 48WH	τ	7.3 ^S 48B22
σ_s bound	1.5	49S12			
$E_n = 0.025\text{ev}$					
σ_a	0.22 0.23	49P3 49H2			
σ_s	1.35	(48WH)			
σ_t	1.6	See graphs			
E_o	Resonances 2300ev > 10000 9100 60	49H18 49H18 47L18 48C24			
$E_n = 1\text{Mev}$					
σ_t	~2.5	See graphs		$Mg^{25}-p-n$	48B22
26 13 13				27 13 14	
τ	6.3 ^S 7.2 7.0	48B22 48W13 48P3, 48A8, 39W2, 34F1		100%	42A2
β^+	2.8 2.6 3.4	a a a	48A8 38B6 (48B27) 34F1 (48B27)	I	5/2 S 38H6 M 49L15
				μ	3.639 I 49Z2, 49B7 M 39M8
				q	0.156 M 49L15
Levels		49AH			
10 levels between 5.18Mev and (5.18 + 0.8) Mev from resonances in Mg-p- γ		39C8, 47T19		σ 's	
				(th n, γ) 2.3 ^M Al	0.21 47S33
				(~1Mev n, γ) 2.3 ^M Al	0.4mb 49H5
				(~1Mev n, p) 9.6 ^M Mg	2.8mb 46Q31
				(14Mev n, p) 9.6 ^M Mg	~30 mb 50Q2
				(~1Mev n, α) 14.9 ^M Na	0.6mb 46Q31
				See also natural element	
				Other fast n, γ ; n, p; n, α values	49B4, 48WH
Mg ²⁶ -p-n		48B22			
Al- γ -n		46B7			
threshold = 14.4		47B25			
14.0		49M17			
rel σ		48P3, 48W13			
Na- α -n		37M1, 34F1			
Mg-p- γ		47T19, 39C8			
				Levels	49AH
				0.84	Al-p-p, Mg ²⁷
				1.07	Al-p-p, Mg- α -p, Mg ²⁷ ?
				1.48 ?	Mg ²⁷
				1.79	Al-p-p, Mg ²⁷
				2.28	Al-p-p
				2.82	Al-p-p
				3.07	Al-p-p
				Al-p-p	48H59, 49B30, 48F13, 43D3, 46R12
				10 levels between 8.28Mev and (8.28 + 0.96) Mev from resonances in Mg-p- γ	47T19, 39C8
				Mg- α -p	Q = -1.82, -2.87 34D1 (37LB)

13 ALUMINUM Al

28				
13 15				
	τ	2.30 ^m	49S40, 43E7, 35A1	
		2.4	36E1	
		2.6	35M2, 36C1, 37R1	
	β^-	3.01	s 48B3	Levels in Al ²⁸
		2.75	a $\beta\gamma$ 47B4	49AH, 49P21
		3.10	a 47D2	
	γ	1.80	s 49B3, 41I1	
		1.80	ac 47B4	
Al-d-p Q = 5.45, 4.42, 3.68, 3.29, 2.84, 2.48, 2.04, 1.55, 0.98, 0.73, 0.57, 0.29, 0.01, -0.31 49P21 Q = 5.46, 4.46, 3.98, 3.31 49A14 Q = 5.79, 5.11, 3.10, 2.12, 0.84 35M2	Al-n- γ	σ	47S33	
	Si-n-p		35A1, 47B4	
	Si- γ -p		46B7	
	Mg- α -p	rel σ	47H4, 48P3	
		f, rel σ	48S35	
		Q = -1.05	34D1	
	P-n- α	chem	35A1	
		threshold ~3	45T7	
13 levels between 7.63 Mev and (7.63 + 2.8) Mev from resonances in Al-n-γ 47A7, 47S35, 47L18				

29				
13 16				
τ	6.56 ^m		49S40	
	6.7		39B9	
	6.8		48P3	
Decay scheme proposed by 49S40				
$\beta_1^- \sim 30\%$	1.4	a $\beta\gamma$	49S40	See also Si ²⁹
$\beta_2^- \sim 70\%$	2.5	a $\beta\gamma$	49S40	
γ_1	2.3	ac	49S40	
γ_2	1.2	ac	49S40	
$\beta\gamma$ coincidences			49S40	
		Si- γ -p	46B7	
		Si-n-p	σ 48P3, 47H4	
		P- γ -2p	46B7	
		Mg- α -p	48P3, 47H4	
			39B9, 49S40	

14 SILICON Si

[illegible]

15 PHOSPHORUS P

Neutron Cross Sections for Natural Element		29 15 14	
σ_a	$E_n = 0.025\text{ev}$ 0.15 48P3	τ	4.6 ^S 41W2
σ_s	10.4 37G1		
σ_t	4.3 See graphs 13.6 37G1	β^+	3.6 cc 41W2
σ_t	$E_n = 1\text{Mev}$ ~3 See graphs		
Other fast n values 48WH			
Graphs Available			
σ_t	0.02-300ev 47G1F, 50Ad 0.03-3Mev 47G1F, 50Ad	S1-p-n P- γ -2n	41W2 46B7 48P3
$\sigma(n, p)$	1.4-5Mev 45T7, 47G1F	S1-d-n	rel σ Q = -0.80 48P15

30			31		
15	15		15	16	
τ	2.18 ^m	38C2		100%	42A2
	2.55	37R1			
	2.5	48F3			
β^+	3.5 s	41M4	I	1/2 B	33A1
	3.4 a	34F1 (46B27)		S	49C31
	3.0 cc	40B1			
Levels		49AH			49AH
	1.02	Al- α -n, S1-d-n			S1-d-n
	5.64 $\pm$ 0.315	S1-p- γ	μ	1.1309	1.02 S1- α -p, S1-d-n
	5.64 $\pm$ 0.400	S1-p- γ			1.74 S1- α -p, S1-d-n
S1-p- γ		47T19		I	8.02 $\pm$ 0.355 S1-p- γ
E_γ (mean) = 5.2		47T19		S	8.02 $\pm$ 0.483 S1-p- γ
					S1-p- γ 47T19
Al- α -n	yield, σ	49H46			7 levels between 10.26MeV and (10.26 $\pm$ 6.8) MeV from resonances in
	chem	41M4			Al- α -n 36W1, 35F5, 37S8
	Q = -2.93, -3.91	48P15	(th n, γ) 14.3 ^d p	0.2	Al- α -p 32C1, 34D1
S1-p-n		40B1	(th n, γ)	0.15	
S1-d-n	Q = +3.38, +2.11	48P15	($\sim$ 3MeV n, p) 2.6 ^h S1	0.074	
P-n-2n		37F2			
	threshold = 5-7	38S14	Graphs Available		
P- γ -n	rel σ	48F3	σ (n, p) 1.4-5MeV	45T7, 47G1F	
	threshold = 12.3	49M17			
	Not produced by				
P-d-t	σ (7.5MeV d, t) $< 5 \times 10^{-6}$	49K36			

15 PHOSPHORUS P

32			33		
15 17			15 18		
T		14.30 ^d 14.35 14.07		36C1 46K28 40M7	
β	1.712 s 1.715 s 1.69 s 1.72 s 1.75 s	46S9 47P17 49L6 39L6 41W7	Average disintegration energy found to be 0.685 calorimetrically 47C16 <5x10 ⁻⁵ e ⁺ per disintegration due to pair formation 47S29 Complex e ⁻ from Pb radiator attributed to ejection of L and M e ⁻ by K X-rays. Found with both P ³² and Bi ²¹⁰ (RaE) 47S29		
No γ		36K2			
P-n- γ	σ	47S33			
P-d-p	chem yield Q = +5.9	37N1 47C9 40P5			
S-n-p	chem f Q = -0.93	35A1 46K28, 47B26 41H10			
Cl-n- α		35A1 47M31			
Si- α -p	Q = +0.44, σ	39K1			
34					
15 19					
T	12.4 ^s 12.7	46B1 40C12			
β	25% 3.2 a 75% 5.1 a	46B1 46B1			
S-n-p	chem	46B1, 40C12			
Cl-n- α	chem	46B1, 45H2			

16 SULPHUR S

Neutron Cross Sections for Natural Element			31		32	
			16	15	16	16
σ_s coh	1.2	49S12	τ	3.18 ^S 3.2 2.9	41E3 41W2 41H15, 46W13	95.06% 38N2
σ_s bound	1	49S12	β^+	3.87 cc 3.85 cc	41E3 41W2	I 0 B 3601
$E_n = 0.025$ ev						Levels 49AH
σ_a	0.47 0.52	49P3 49H2				2.25 S-p-p 4.34 S-p-p
σ_s	1.1	37G1				S-p-p 43D3
σ_t	1.6	See graphs				5 levels between 10.0MeV and (10.0+0.92) MeV from reson- ances in
Values at other energies		49H16				P-p- γ 47T19, 39C8
Resonances						σ 's
E_0	σ_0	Γ				(2.9MeV n, α) 2.9 41H10 (~1MeV n, p) 14.3 ^d P ~0.012 48G31
108kev	21.5	18				Other fast n values 48WH
205						Graphs Available
Many resonances between 0.5 and 2MeV		49W21	P-p-n 41W2 S1- α -n 41E3 S- γ -n 41H15 relo 48W13 threshold = 14.8 49M17 15.0 47B25			σ (n, p) 2-3.7MeV 47B26, 50AD 1.6-5.8MeV 48K28
Graphs Available						
σ_t	0.025-10ev 50Ad, 48R6, 47GIF 0.016-0.250MeV 49A13 0.5-2MeV 49W21					
Other references on graphs and in		48WH				

33		34		35	
16	17	16	18	16	19
0.74%	38N2	4.18%	38N2	τ	87.1 ^d 88 43H6 40L8, 41K3
I	3/2 Mic 48T13	I	0 ? 47T18	I	3/2 Mic 49C12
μ	0.6-0.9 Mic 49J9			q	+0.06 Mic 49C12(49T17)
q	-0.08 Mic 49T17			β^-	0.166 s 48A3 0.167 s 49P20 0.169 s 48B1 0.167 a 47S28
Levels	49AH	Levels	49AH 0.82 S-d-p 1.9 p ^{3/2} 3.4 Cl ^{3/2} ? P- α -p	Fermi plot straight above 1ekev 48A3	
0.79 4.15 1.90 4.42 2.17 4.70 2.85 5.11 3.15 5.63 3.88 6.30		σ 's	(th n, γ) 87 ^d S 0.26 47S33	Discussions of spectral shape 48C10, 48B1, 48A3, 49C32	
all from S-d-p				Cl ³⁵ -n-p chem 42K9 Cl-n-p chem, yield 41K3 σ 49M27, 47S33 Q = +0.52 44O4 Cl-d- α chem, yield 41K3 S-n- γ σ 47S33 S-d-p chem 39C7	
2 levels from S-n- α	48S34	S-d-p Q = 8.87, 7.85 49D28 P- α -p Q = 0.31, -1.0, -2.5, -4.5 36M2 (37LB), 36P1 (37LB)			
S-d-p 49D28, 41S15 Q = 6.48, 5.69, 4.58, 4.31, 3.63, 3.33, 2.60, 2.33, 2.06, 1.78, 1.37, 0.85, 0.18 49D28 Q = 6.82, 5.57, 4.45, 3.40, 2.29, 1.30 41S15 Cl-d- α Q = 9.1 41S14 S-n- γ E_γ (max) = 7.6 49K15					

16 SULPHUR S

36 16 20			37 16 21			
	0.0136%	49L21	τ	5.04 ^m	46B1	
	0.016	68N2		5.0	46H25	
I	0	Mic	49L21	β_1^- 10%	4.3 a	46B1
				4.0		46H25
				β_2^- 90%	1.6 a	46B1
				1.4		46H25
				γ	2.6 a	46B1
					2.75 ac	46H25
				$\beta\gamma$ coincidences		46B1
(th n, γ) 5.0 ^m S	σ^{TS}	0.14	46H35			
				Cl-n-p	chem	46B1
				S-n- γ		46H25
				A-n- α	Q = -1.8 γ, σ	46G32

17 CHLORINE Cl

Neutron Cross Sections for Natural Element			33			34				
			17	16		17	17			
σ_s coh	12.2	49S12	τ	2.8 ^S 2.4	48S20, 40H7 41W2	τ	33.2 ^m 33.0 33	48W13 48P3 38B6, 36S1		
σ_s bound	15	49S12	β^+	4.1	cc	41W2	β^+ 20% 80%	2.4 5.1	cc cc	46H1 46H1
σ_a	$E_n = 0.025\text{ev}$ 32.7 32.1	49P3 49H2						3.0 3.4	a a	38B6 (46B27) 34F1 (46B27)
σ_t	55	See graph				γ	3.4	cc		46H1
	Resonance									
E_o	1800 ev	47L18								
Assigmed to	Cl^{37}	47L18								
σ_t	$E_n \sim 3\text{Mev}$ 3.4	39Z1								
Other fast n values		48WH								
	Graphs Available									
σ_t	0.023-70 ev	47GIF	S-d-n		48S20, 40H7	P-a-n	chem			38B6, 34F1
See also		49H16	S-p-n		41W2	yield				37R1
						S-d-n	chem			46H1, 36S1
						Cl- γ -n	relo			48P3, 48W13
						Cl-n-2n	chem			37P2
						S-a	chem			40S7
						S-t-n				50K14

35			36					
17	18		17	18				
	75.4%	36N4	τ	4.4x10 ⁵ ^Y 3.6x10 ⁵ 2.0x10 ⁵ 10 ⁶	From specific disintegration rate From specific disintegration rate From n, γ yield From n, γ yield	49W15 49R11 49R11 47O3		
I	3/2 Mic	47T16	I	2 Mic	49T10	β^-	0.713 s 0.73 a 0.66 a 0.64 a	49W16 49R11, 49W15 47O3 41Q2
μ	0.8210	49P0 I 49C2, 49B7 M 40S12	Q	-0.0172 Mic	49T10	γ weak	0.10 a 0.57 a	49J8 49J8
q	-0.0795 M	49D14 Mic 49T17, 48Q22	Levels	0.96 4.81	49AH Cl ³⁵ -d-p Cl ³⁵ -d-p	bremsstrahlung or annihilation?		49J9
Levels	0.6 1.5	49AH S-a-p S-a-p				No γ unless of energy < 20kev or of low intensity		49W15
σ 's						$\beta^+/\beta^- < 10^{-4}$ 0.57 $\gamma/\beta^- < 3 \times 10^{-4}$		49W15 49J8
(th n, p) 87.1 ^d S	0.34	49M27				β spectrum has forbidden shape consistent with $\Delta I = 3$, no		49W16
(th n, p)	0.17	47S33						
(th n, γ)	0.34	44O4						
($\sim 3\text{Mev}$ n, α) 14.3 ^d P	17mb	47M31						
Other fast n values		48WH						
S-a-p	Q = -2.1, -2.7, -3.6	35H7 (37LB) 36B7 (37LB)	Cl ³⁵ -d-p	Q = 6.31, 5.35, 1.50	41S14 41Q2	Cl-n- γ	chem	41Q2
						σ		47S33, 49M27
						E_γ (max) = 9.8		49K15

18 ARGON* A

Neutron Cross Sections for Natural Element			35		36		
			18	17	18	18	
σ_a	$E_n = 0.025\text{ev}$ 0.6	43W6	τ	1.84 ^S 1.88 2.2	48S20 41E3 41W2	0.337% 0.35	50N1 47D9
σ_s	0.75	50H5	β^+	4.4	cc 41E1, 41W2		
σ_t	1.4	See graph					
E_o	Resonances > 1000ev	50H5, 49M40					
σ_t	Graphs Available 0.01-200ev 15-10,000ev	48M34, 50A4 49M40, 50A4	S- α -n Cl-p-n	chem	41E3, 48S20 41W2		

37			38			
18 19			18 20			
τ	34.1 ^d	44W2		0.063% 0.08	50N1 47D9	
K capture	44W2	Levels	49D29	Levels	49AH	
L capture	49P22	1.53	} A ³⁶ -d-p	2.15	Cl- α -p, Cl ³⁸ , K ³⁸	
		1.67		3.75	Cl- α -p, Cl ³⁸	
L capture /K capture ~0.08	49P22	2.27				
		2.56				
No γ	44W2	3.46		7 levels between 10.44MeV and		
Cl K _a X-ray	44W2	5.01		(10.44 + 0.97)MeV from resonances in		
				Cl-p- γ	47T19, 39C8	
Cl-p-n	chem, yield	} A ³⁶ -d-p				
Cl-d-2n	chem, yield		Q = 6.59, 5.06, 4.92, 4.32, 4.03,			
K-d- α	chem, yield		3.13, 1.58	49D29	Cl- α -p	Q = 0.1, -2.5, -4.2 36P1
S- α -n	chem, yield		Possibly others	49D29		
Ca-n- α	chem, yield					
	Not produced by	Cl-p-n				
K-n	44W2	Q = -1.596	48R10			
Cl- α	44W2					

* "chem" on the Argon pages indicates separation which was carried out by physical means.

18 ARGON* A

39 18 21		40 18 22		
τ	long	49H30	99.600% 99.57	50N1 47D9
4 ^m activity sometimes assigned here not found from A- γ -n K-n-p		Relative abundance of A ⁴⁰ higher in potassium minerals than in the atmosphere due to decay of K ⁴⁰		
		49A5		
		Levels	1.5 2.4	49AH K ⁴⁰ , A-p-p A-p-p
		A-p-p		47H30
		σ 's		
		(th n, γ)	0.6	43W3
		(pile n, γ)1.78 ^h A	1.2	43K6
		(~1MeV n, γ)1.78 ^h A	0.93mb	49H28
d 55 ^m Cl ?		49H30		
41 18 23				
τ	1.78 ^h 1.82		49B57 46B11,36S2	
		β^- simple	1.25 1.18 1.1	s a a
				49B57 46B11 36S2
		0.7%	2.55	a
				46B11
Levels	0.66 1.21 1.34 1.94 2.27 2.80 3.29 3.69 4.01	49D29		
		γ	1.3 1.3 1.4 $\alpha \sim 0$	ac cc cc 49B57
		γ in coincidence with 1.18 β		46B11
		A-d-p	chem, f	36S2
		A-n- γ		36S2
		σ		43K6
		K-n-p		46B11, 37H1
A-d-p	Q = 3.84, 3.18, 2.83, 2.50, 1.90, 1.57, 1.04, 0.55, 0.15, -0.17	49D29		

* "chem" on the Argon pages indicates separation which was carried out by physical means.

19 POTASSIUM K

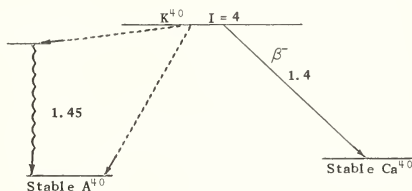
Neutron Cross Sections for Natural Element				
σ_s coh	1.5	49S12		
σ_s bound	~ 2	49S12		
	$E_n = 0.025\text{ev}$			
σ_a	2.05	49P3, 49H2		
σ_s	5.6	37G1		
σ_t	8.2	35D4		
Graphs Available				
σ_t	0.015-0.6Mev	49P23, 50Ad		
	many resonances			
	0.02-2.8Mev	47GIF		
Other references on graphs and in				
		48WH		
?			38	
			19 19	
τ	1.3^S	48L7	τ	7.5 ^m 47R3
				7.6 48P3
				7.7 37R1
				7.8 37H1
			β^+	2.53 a 47R3
				2.3 a 37R1
				2.6 a 37H1 (48B27)
			γ	~ 2.1 a coin 47R3
			39	
			19 20	
			93.08% 50N1	
			93.25 49H32	
			K^{39}/K^{41} abundance = 13.6 48W9	
			I	3/2 M 40K9
				Z 35M8
			μ	0.3905 49P0
				M 49K33
			σ^s	
			(th n, γ) $K^{40} \sim 3$ 49H48	
K- γ -2n ?		48L7	Cl- α -n	chem 37H1, 47R3
				chem, yield 37R1
			Ca-d- α	chem 37H1
			K-n-2n	37P2
			K- γ -n	rel σ 48W13, 48P3
				threshold = 13.2 49H17

19 POTASSIUM K

40
19 21

	0.0119%	50N1
	0.010	49H32
Summary of early work on K abundances		48W6
τ_{β}	16.1×10^8 y *	49F19
	15.0×10^8 **	48G8
	13.2×10^8 **	49S42
	12.0×10^8 **	48H58
	15.4×10^8 **	38B8
	7.0×10^8 ***	47B7

Radioactivity assigned to K^{40} ms 37S4



I	4	M	49D1	β^-	1.40 s	49A15	K capture/ β^-	1.9 †	47B7, 48G8
μ	-1.29	M	49D1		1.36 scin	50B8		~3 ††	48A4
					1.35 s	46D1		~3.5 †	43T1
					1.41 a	48H58, 46H7		<0.1 †††	48S15
					1.45 a	49F19		~0.02 †††	48A5
					1.3 a	47H8			
					1.7 cc	48F1			
Levels in K^{40}			49AH	β spectrum has third forbidden shape			†	From measurement of ratio of X-rays to β 's	
0.81				No $\beta\gamma$ coincidences		50B8	††	From measurement of ratio (radiogenic Ca^{40})/ K^{40} = 11 for lepidolite 2.1×10^5 years old. This ratio determines τ (K-capture) if τ_{β} is known. Assuming $\tau_{\beta} = 16.0 \times 10^8$ τ (K-capture) = 5.1×10^8 (total) = 3.9×10^8	
2.01				γ	1.45 scin	50B9		†††	From measurement of Argon content in minerals
2.56					1.47 scin	50P4			
3.3					1.54 a coin	46H7, 48H58			
3.7					1.55 a	47G7			
4.2					1.5 s	49C33			
4.8					1.5 a	47M7			
				γ 's/sec(gram of K) = 3.6	47G7, 49S31				
				E_{γ} /sec(gram of K) = 4.9 Mev	48A4				
				$\gamma/\beta^- = 0.05$	49F19				
				0.087	48H58				
				0.127	48G8				
K^{39} -d-p				$\beta^+/\gamma < 0.025$	50B9				
Q = 5.48, 4.67, 3.47, 2.92, 2.2, 1.8, 1.3, 0.7			50S3	Argon K X-ray	47B7				
A-p-n	f		48R11	X-ray	43T1				
K-n- γ	chem, σ		49H48						
$E_{\gamma}(\max) = 7.2$			49K15						

19 POTASSIUM K

41 19 22				42 19 23			
6.91% 50N1 6.75 49H32 abundance = 13.6 48W9 I 3/2 Z 36M3 M 40K9 μ 0.2148 49P0 M 40K9 Levels 1.3 A⁴¹ 5 levels between 7.80MeV and (7.80 + 1.2)MeV from resonances in A⁴⁰-p-γ 46B26 σ's (th n,γ)12.4^hK 1.0 47S33 (~1MeV n,γ)12.4^hK 2.9mb 49H5				τ 12.44^h 12.5 37H1 Decay scheme 47S8 Levels in K⁴² 0.62 1.18 1.97 2.29 K⁴¹-d-p Q = 5.12, 4.50, 3.94, 3.15, 2.83 50S3 K-d-p chem, yield 37H1 yield 46C9 K-n-γ chem 37H1 σ 47S33 Sc-n-α chem 37H1, 47B4 Ca-n-p chem 37H1 β_1^- 3.58 s 47S8 3.60 s 47P17 ~70% 3.5 a 47B4 Spectral shape consistent with $\Delta I = 2$, yes 47S8(49S41) β_2^- 16-25% 1.92 s 47S37 1.9 s 47P17 ~30% ~1.8 a 47B4 complex 47B4 γ 1.51 s 47S8 1.50 s 47P17 inhomogeneous 47B4 Possibly very weak high energy γ 47S8 β_1^- not in coincidence with any γ 47B4 Summary of early work on K⁴² 47S8 No $\gamma\gamma$ coincidences 47S37			
43 19 23				?			
τ 22.4^h 4905 β^- 0.24 s 4905 0.81 s 4905 γ ~0.4 a 4905 No β^+ 4905 A-α-p chem 4905				τ 18^m 37W1 Ca-n-p ? chem 37W1 Not produced by A-α 40W2			

20 CALCIUM Ca

Neutron Cross Sections for Natural Element			?		39 20 19	
σ_s coh	2.9	49S12	τ	4.5 ^m	37P2, 40W2	τ 1.06 ^s 43H2
σ_a	$E_n = 0.025\text{ev}$ 0.41 0.43	49P3 49H2				
σ_t	4.4	40R9				
σ_t (CaCO ₃)	5.5 cc See graph per molecule					
σ_t	$E_n \sim 2.5\text{Mev}$ 3.9	39A5				
σ_t (CaCO ₃)	Graphs Available 0.06-10,000ev	48H46	Ca-fast n	37P2, 40W2	Ca- γ -n rel ^o threshold = 15.9	48W13 49M17 47B25
σ_t	0.02-0.6Mev several resonances	49A8, 50Ad			16	
40 20 20			41 20 21		42 20 22	
96.92% 96.96	48W9 38N2		τ	?	0.64%	48W9, 38N2
			8.5 ^d activity formerly assigned here not found 47M12, 47O5			
			Levels	49AH		
			1.95	} Ca-d-p		
			2.41			
			2.96			
			3.23			
			3.49			
			3.67			
			3.86			
			6 levels between 8.28Mev and (8.28 + 0.5) Mev from resonances in Ca-n- γ			
			K-p-n			
			Q = -1.22	48R10	K- α -p	Q = -0.89, -2.3, -3.5 36P1 (37LB)
			Ca-d-p			
			Q = 6.09, 4.14, 3.88, 3.13, 2.86, 2.60, 2.42, 2.23			
				49S44, 49S43		
					Levels	49AH K ⁴² , K- α -p K- α -p
					1.5 2.6	

20 CALCIUM Ca

⁴³ 20 23			⁴⁴ 20 24			⁴⁵ 20 25		
	0.13%	48W9 38N2		2.13% 2.06	48W9 38N2	τ	152 ^d 180	47M12 40W2
	0.14					β^-	0.254 s 0.248 s 0.260 a 0.22 a	50M3 47P10 48S2 49M32
						No harder β		48S2
Levels	~ 0.4 1.0	K ⁴³ Sc ⁴³	Levels	1.33	Sc ⁴⁴	No γ		49M32, 48S2, 47P10
A- α -n	f $Q = -4.0, -5.6 ?$	38P7	(th n, γ) 152 ^d Ca	0's 0.6	47S33	Sc-n-p		48B2 40W2
						Ca-d-p	chem	40W2
						Ca-n- γ	chem	40W2
						σ		47S33
						Tl-n-a	chem	48H47
⁴⁶ 20 26			⁴⁷ ?			⁴⁸ 20 28		
	0.0032%	48W9 38N2	τ	5.8 ^d	47M12		0.179% 0.19	48W9 38N2
	0.0033		β^-	1.1	47M12			
			γ	1.3	47M12			
			Production methods not stated					47M12

20 CALCIUM Ca

49 20 29					
τ	8.5^m		49D30		
β^-	2.7	a	49D30		
γ	2.7	a	49D30		
2.5 ^h and 30 ^m activities previously assigned here probably due to impurities 49D30					
Ca ⁴⁸ -n- γ	chem		49D30		

21 SCANDIUM Sc

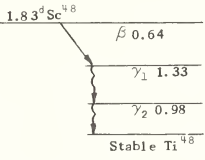
Neutron Cross Sections for Natural Element								
$E_n = 0.025\text{eV}$ σ_a 12 49F3 31 49H2 See activation σ of Sc^{45}								
41 21 20			42 21 21			43 21 22		
τ	0.87 ^s	41E3				τ	3.92 ^h 4.0	45H3 40W1
β^+	4.94 cc	41E3				β^+	0.4 a 1.1 s, a 1.4 n	40W1 45H3 40W1
						γ	1.05 s 1.0 a 1.65 a	46F1 40W1 45H3
						$\beta^+/\gamma \sim 4$		45H3
Ca-d-n		41E3				Ca- α -p	chem	45H3, 37W2
						Ca-d-n	chem	45H3
						Ca-p-n	chem	45H3
						Can be detected in presence of 3.9 ^h Sc ⁴⁴		
						45H3		

21 SCANDIUM Sc

44						45			
21 23						21 24			
τ_1	2.44 ^d	45H3	τ_2	3.96 ^h	48W13	100%		42A2	
	2.2	48W13, 40W1, 42S1		3.92	45H3				
				4.1	42S1				
IT		42S1, 40W1	K		45H3	I	7/2 S	34S1, 34K1	
γ	0.269 sc	42S1	β^+	1.45 s	42S1	μ	4.8 S	37K2	
	$\alpha = 0.07$, K/L = 8	42S1	Fermi plot not straight.						
	$\alpha = 0.5$	41H1	Spectrum complex?						
	0.28 ac	45H3		1.43 a	45H3(46B27)				
				1.5 a	40W1				
			γ	1.33 a	45H3				
			$\beta^+/\gamma \sim 1/3$		45H3				
			K X-ray		45H3				
Sc-n-2n	chem	45H3	Sc-n-2n	chem	45H3	σ 's			
Sc- γ -n	relo	48W13	Sc- γ -n	relo	48W13	(pile n, γ) 20 ⁵ Sc	10	48G16	
K- α -n	chem	45H3, 40W1	K- α -n	chem	45H3, 40W1	(th n, γ) 85 ^d Sc	>13	46B25	
Ca-d-n	chem	45H3	Ca-d-n	chem	45H3		22	47S33	
threshold = 4		42S1	Ca-p-n	chem	45H3	See also natural element			
p 3.9 ^b Sc		42S1, 40W1	d 2.4 ^d Sc		42S1, 40W1	Activation σ falls off faster than 1/v for both 20 ⁵ and 85 ^d Sc		48G16	

46									
21 25									
τ_1	20 ⁵	48G16	τ_2	85 ^d	49F2, 37W4	β_1^- 98%	0.36 s	48P2	
							0.358 s	47F2	
							0.36 s	47M9	
Additional level of Sc ⁴⁶ at 2.30Mev. See Sc-d-p below.						β_2^- 2%	1.49 s	48P2	
							1.5 a	40W1	
						γ_1	0.18 a	48G16	
							$\alpha \sim 1$	48G16	
						γ_2	1.12 s	48P2	
							$\alpha_K = 0.0004$	48P2	
							1.115 s	47F2	
							1.12 s	47M9	
						γ_3	0.89 s	48P2	
							$\alpha_K = 0.0008$	48P2	
							0.883 s	47F2	
							0.90 s	47M9	
$\gamma\gamma$ angular correlation consistent with I = 4, 2, 0 20 ⁵ Sc ⁴⁶ produced by Sc-n- γ Ti-n-p Ca- α -p Sc-d-p Ti-d- α					85 ^d Sc ⁴⁶ produced by Sc-n- γ Ti-n-p Ca- α -p Sc-d-p Ti-d- α				
		49B18			46B25, 47S33	γ_4	1.63 < E _{γ} < 2.3 in	49F5	
					46H47	1.2x10 ⁻⁵ % of disintegrations			
					40W1	$\gamma\gamma$ coincidences		48M9, 48J7	
					37W4	No K capture		47M9	
					36D7	$\beta\gamma$ coincidences only for 0.36 β^-		48M9, 48J7	
					37W3				

21 SCANDIUM Sc

47 21 26			48 21 27		
τ	3.43 ^d 3.4	49K12 46H4	τ	1.83 ^d	49K12, 46H4
β^-	0.61 a	49K12			
γ		49K12	β^-	0.64 s 0.57 a	42S1 49K12, 46H4
Level	1.3	Ca ⁴⁷	γ_1	1.33 s 1.35 s 1.34 a	46P1 43M3 46H4
			γ_2	0.98 s	46P1
			Probably softer γ 's K X-ray $\gamma/e^- \sim 14$ See also Ti ⁴⁸		
Ti ⁴⁹ -d- α	chem	49K12	V-n- α	chem	} 45H4 44H3
Ca- α -p	chem	46H4	Ca-p-n	chem	
Ti-d- α	chem	44H3	Ti-n-p	chem	
Ti-n-p	σ_{eff}	46H47	Ca-d- α	chem	
			Ti-d- α		
49 21 28					
τ	57 ^m 1h	47S33, 40W1 49D18			
β^-	2.4 a 1.8 a	49D18 37W6			
No γ		40W1			
Ca-d-n	chem	37W6, 40W1			
Ti-n-p	chem	37P2, 40W1			
Ti- γ -p	rel σ	49H4			
d 8, 5 ^a Ca		49D11			

22 TITANIUM Ti

Neutron Cross Sections for Natural Element				⁴³ 22 21		⁴⁴ 22 22			
σ_s coh	1.8	(-)	49S12	τ	0.58 ^s	48S20	τ	<1 ^m or >100 ^y from Sc-d	49B55
σ_s bound	~6		49S12						
σ_a	$E_n = 0.025\text{ev}$								
	5.8		49P3						
	5.9		49H2						
σ_s (TiO ₂)	14		37G1						
σ_t (TiO ₂)	28		46D13						
Values at other energies 46D13, 49H16									
σ_t	$E_n = 2.5\text{Mev}$								
	1.7		39A5						
Graphs Available									
σ_t	0.1-1.4Mev		50Ad	Ca- α -n		48S20			

⁴⁵ 22 23				⁴⁶ 22 24		⁴⁷ 22 25	
τ	3.08 ^h		41A2	7.95%	38N2	7.75%	38N2
	3.1		49W13	8.22	49H38	7.42	49H38
β^+	1.2	cc	41A2				
(19)*	1.00	s	49K36				
γ	(4)*	0.48	s				
	(1)*	0.80	s				
3.1 ^d activity reported from Sc-p-n (given as 21 ^d due to typographical error) probably attributable to 80 ^b Zr from Y impurity.				Levels	0.89 2.01	Sc ⁴⁶	
* relative intensities							
Ca- α -n	chem	}	41A2				
Sc-p-n	chem						
Sc-d-2n	chem						
Ti-n-2n	chem						
Ti- γ -n	rel σ		48W13				

22 TITANIUM Ti

48 22 26		49 22 27
73.45% 73.38 38N2 49H38 Stable Ti ⁴⁸ Stable Sc ⁴⁹ + α-p 8C-α-p $Q_0 = -0.3$ $Q_1 = -1.4$ $Q_2 = -2.6$ 38P6	V¹⁹⁺ compound nucleus 16^d V⁴⁸ 2mc² 1.83^d Sc⁴⁸ 2.31 0.98 8.8 MeV α Proton groups Q₀	5.51% 5.56 38N2 49H38
50 22 28	51 22 29	
5.34% 5.41 38N2 49H38 (th n, γ) ^{6m}Ti 0.14 47S33 σ's 72^d activity previously assigned here not found by Ti-n-γ	τ 6^m 47S33, 49S13 β^- 1.6 a 47S33, 49S13 γ 37W3 Ti-n-γ σ 47S33 Ti-d-p 37W3	

23 VANADIUM V

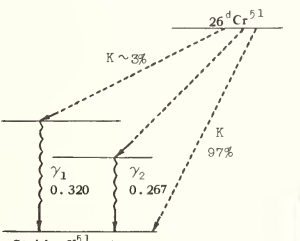
Neutron Cross Sections for Natural Element			47 23 24	
σ_s coh	<0.1	49S12	τ	33 ^m 37W3, 4201
σ_s bound	5	49S12	β^+	1.65 a 49K12 1.8 a 4201 2.0 a 37W3 (46B27)
σ_a	$E_n = 0.025$ ev 4.7 5.6	49P3 49B2	γ	49K12
σ_s	<4	37G1		
σ_t (V_2O_5)	40	46D13		
Resonance				
E_0 3370 ev		47L18		
			Tl^{47} -p-n 49K12 Tl -d-n chem 37W3 Tl -p-n chem 4201 Not produced by Tl - α , Sc- α , V-n-2n 49K12	
48 23 25			49 23 26	
τ	16.0 ^d	37W3	τ	600 ^d 39W1
See also Tl^{48}				
$\gamma/\beta^+ = 2$		46P1		
$\gamma/\beta^+ = 4$		38R2		
Sc- α -n	chem	37W3		
Tl -d-n	chem	37W3, 44B3		
Tl -p-n		44D9		
Cr-d- α	chem	37W3, 46P1		
			Tl -d-n chem 39W1	

23 VANADIUM V

50 23 27	51 23 28	52 23 29
0.25% 49H33 0.23 49L13	~100% 24A1 I 7/2 S 38K4 μ 5.15 I 49K24 Levels 0.267 Cr⁵¹ 0.320 Cr⁵¹ 1.1 Tl-α-p 38D7 4.7 Tl-α-p 38D7 σ's (th n, γ) 3.7^mv 4.5 47S33 (~1Mev n, γ) 3.7^mv 2.2mb 49H5 Other fast n values 48WH (1.6Mev p, n) 26⁶Cr 10mb 48S29 Tl-α-p 38D7 Q = 1.10, 0.00, -3.63 38D7	τ 3.74^m 47M17 3.9 37W3 β^- 1.98 a 40G3 2.7 cc 42Y1 γ 1.45 a 47M17 1.44 42K8 See also Mn⁵² $\gamma/\beta = 0.65$ 47B20 = 0.36 47M17 β/β independent of β energy 47B20 Evidence for ~0.25Mev e⁻'s not in coincidence with β's or γ's 47B20 Levels ? 2.47 V-d-p 39D7 4.70 V-d-p 39D7 V-n-γ σ 47S33 V-d-p Q = 7.80, 5.33, 3.10 39D7, 37W3 Cr-n-p 39D7 Cr-γ-p 37W3, 37P2 Mn-n-α relσ 47H4 37W3, 37P2
No vanadium X or γ activity of ~4^h found from Tl-d, Ti-α, V-fast n or Ti-p. Activity of this period previously reported by 37W3 and 40A3 possibly due to Sc⁴⁴. 49K12		

24 CHROMIUM Cr

Neutron Cross Sections for Natural Element			49 24 25		50 24 26			
σ_a	$E_n = 0.025\text{ev}$		τ	41.9 ^m	4201	4.41%	49H3	
	2.8	49P3		45	48W13	4.31	48W9	
	3.1	49H2		40	49H29	4.49	39N2	
σ_s	~ 3.6	37G1	β^+	1.45	a, cc	4201		
σ_t	7.3	47G1F	γ	0.19	a	4201		
Values at other energies		49H16		1.55	a	4201		
Resonances			γ 's $\sim$ equal intensity		4201			
E_o								
115-300ev		49H16						
4,200		49H18						
$E_n \sim 2.8\text{Mev}$								
σ_t	3.4	39A5						
Other fast n values		48WH				σ 's		
Graphs Available						(th n, γ) 26.5 ^d Cr	11	47S33
						(th n, γ)	16.3	49P4
σ_t	0.01-1000ev	47G1F, 50Ad	Tl- α -n	chem	4201			
			Cr-n-2n	chem	4201			
			Cr- γ -n	rel σ	49P5, 48W13			

51 24 27				52 24 28			
τ		26.5 ^d 26 25		40W3 48H4 49H29		83.46% 83.76 83.78	49H3 48W9 39N2
				K	45B1		
			No β^+		45B1, 48K10		
			γ_1	0.320 s	48K10, 48M6		
				0.323 sc	49K14		
			$\sim 3\%$	0.330 sc	45B1		
				$\alpha_K \sim 0.02$	45B1		
			γ_2	0.267 sc	49K14		
				0.237 sc	45B1		
				$\alpha = \infty$	45B1		
			V K_{α} X-ray		45B1, 40W3		
Ti- α -n	chem	40W3					
Cr-d-p	chem	40W3					
Cr-n- γ	σ	47S33					
V-p-n	chem	45B1					
	σ	Q = -1.534	48S29				
						Levels	1.46
							2.40
							3.13
						See Mn ⁵² for diagram	
						σ 's	
						(th n, γ)	0.73
							49P4
							Mn ⁵² , V ⁵²
							Mn ⁵²
							Mn ⁵²

24 CHROMIUM Cr

53 24 29			54 24 30			55 24 31		
9.54%	49H3		2.61%	49H3	τ	1.3 ^h	47S33	
9.55	48W9		2.38	48W9		1.6	40A3	
9.43	39N2		2.30	39N2		2.3	40D2	

25 MANGANESE Mn

Neutron Cross Sections for Natural Element				51		
				25	26	
σ_s coh	1.3	(-)	49S12	τ	46 ^m 45	38L1 48M12
σ_s bound	2.2		49S12	β^+	2.4	a 38L1(46B27)
$E_n = 0.025$ eV						
σ_a	12.8		49P3			
	12.5		49H2			
σ_s	2.3	(48WH)				
σ_t	15.5	(48WH)				
Values at other energies			49H16			
Resonances						
E_0	σ_0	Γ				
300 eV	~5,000	~10	49S1			
Scattering resonance			49S1			
$E_n \sim 2.5$ MeV						
σ_t	~3		39A5	Cr-d-n	chem	38L1
Other fast n values			48WH	Cr-p- γ	chem	39D1
				Cu-d	chem	48M12
Graph Available						
σ_t	0.015-5,000 eV		47R6, 47G1F			

52
25 27

τ_1	21.3 ^m 21	40H1 38L1	τ_2	5.8 ^d 6.2 6.5	49M20 49H29 38L1																																																		
3.7^mV⁵² 21.3^mMn⁵² 5.8^dMn K 65% γ_1 0.05% 0.39 β_2^+ 35% 0.582 β_1^+ 99.95% 2.66 γ_2 0.73 γ_3 0.94 γ_4 1.46 Stable Cr⁵²																																																							
Order of γ_2, γ_3 not established																																																							
21.3 ^m Mn produced by			5.8 ^d Mn produced by																																																				
Cr-d-2n	chem	46P1	Cr-d-2n	chem	46P1																																																		
Cr-p-n	chem, rel σ	40H1	Cr-p-n	yield	46O9																																																		
	threshold ~8.3	40H1		threshold = 8	46O9																																																		
Fe-d- α	chem	38L1	Cr-p-n	chem, rel σ	40H1																																																		
				threshold ~8.3	40H1																																																		
d 7.6 ^h Fe		48M12	Fe-d- α	chem	38L1																																																		
<table><tr><td>21.3^mMn</td><td></td><td></td><td></td><td></td></tr><tr><td>β_1^+</td><td>99.95%</td><td>2.66</td><td>s</td><td>4701</td></tr><tr><td>γ_1</td><td>0.05%</td><td>0.39</td><td>sc</td><td>4701</td></tr><tr><td>5.8^dMn</td><td></td><td></td><td></td><td></td></tr><tr><td>K</td><td>65%</td><td></td><td></td><td>46G1</td></tr><tr><td>β_2^+</td><td>35%</td><td></td><td></td><td>46G1</td></tr><tr><td></td><td></td><td>0.582</td><td>s</td><td>46P1</td></tr><tr><td>γ_2</td><td></td><td>0.734</td><td>s</td><td>46P1</td></tr><tr><td>γ_3</td><td></td><td>0.94</td><td>s</td><td>46P1</td></tr><tr><td>γ_4</td><td></td><td>1.46</td><td>s</td><td>46P1</td></tr></table>						21.3 ^m Mn					β_1^+	99.95%	2.66	s	4701	γ_1	0.05%	0.39	sc	4701	5.8 ^d Mn					K	65%			46G1	β_2^+	35%			46G1			0.582	s	46P1	γ_2		0.734	s	46P1	γ_3		0.94	s	46P1	γ_4		1.46	s	46P1
21.3 ^m Mn																																																							
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γ_1	0.05%	0.39	sc	4701																																																			
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γ_2		0.734	s	46P1																																																			
γ_3		0.94	s	46P1																																																			
γ_4		1.46	s	46P1																																																			

25 MANGANESE Mn

53 25 28		54 25 29		55 25 30	
		τ	310 ^d	38L1	100% 36S4
		K		39A2	I 5/2 S 30W1, 39F3
		No β^+		49K16	μ 3.0 S 39F3
		β^-	<0.1% 1.0 cc	49K16	
		γ	0.835 s 0.85 s Not identical with 0.845 γ of Mn ⁵⁶	44D1 38L1 43E4	
		Cr K α (?) X-ray		38A2	
		Xy coincidences		44D1	σ 's (th n, γ) 2.6 ^b Mn 13.0 44D10 (~1Mev n, γ) 2.6 ^b Mn 3.5mb 49H5 Other fast n values 48WH, 49B4
		V- α -n		38L1	(1.2Mev p, n) 4 ⁱ Fe 0.5mb 48S29
		Cr-d-n	chem	38L1	
		Cr-p-n		44D9	
		Fe-d- α	chem	38L1	
		Mn- γ -n		49H17	
		threshold = 10.2		49H17	

56 25 31					
τ		2.59 ^h 2.62	38L1 48P3	β_1^- 15% 20%	0.73 s 0.75 s 43E4 46S2
		2.6 ^b Mn ⁵⁶		β_2^- 25% 30%	1.05 s 1.04 s 43E4 46S2
		β_3 60% 2.86		β_3^- 60% 50%	2.86 s 2.81 s 43E4 46S2
		β_1 15% 0.73		γ_1	2.13 s 43E4
		β_2 25% 1.05		γ_2	1.81 s 43E4
		γ_1 2.13		γ_3	0.845 s 46S2
		γ_2 1.81		γ_3	0.822 s 46S2
		γ_3 0.845		γ_3	0.866 s 42K8
		Stable Fe ⁵⁶		γ_3	0.845 s 43E4
See also Co ⁵⁶				γ_3	0.822 s 46S2
$\gamma \sim 2.7$ Mev in $\sim 0.23\%$ of disintegrations			47L23	γ_3	0.866 s 42K8
Levels of Mn ⁵⁶ at 1.07, 1.77, 2.48, 3.61, 4.38 from Mn-d-p, assuming most energetic protons go to ground state.			47M26	γ_3	0.845 s 43E4
Mn-n- γ		σ	44D10	γ_3	0.822 s 46S2
Mn-d-p		chem	38L1	γ_3	0.866 s 42K8
Fe-d- α		chem	38L1	γ_3	0.845 s 43E4
Fe- γ -p		rel σ	48P3	γ_3	0.822 s 46S2
Fe-n-p		chem	38L1	γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
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				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8
				γ_3	0.845 s 43E4
				γ_3	0.822 s 46S2
				γ_3	0.866 s 42K8

26 IRON Fe

Neutron Cross Sections for Natural Element			51 26 25		52 26 26	
σ_s coh	10.3	49S12			τ	7.8 ^h 48M12
σ_s bound	11.4	49S12			β^+	~ 0.55 a 48M12
$E_n = 0.025\text{ev}$						
σ_a	2.39	49P3				
	2.46	49H2				
σ_s	11	(48WH)				
σ_t	13	(48WH)				
$E_n = 1\text{Mev}$						
σ_t	~ 2.5	See graphs				
Graphs Available						
σ_t	0.013-1,000ev	48H46			Cu-d	chem, rel σ 48M12
	0.013-2,000ev	50Ad,				
		49H18				
	0.025-15Mev	47GIF				
	0.02-0.5Mev	48B24				
	0.02-1.4Mev	50Ad			p 21 ^{Mn}	48M12
	1-40Mev	50Ad				
53 26 27			54 26 28		55 26 29	
τ	8.9 ^m	44H5, 38L6	5.90%	49H3	τ	2.91 ^y 49B35
			5.81	48W9		~ 4 48V8
β^+		49P5			K	46B5
					No β^+ or e^-	46B5
					2x10 ⁻⁵ γ 's with average energy 0.07 per disintegration	46B5
					No γ	46P4
					Mn K X-ray	46B5
					Levels	0.935 1.41 Co ⁵⁵
Fe- γ -n	rel σ	49P5, 48W13			Mn-p-n	chem 46B5
	threshold = 13.8	49M17				$\sigma, Q = -1.16$ 48S29
	14.2	45B12			Mn-d-2n	48H35
Cr- α -n	chem	38L6			Fe-d-p	chem 39L8
Fe-n-2n	chem	38L6				d 18.2 ^h Co 41L1

26 IRON Fe

56 26 30			57 26 31			58 26 32		
91.52%	49H3		2.245%	49H3		0.33%	49H3	
91.64	48W9		2.21	48W9		0.34	48W9	
			μ	~ 0	S	49B20, 49G6		
Levels	0.845	Mn ⁵⁶ , Co ⁵⁶	Levels	0.014	Co ⁵⁷	Level	0.81	Co ⁵⁸
	2.66	Mn ⁵⁶		0.131				
	2.98	Mn ⁵⁶						
	Others ?	Co ⁵⁶						
			Fe-n- γ		49K15			
			E_{γ} (max) = 7.8					
						(th n, γ) 47 ^d Fe	σ 's	47S33
							0.36	4804
						(th n, α)	≤ 1.5 mb	44H6
59 26 33			60 26 34					
τ	46.3 ^d	47S22						
	45.5	43G3						
	46	49H29						
Probable decay scheme		42D1						
46.3^dFe⁵⁹ β_1 50% 0.26 s β_2 50% 0.46 s γ_1 1.1 s γ_2 1.3 s Stable Co⁵⁹ 7/2								
Fe-n- γ	σ	47S33						
Co-n-p	chem	36L6, 46I2						
Co-d-2p		48T4						
Fe-d-p	chem	36L6, 42D1						
Cu-d	chem	48M12						

27 COBALT Co

Neutron Cross Sections for Natural Element			55 27 28		
σ_s coh	1.76	49S12	τ	18.2 ^h 18.0	37D1 41L1
σ_s bound	~5	49S12	18^hCo⁵⁵ 2mc² K₁ 6% K₂ 34% β₁⁺ 30% 1.01 s β₂⁺ 30% 1.50 s γ₁ 18% 0.477 s α ~ 0.0025 γ₂ 82% 0.935 s α ~ 0.0004 strong 0.8 cc γ₃ 18% 1.41 s α ~ 0.0001 weaker 1.2 cc γ₄ weak 0.095 sc Probably not in Co⁵⁵ 57 coincidences support decay scheme.		
$E_n = 0.025\text{ev}$					
σ_a	34 36	49P3 49H2			
σ_s	~5	37G1			
σ_t	~41 Extrapolation	49B2			
Resonances					
E_o	σ_o	Γ			
108	12, 500	2			
115					
Scattering resonance	47H23, 49S1, 49H16				
$E_n = 2.6\text{Mev}$					
σ_t	2.6	39A5			
Graphs Available					
σ_t	0.03-0.7ev 0.15-10,000ev	49B2 47W8, 47G1F, 50Ad			
Fe-d-n	chem	49D2			
Fe-p-γ	p 2.91 ^h Fe	41L1 41L1			

56 27 29			57 27 30		
τ	80 ^d 72	42C1 41L1	τ	270 ^d	41L1
β^+	1.50 s	43E2	270^dCo⁵⁷ 2mc² β 0.26 γ₁ 0.014 0.11^{μs} γ₂ 0.119 0.11^{μs} γ₃ 0.131 0.014 Stable Fe⁵⁷		
γ 1.0*	0.845 s	} 43E2			
0.5	1.26 s				
0.2	1.74 s				
0.1	2.01 s				
0.2	2.55 s				
0.2	3.25 s				
* Relative Intensities					
Fe-d-2n		41L1	Fe-d-n	chem	41L1
threshold > 5.5		41L1	Fe-p-γ		41L1
Fe-α-np		41L1			
Ni-d-α		42C1			
					β ⁺ 0.26 41L1 γ ₁ 0.014 0.11 ^{μs} delay } 49H34 α < α γ ₂ 0.119 s 43E4 0.117 s 42P1 α _K ~ 1 K/L = 7 42P1 γ ₃ 0.131 s 43E4 0.130 s 42P1 α _K ~ 1 K/L = 7 42P1 Level in Co ⁵⁷ 1.97 ? NI ⁵⁷

27 COBALT Co

58				59			
27		31		27		32	
τ_1	9.3 ^h	49S29	τ_2 72 ^d	41L1	100%		41M5
IT		49S29	K 85.5%	46G1	I	7/2 S	35K5, 34M2
γ	0.023	49S29	β^+ 14.5%	46G1 44D1	μ	2.7 S	35M7
			0.47				
			γ 0.81	44D1			
					Levels	1.1 1.3	Fe ⁵⁹
					σ^1s		
					(th n, γ) 10.7 ^m Co	0.66	47S33
					(th n, γ) 5.3 ^y Co	22	47S33
					(1Mev n, γ) 10.7 ^m Co	0.23mb	49H5
		Mn- α -n		} 41L1			
		Fe-d-n					
		Fe- α -pn					
		Fe-p- γ					
		NI-n-p	chem	44D1			

60			
27		33	
τ_1	10.7^m	41L1	τ_2
			5.2^y
			5.3
			49B35
			41L1
Stable Ni⁶⁰			
Angular correlation of γ's consistent with I = 4, 2, 0			
48B18			
10.7^mCo^{60} produced by			
Co-n- γ	σ	47S33	
Co-d-p	chem	45D1	
Ni-n-p		41L1, 37H3	
10.7^mCo^{60}			
β_1	<10%	1.56 s	47P10
		1.35 s	42N1
		1.25 s	45D1
γ_1	>90%	0.0589 sc	49C1
		0.056 s	45D1
5.2^yCo^{60}			
β_2	0.31	s	47M10, 45D1
γ_2	1.172 s	49H23, 49L8	
	1.169 s	49J2	
	1.16 s	47P10, 47M10	
γ_3	1.332 s	49L8	
	1.331 s	49J2, 49H23	
	1.32 s	47P10, 47M10	
Cross-over γ's per disintegration			
< 2×10^{-6} 49M8			
< 2×10^{-7} 49F5			
γ with 1.63 ± 2.3 per 10^5 disintegrations 49F5			
Lifetime of γ's < 2×10^{-9} s 49D22			
< 3×10^{-9} 49B39			
No $\beta\gamma$ angular correlation 49G21			
5.2^yCo^{60} produced by			
Co-n- γ	σ	47S33	
	E_γ (max) = 7.7	49K15	
Co-d-p	chem	45D1	
Ni-d- α		41L1	
Cu-n- α		46M4	

27 COBALT Co

61 27 34			62 27 35					
τ	1.75 ^h 1.74 1.83	49P1 48P3 49H20	τ_1	13.9 ^m	49P1	τ_2	1.6 ^m	49P1
β^-	1.3	a 49P1	β^-	2.3	a 49P1	β^-		49P1
No γ		49P1	γ	1.3	a 49P1	γ		49P1
			$\beta/\gamma \sim 1$		49P1			
Ni-d-2n Ni ⁶¹ -n-p Ni ⁶⁴ -p- α Ni ⁶⁴ -d- α n Cu-n-n α Ni- γ -p Cu- γ -2p	ms chem chem chem chem rel σ rel σ	} 49P1 48P3 48P3	Ni ⁶² -n-p	chem	49P1	Ni ⁶² -n-p Ni ⁶⁴ -d- α		49P1 49P1
63 27 36			64 27 37					
			τ	4-5 ^m	49P1			
						</		

28 NICKEL Ni

Neutron Cross Sections for Natural Element			57 28 29			58 28 30		
σ_s coh	13.5	49812	τ	36 ^h 37 34	49M38,38L3 44H5 48H4		67.76% 67.92 69.18	48W9 48I6 48E6
σ_s bound	17.2	49812	β^+	0.73 a 0.67 a	49M38 38L3			
$E_n = 0.025\text{ev}$								
σ_n	4.5	49F3,49H2	γ	1.97 a coin 1.9 a, scin, γn	49M38 50F2			
σ_s	17.5	47T14	$\gamma\gamma$ coincidences indicate 2 γ 's in cascade.		49M38			
σ_t	~ 18.5 ce	48H46	$\beta\gamma$ coincidences indicate only one β .		49M38			
E_0 3600ev			Coincidence between hard γ and annihilation γ		50F2 50F2	σ 's		
$E_n = 1\text{Mev}$			Co K X-ray			(th n, γ)	4.2	49P4
σ_t	~ 3.5	47G1F,50Ad	Fe- α -n chem	50F2, 49M38, 42N2		σ_t graph 0.025-0.5ev		49B2
Graphs Available			Ni-n-2n chem	42N2		B1g σ_s due to this isotope		
σ_t	0.01-1000ev	48H46	Ni- γ -n rel	49P5, 48P3, 44H5		σ_s coh	26	49S12
	0.01-3000ev	50Ad	threshold = 11.7	49C2		σ_s bound	25	49S12
See also Ni ⁵⁸ and Ni ⁶⁰								
59 28 31			60 28 32			61 28 33		
τ	(2-3) $\times 10^{5\gamma}$ 1.5 $\times 10^5$	49F6 49B38		26.16% 26.22	48W9 48I6		1.25% 1.16	48W9 48I6
Both results from yield measurements				25.82	48E6		0.97	48E6
K		49F6, 48B13						
No β^-		48B13						
Co K X-ray		49F6						
			Levels	1.33 1.5 2.50	Co ⁶⁰ Cu ⁶⁰ Co ⁶⁰			
			σ 's					
			(th n, γ)	2.7	49P4	(th n, γ)	1.8	49P4
			σ_t graph 0.025-0.5ev		49B2	(6.1Mev p, n) ^{61}Cu	0.11	38S5
Ni ⁵⁸ -n- γ chem		49F6	σ_s coh	1.0	49S12			
Co-d-2n chem		48B13	σ_s bound	1.0	49S12			
Ni-n- γ		48B13						

28 NICKEL Ni

62 28 34		63 28 35				64 28 36	
3.66%	48W9	τ	85 ^y	49B38		1.16%	48W9
3.71	48I6		From yield			0.98	48I6
3.28	48E6					0.75	48E6
		β^-	0.063 pc	49W10			
			~0.05 a	49F6			
			0.05 a	48B13			
		No β^+		49W10			
		No γ observed (<1%)		49F6, 49W10			
Levels	0.6				Level	1.34	Cu ⁶⁴
	1.3						
	σ 's					σ 's	
(th n, γ)	14.8	49P4			(th n, γ) 2.6 ^h Ni	2.6	48H32
(6.1Mev p, n) 10 ^m Cu	0.15	38S5				1.5	47G33
					(~1Mev n, γ) 2.6 ^h Ni	6.7mb	49H5
		Ni ⁶² -n- γ	chem	49F6, 48B13			
		Ni ⁶¹ -n- γ	chem	49W10, 48F4			

65 28 37				66 28 38	
τ	2.564 ^h		49S2	τ	56 ^h
	2.6		49M38, 48H4, 38L3		48H4, 48G1
Proposed decay scheme	49S21				
β_1	29%	0.60 s	49S21	β^-	48G1
		0.44 a, $\beta\gamma$	49M38		
β_2	14%	1.01 s	49S21		
β_3	57%	2.10 s	49S21		
		1.97 a	49M38		
		1.9 a	48S8, 38L3		
γ_1		0.37 s	49S21		
γ_2		1.12 s	49S21		
γ_3		1.49 s	49S21		
		1.64 a	49M38		
Cu ⁶⁵ -n-p	chem	46S8		B1 fission	48G1
Ni ⁶⁴ -n- γ		46C3, 46G15		As-d	48H4
Ni ⁶¹ -n- γ	chem	42N2			
Zn-n- α		37H3			
Ni-d-p		42N2			
			$\beta\gamma$, $\gamma\gamma$ coincidences support decay scheme		
				p 4.34 ^m Cu	49G13, 48G1

29 COPPER Cu

Neutron Cross Sections for Natural Element			58 ? 29 29		
σ_s coh	7.3	49S12	τ	3 ^S	49A1
σ_s bound	7.7	49S12			
σ_a	$E_0 = 0.025\text{ev}$				
	3.66	49P3			
	3.63	49H2			
σ_s	7	(48WH)			
σ_t	~ 11 ce	48H46			
Resonance					
E_0					
3,000ev ?		48H46			
570		47L18			
Scattering resonance 500-1000ev, 48H57					
140 (12 ^B Cu), 100 (5 ^B Cu)		48C24			
Graphs Available					
σ_t	0.015-10,000ev	50Ad,	$N1^{58}\text{-p}$		49A1
		48H46			
	0.015-100ev	47GIF			
	See also	49H16			
	0.025-14Mev	47GIF			
	0.2-1.5Mev	50Ad			
59 ? 29 30			59 ? 29 30		
τ	10 ^m	47L7	τ	81 ^S	47L7, 39D1
	7.9	39D1			
β^+		39D1	β^+		39D1
$N1\text{-p-n}$	chem	39D1	$N1\text{-p-n}$	chem	39D1
$N1^{58}\text{-p}$	chem	47L7	$N1^{58}\text{-p}$		47L7
$N1\text{-d}$		42C2			
60 29 31			60 29 31		
τ	24.6 ^m	47L7	τ	24.6 ^m	47L7
	~ 20	48H4			
Possible decay scheme			47L7		
$N1^{60}\text{-p-n}$	ms, chem		$N1^{60}\text{-p-n}$	ms, chem	
	threshold = 5.1				
$N1^{60}\text{-d-2n}$			$N1^{60}\text{-d-2n}$		
$N1^{58}\text{-alpha-pn}$			$N1^{58}\text{-alpha-pn}$		

29 COPPER Cu

61			62			63		
29 32			29 33			29 34		
τ	3.33 ^h	48C8	τ	9.9 ^m	49P15, 48P3		69.09%	48H40
	3.3	48H4		10.1	47L7		68.94	48W9
	3.4	49B16, 37T1, 37R1		10.5	37H3		68.39	44E1(48H40)
							67.66	47D13(48H40)
K		49B16, 38A2	β^+	2.83 s	49B17	I	3/2	32R2
β^+	1.205 s	48C8		2.92 s	49H42			
	1.225 s	48B2		2.92 a	50K1	μ	2.2215	49P0
$K/\beta^+ = 0.32$		49H21	γ	0.56 a	47T9	I		49B7, 49Z2, 48P11
0.55		49B16				q	-0.1 S	36S7
No γ		46B2, 38G1				Levels	0.96	2n ⁶³
			$N1^{62}$ -p-n		47L7		1.89	
Spectral shape	4904		Cu- γ -n rel σ		48P3		2.60	
β spectrum probably complex	50B4		threshold = 10.9	45B12, 49M17				
$N1^{61}$ -p-n	47L7		$N1$ -p-n σ, f	38S6		σ 's		
$N1$ -p-n σ	38S6		$N1$ -p- γ threshold < 3	38S6		(th n, γ) 12.8 ^h Cu 2.8	47S33	
threshold > 3	38S6		Co- α -n chem	37R1		(th n, γ) 4.3	49P4	
threshold = 2.7	39D1		Cu-n-2n chem	37H3		(14MeV n, γ) 12.8 ^h Cu 0.009	49H5	
$N1$ -d-n chem	37T1		threshold ~ 12	40S10, 38S14		(14MeV n, 2n) 10 ⁶ Cu 0.48	49F14	
$N1$ - α -p chem	37R1		threshold = 11.2, σ	49F14			0.32	49P15
Cu- γ -2n rel σ	48P3		Cu-e ⁻ -e ⁻ n f	48S3		For other fast n values		
$N1$ -p- γ chem	39D1		Cu-d-t $Q = 5.2$	46H7		see 48W1, 49B4		
			d 9.5 ^h 2n	48M12		(6.1MeV p, n) 38 ^m 2n 0.093	38S6	
						(14MeV d, 2n) 38 ^m 2n 0.30	46C6	

64
29 35

τ	12.88 ^h	49S2						
	12.8	48W13, 36V2						
K_1	12.8 ^h Cu ⁶⁴							
γ^*	1.34							
K_2	0.57							
β^+	0.65							
	Stable Zn ⁶⁴							
	Stable Ni ⁶⁴							
* Coincidence measurements show this line follows K capture 46B3								
$N1$ -p-n chem, σ	39D1, 38S6							
threshold = 2.1-2.3	39D1							
2.5	38S6							
Zn-n-p chem	37H3							
Cu-d-p	36V2							
Cu-n-2n	37H3							
Cu-n- γ $E_{\gamma}(\max) = 7.7$	49K15							
Cu-p-pn threshold ~ 13	46R2							
Cu- γ -n	44H5							
threshold = 10.2	49M17							
rel σ	48W13, 49P5							
β^+	0.657 s	48C2						
	0.644 s	47P10						
	0.659 s	46B3						
β^-	0.571 s	48C2						
	0.570 s	47P10						
	0.578 s	46B3						
γ	1.34 s	48K10						
	$\alpha < 5 \times 10^{-3}$	48M28						
	1.35 s	47D7						
	1.20 a coin	46B3						
Spectral shapes		49W1						
β^-/β^+	2.08	47P10						
	2.0	48C2, 49B16						
	2.1	46B3						
K/β^+	2.65	49B16						
	1.75	49H21						
	3.5	48C14						
γ/β^+	0.05	49B16						
$N1 K_{\alpha}, K_{\beta}$ X-rays		49C4						

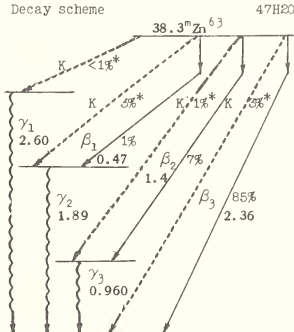
29 COPPER Cu

65			66			67		
29	36		29	37		29	38	
	30.91%	48H40	τ	4.34 ^m	49S2	τ	56 ^h	49G13
	31.06	48W9		5.05	46M7		61	48H4
	32.34	47D13(48H40)						
	31.61	44E1(48H40)	β^-	2.58	40G3	β^-	0.5	a 49G13
I	3/2	32R2		2.9	cc, KU			
μ	2.3796	49P0	γ	1.32	a 46M7			
		I 49B7, 49Z2, 48P11						
q	-0.1	36S7						
Levels	1.12	Ni ⁶⁵ , Zn ⁶⁵						
	1.49	Ni ⁶⁵						
	σ 's							
(th n, γ)	2.1	49P4						
(th n, γ) 4.3 ^m Cu	1.8	47S33						
(14MeV n, γ) 4.3 ^m Cu	0.006	49H5	Cu-n- γ	σ	47S33	B1 fission		49G13
For other fast n values see		49B4,	Cu-d-p		46M7	AS-d		48H4
		48WH	Zn-n-p		37H3			
(14MeV d, 2n) 250 ^d Zn	0.51	46C5	Ga-n- α		37C1			
			d 56 ^h Ni		49G13, 48G1			

30 ZINC Zn

Neutron Cross Sections for Natural Element			62		
			30	32	
σ_s coh	4.3	49S12	τ 9.5 ^h 48M12 9.2 49H42 10 49H14		
σ_s bound	4.2	49S12			
$E_n = 0.025\text{ev}$			K 90% 49H42 β^+ 10% 0.665 s 49H42 γ 0.0418 s 49H42		
σ_a	1.0	49P3			
	1.1	49H2			
σ_s	3.6	(48WH)	Other references on graphs and in 48WH		
σ_t	4.5	(48WH)			
Resonances			Cu-d-3n or Cu-d-5n chem 48M12 Zn- γ -2n relcr 49H44		
E_o	>300ev	49H16			
	480 strong	48H45	p 9.9 ^u Cu 48M12		
	800 possible				
	3100				
	14000				
480ev resonance assigned to Zn ⁶⁸ (n, γ) 52 ^m Zn ⁶⁹ $\Gamma \sim 4$ 48C24					
Scattering resonances observed 48H57					
$E_n = 1\text{Mev}$					
σ_t	~ 4	See graphs			

63

			30 33		
τ			38.3 ^m	48W13, 38S5	
			38	39B5, 39D1	
			39	49H14	
Decay scheme					
			β_1^+ 1% 0.47 s 47H20		
			β_2^+ 7% 1.40 s 47H20		
			β_3^+ 85% 2.36 s 47H20		
			2.3 s 41T1		
			2.3 a 39D1 (46B27), 38S5		
			γ_1 2.60 s 47H20		
			γ_2 1.89 s 47H20	Zn-n-2n chem threshold = 9-10 37H3, 37P2	
			γ_3 0.960 sc 47H20	Cu-p-n f 39D1, 38S5	
			$\alpha \sim 1.8 \times 10^{-4}$ 47H20	threshold = 4.1 38S5	
			Cu K X-ray 47H20	3.6 39D1	
			Hard secondary γ found from absorption of β^+ in Pb. Ascribed to hard annihilation γ since intensity is greater than expected intensity from bremsstrahlung 47H20	N1- α -n 37R1	
				Zn- γ -n relcr threshold = 11.8 49H44, 49P5, 48W13	
				11.6 49H17	
				Cu-d-2n f 46C5	
				threshold = 6.5 46C9	
				~ 7 40L4	
				rel yield 48M12	

30 ZINC Zn

64 30 34	65 30 35	65 30 35
48.87% 49H3 48.89 48L5, 48H40 Possible levels or level groups from n groups in Cu-d-n 49G5 σ's (th n, γ) ^{250}Zn 0.51 47S33 (th n, p) $^{12.8}\text{Cu}$ $< 10^{-5}$ 49M27	τ 250^dZn⁶⁵ 2mc² 51% β 0.32 46% 1.11 Stable Cu⁶⁵ 3/2 Zn-d-p chem 39L2 Zn-n-γ chem 39S2 σ 47S33 Cu-p-n chem 39L2 threshold = 2.16 48S33 Cu-d-2n chem 39L2, 38F1 f 48C5 yield 48C9 threshold = 4.6 48C9	250^d long β^+ 2.8% 47Z2 2.2 48G2 0.32 s 47P1 γ 46% 1.11 s 49J2 1.14 s 42D3, 43M4 Cu X-ray 38A2 Xy coincidences show 46% of K captures go to 1.11 level 48G2 γ's of 0.45, 0.65, and 1.0 cc 40W4
66 30 36	67 30 37	68 30 38
27.62% 49H3 27.81 48L5 27.82 48H40 Possible levels or level groups from n groups in Cu-d-n 49G5 Level 1.32 Cu⁶⁶ σ's (~4Mev n, p) $^{4.3}\text{Cu}$ 3.7mb 40D8	4.12% 49H3 4.07 48L5 4.14 48H40 I 5/2 S 37L7, 48A6 μ 0.9 S 37L7 Levels 0.093 Ga⁶⁷ 0.390 0.570	18.71% 49H3 18.61 49L5 18.54 48H40 σ's (th n, γ) $^{13.8}\text{Zn}$ 0.89 49H5 (th n, γ) ^{52}Zn 0.085 49H5 (~4Mev n, γ) $^{13.8}\text{Zn}$ 0.007 49H5 (~4Mev n, γ) ^{52}Zn 0.013 49H5 E₀ (n, γ) ^{52}Zn = 500ev 48C24 Γ = 1.7-5.5ev 48C24

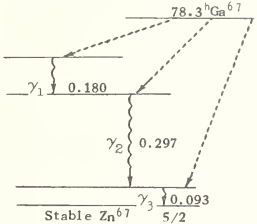
30 ZINC Zn

69				70			
30		39		30		40	
τ_1	13.8 ^h 14	39L2 48H4		τ_2	52 ^m 51 57	49H17 48H4 39L2	
				0.69% 49H3 0.620 48L5 0.617 48H40			
γ	0.439 sc 41H1, 41G1 $\alpha \sim 0.01-0.1$ 41H1 0.450 44N7 $\alpha = 0.06$ 44N7			β^-	0.86 a 39L2(46B27) 1.0 a 39K4		
No $\beta\gamma$ coincidences 39K4				(th n, γ) 2.2 ^m Zn σ 's 0.085 49H5 0.086 46H25			
Zn-d-p	chem	39K4		Zn-d-p	chem	39K4	
Zn-n- γ	chem	39L2		Zn-n- γ	chem	39L2	
σ		49H5		σ		49H5	
Ga-d- α	chem	39L2		Ga-d- α	chem	39L2	
Ga-n-p	chem	39L2		Ga-n-p	chem	39L2	
				Zn ⁷⁰ - γ -n		49H17	
				threshold = 9.2		49H17	
71				72			
30		41		30		42	
τ	2.2 ^m	46H25		τ	49 ^h ~ 50	50s1 48H4	
β^-	2.1	46H25		β^- 95%	0.3 a 50s1		
γ		46H25		5%	1.6 a 50s1		
				γ		50s1	
Zn-n- γ	σ	46H25		Fission	chem	50s1	
Ge-n- α		46H25					
				p 14.26 ^h Ga		50s1	
73				74			
30		43		30		44	
τ	< 2 ^m			τ		50s1	

31 GALLIUM Ga

Neutron Cross Sections for Natural Element			63 31 32		
σ_a	$E_n = 0.025\text{ev}$ 2.8 3.1	49P3 49H2			
σ_t	~ 19	42L1			
Resonances Scattering resonance in both iso- topes in range 100-500ev			48H57		
64 31 33			65 31 34		
τ	48 ^m	38B4	τ	18.5 ^m	39V2
β^+		38B4	γ	0.054 sc 0.117 sc	39V2 39V2
			Assignment of 0.117 γ to this activity doubtful		
Zn-p-n	chem, f threshold = 4.1	38B4 38B4	Zn-d-n	chem	39V2
			Zn-p- γ		39V2
			66 31 35		
			τ	9.4 ^h 9.2 10	38B4, 37R1 37M2 48H4
			β^+	3.9 a	37M2 (46B27)
			Cu- α -n	chem, f	37M2, 38B4
			Zn-p-n		38B4
			(Not obtained with p's <3.5)		
			Zn-d-Zn		42C2
			d 2.5 ^b Ge		49H29

31 GALLIUM Ga

67				68			
31		36		31		37	
τ		78.3 ^h 83		68 ^m		37R1, 48P3, 48H4	
		γ_1 weakest 0.180 s 41H1 0.187 s 42C2 γ_2 0.297 s 41H1 0.302 s 42C2 0.292 s 41O1 γ_3 strong 0.093 s 41H1 $\alpha=2, K/L=8$ 41H1 0.094 s 42C2 Additional γ of 0.174 found 42C2		β^+		1.9 a 37R1 1.97 a 37M2	
Zn X-ray		38A2		Cu- α -n chem, f		37R1, 37M2	
Zn-d-n chem		38G2, 39V2		Zn-p-n chem, f		38B4	
Zn- α -p chem		38M1, 48M32		threshold = 3.7		38B4	
Zn-p-n		39V2		Zn-d-n chem		38G2, 39V2	
Zn-d-2n		42C2		Ga-n-2n chem		37P2	
d 21 ^m Ge		48H29		threshold = 6-7		38S14	
				Ga- γ -n		39B6	
				rel yield		48P3	
				Ge- γ -pn rel yield		49P5	
				Ge-d- α chem		41S2	
				d 250 ^d Ge		48H4	

69				70				71			
31		38		31		39		31		40	
60.2%		48I3		τ		20.3 ^m		39.8%		48I3	
60.0		49H3				20		40.0		49H3	
I		3/2 S 32J1, 33C2		β^-		1.65 s 48H23		I		3/2 S 32J1, 33C2	
		M 48B17				1.62 a 47B13				M 48B17	
		Z 40R6				1.68 cc 39S9				Z 40R6	
μ		2.012 48P9, 48B17 (49P0)		γ		48H23		μ		2.556 48P9, 48B17 (49P0)	
		2.11 Z 40R6								2.69 Z 40R6	
q		+0.2318 48B17 (49D14)						q		+0.1461 48B17 (49D14)	
		0.20 40R3								0.13 40R3	
Level		1.22 0e ⁶⁹									
σ 's				Zn-p-n chem, f		40D1, 39V2		σ 's			
(th n, γ) 20 ^m Ga		1.4 47S33		threshold = 1.6		40D1		(th n, γ) 14 ^h Ga		3.4 47S33	
		1.5 49H5		Zn- α -p chem, rel yield		38M1					
(~1Mev n, γ) 20 ^m Ga		23mb 49H5		Ga-n- γ σ		47S33					
				Ga-n-2n		37P2					
				Ga- γ -n		39B6					
				rel yield		48P3					
				Ge-n-p chem		41S2, 45G2					

72			74		
31 41			31 42		
τ 14.25^h 50s1 14.1 39G2 Decay scheme proposed from spectrometer results 45H23 Figures in parentheses represent intensities relative to the 0.83 line Ga-d-p chem 38L6 Ga-n-γ chem 50s1 σ 47S33 Ge-n-p chem 50s1, 41S2 Fission chem 50s1, 48BP d 49^h2n 50s1			Decay scheme proposed from spectrometer results 48M17 β^- coincidences 48J7 $\beta\gamma$ and $\gamma\gamma$ coincidences 47M29 Average γ energy per $\beta = 2.6$ 47B22 Only 2.51MeV γ produces D-γ-pn 49B25 *Only line converted 48M1, 48H23		
73 31 42 τ 5.0^h 50s1 β^- 1.4 a 50s1 No γ 50s1 Ge-n-p 50s1 Ge-γ-p rel yield 49P5 Fission chem 46PP d $< 2^m$2n ? 46PP			No long-lived activity produced by Ge⁷⁶-d-α 48M32 No Ga with $\tau > 1^d$ found in fission 50s1		

32 GERMANIUM Ge

Neutron Cross Sections for Natural Element						66 32 34		
σ_s coh	8.5	49S12				τ	$\sim 2.5^h$	49H29
σ_s bound	8.5	49S12						
σ_a	$E_n = 0.025\text{ev}$ 2.2 3.5	49P3 49H2						
σ_t	~ 6 ce	47W8						
E_o 95ev	Resonance $\sigma_a \Gamma^2$ 800	47W8						
Graphs Available								
σ_t	0.015-5000ev	47GIF, 47W8				Ge-d-p5n		49H29
						p 9.4 ^hGa		49H29
67 32 35			68 32 36			69 32 37		
τ	21^m	49H29	τ	250^d ~ 195	49H29 38M1	τ	39.6^h 40 36	48M32 49H29 44H5
β^+		49H29	K		48H4	K 67%		48M32
						β^+ 33%	1.0 a 1.22 a 1.2 a	48M32 38M1 (46B27) 41S3
						γ	1.22 a	48M32
						X-ray		48M32
						This activity previously confused with 40 ^hAs		
						Ge- γ -n	rel yield	44H5
						Ga-d-2n	chem	48M32
						Zn-a-n	chem, yield	38M1
						Ga-p-n		48D8
Ge-d-p4n		49H29	Zn-a-2n	chem, yield	38M1	Ge-n-2n	chem	48M32, 41S2
			AS-d-a5n	chem	48H4	Not produced by		
				Not produced by		Ge-d-p		48M32
			Ga-d		48M32	Ge-n- γ		49M28
p 78.3 ^hGa		49H29		p 68 ^hGa	48H4		Not d 80 ^hAs	49H14

32 GERMANIUM Ge

70 32 38				71 32 39				72 32 40			
	20.55%	47I13		τ	11.4 ^d	48H4, 48M32			27.38%	47I13	
	20.65	48H35			11	49H29			27.43	48H35	
I	0	Mic	49T9	K		44S5, 48M32, 49M28		I	0	Mic	49T9
				No particles		44S5, 47S33, 48M32					
				No γ		48M32					
				Ga K X-ray		47S33, 48M32		Levels	0.68	As ⁷² , Ga ⁷²	
									$\tau=0.29\mu s$	49M29	
									0.83	Ga ⁷²	
									1.45	Ga ⁷²	
									others ?	As ⁷² , Ga ⁷²	
(th n, γ) ^{11d} Ge	σ 's										
	~ 0.5	47S33		Ga-d-2n		48M32					
				Ge-d-p	chem	48M32					
				Ge-n- γ	σ	47S33					
				As-d- α 2n	chem	48H4					
				Not found from Ge- γ -n		44H5					
				d 50 ^h As		48H27					
73 32 41				74 32 42				75 32 43			
	7.61%	47I13			36.74%	47I13		τ	82 ^m	48M32	
	7.86	48H35			36.34	48H35			89	41S3	
I	9/2	Mic	49T9	I	0	Mic	49T9	β^-	1.2	a	41S3
q	-0.2	Mic	49T9						1.1	cc	41S2
								No γ			48M32
								X-ray			41S3
Levels	0.052	As ⁷³		Level	0.582 ?	As ⁷⁴					
	0.1										
				(th n, γ) 82 ^m Ge	σ 's						
					0.4	47S33		Ge-n- γ	chem	41S2	
								Ge-d-p	chem	41S3, 41S2	
								Ge-n-2n	chem	41S3, 41S2	
								Ge- γ -n	rel yield	49P5, 48W13,	
										44H5	
								As-n-p	chem	48M32	
								Se-n- α	chem	41S3, 41S2	

32 GERMANIUM Ge

[illegible]

33 ARSENIC As

Neutron Cross Sections for Natural Element			68 33 35		69 33 36	
σ_s coh	5	49S12				
σ_s bound	7-8	49S12				
	$E_n = 0.025\text{ev}$					
σ_a	4.1	49P3				
	5.5	49H2				
σ_s	7.1	37G1				
σ_t	9	37F2				
Values at other energies		49H16				

33 ARSENIC As

73 33 40			74 33 41			75 33 42		
τ	76 ^d 90 100	48M31 39S10 43E3	τ	17.5 ^d 19.0 16.8	48M31 48H4 48M33	100%		37N2
K		48M31, 43E3	K	35%	42E4	I	3/2 S 33C1, 32T1, 33R1 Mic	48D8
No β^+		48M31	β^+	35%	0.95 s 0.9 cc	μ	1.5 S	36S5
γ	0.052 sc α large, K/L = 5 0.1 a $\alpha = 0$	43E3 43E3 48M31 48M31	β^-	15%	0.72 s 1.40 s 1.3 cc	q	+0.3 S	36S5
Ge K X-ray		48M31	γ	0.588 $\alpha \sim 0$ 0.582 Follows K and β^+	s s s 42E4 41D1 42E4	Levels	several low	Se ¹⁵
Ge ⁷⁰ - α -p		48M31	Fission	chem	49G13	σ 's		
Ge-d-n	chem	43E3, 48M31	As- γ -n		48M33, 49O2	(th n, γ) ²⁷ As	4.2	47S33
			threshold = 10.3		49O2	(th n, γ)	4.1	49P3
			As-n-2n	chem	38C3	(~1Mev n, γ) ²⁷ As	5.5	48H2
			Ga- α -n	chem	48M31		0.023	49H5
			Ge-d-n	chem	48M31, 42I1	For other fast n values see		49B4, 49H1
			Ge-p-n		44D9			
			Se-d- α	chem	40F3			

76											
33 43											
τ											
			26.8 ^h				42W1				
			26.3				40M4				
			26.1				48P8				
Proposed decay scheme			49M3								
			β_1^-	7%	0.4	s	49M3	γ_3	weak	1.78 s	48W2
			β_2^-	19%	1.4	s	49M3	weak	1.70 s	47S9	48M6
				15%	1.29	s	47S9		1.84 s		
			β_3^-	21%	2.56	s	49M3	γ_4	weak	2.15 s	48M6
				25%	2.49	s	47S9				
			β_4^-	54%	3.12	s	49M3	Cross-over γ	2.3 < E $_{\gamma}$ < 2.76	48M36	
				60%	3.04	s	47S9				
			γ_1		0.567	s	49M3	$\beta^+/\beta^- < 0.1\%$		48W2	
					0.557	s	48W2	< 0.03%		47B8	
					0.55	s	47S9	< 0.5%		49M3	
					0.57	s	48M6	High $\gamma\gamma$ coincidence rate		40M4	
AS-n- γ			chem		48P8			Summary of early work		48P8	
			σ		47S33						
AS-d-p					38C3						
Ge-p-n					48Y8						
Se-n-p			chem		39S10						
Se-d- α			chem		40F3						
Se- γ -p			rel σ		47H4						
Br-n- α					38C3						

33 ARSENIC As

77 33 44			78 33 45			79 33 46		
τ	40 ^h	50s2	τ	90 ^m 80 65	50s2 38C3 39S10			
β^-	0.7 a	50s2	β^- 70% 30%	1.4 a 4.1 a	50s2 50s2			
No γ		49M28	γ	0.27 a	39S10			
Level	0.5	Ge ⁷⁷						
Fission	chem	50s2, 48SP	Fission	chem Br-n- α Se-n-p	50s2 39S10 39S10			
	d 59 ⁵ Ge d 12 ^h Ge Not p 17.6 ⁵ Se	47A1 49M28, 48M32, 50s2 49F10		d 2.1 ^h Ge	50s2			
80 33 47			81 33 48					
			τ	< 10 ^m	49G15	No As found in fission with $\tau > 3^d$	50w2, 5011	
			Fission					

34 SELENIUM Se

Neutron Cross Sections for Natural Element			69		70	
			34	35	34	36
σ_a σ_s σ_t Values at other energies $E_n \sim 3\text{Mev}$ σ_t Other fast n values	$E_n = 0.025\text{ev}$ 12.1 12.5	49P3 49H2			τ 44 ^m β^+ As-d chem p 52 ^m As which has no active Ge daughter	48H4 48H4 48H4 49H14
71			72		73	
34	37		34	38	34	39
			τ 9.7 ^d K As-d-5n chem p 28 ^h As	49H14 48H4 48H4 48H4	τ 6.7 ^h 7.1 K $\sim 50\%$ $\beta^+ \sim 50\%$ 1.29 a γ ? Ge- α -n chem As-d-4n chem Not produced by As-d-2n	48H4 48C7 48C7 48C7 48C7 48C7 48H4 48C7

34 SELENIUM Se

74 34 40				75 34 41			
				T	127 ^d	48C7	
					120	48H4	
					125	50g20	
					115	47F8	
I	0 ?	Mic	49S7	K	47F8, 50g20	As K ⁺ X-ray	47F8, 50g20
				No β^+	47F8		
				γ	49T2	48J13, 48J6	
					0.067		
					0.076	0.077	
Level	0.582 ?		As ⁷⁴		0.099 ?	0.099	
					0.123	0.124	
					0.137	0.139	
						0.203	
					0.267	0.269	
					0.283	0.281	
						0.308	
(th n, γ) 127 ^d Se	22	47F8, 47S33			0.405	0.405	
	26	50g20					
				Note:	0.123 and 0.283 = 0.408		
					0.137 and 0.287 = 0.404		
				No delayed $\beta\gamma$ coincidences	49M26		
						Ge- α -n	chem 48C7
						As-p-n	44D9
						As-d-2n	chem 48C7, 42K5
						Se-n- γ	chem, σ 47F8, 50g20
						d 1.7 ^d Br ? 125 ^d activity	
						found after Se ⁷⁴ -p	48W8

76 34 42				77 34 43				
				T	17.5 ^s	4904, 47A1	7.50%	49H3
							7.58	48W9
I	0 ?	Mic	49S7	IT		48G17	I	1/2 ? Mic 49S7
								>1/2 S 49M11
				γ	~0.15	a		
					0.15	ac		
				Se K X-ray		48G17		
Levels	0.567		As ⁷⁶				Levels	0.7 Br ⁷⁷
	1.8		As ⁷⁶ , Br ⁷⁶ ?					1.45 49G4
	2.7		As ⁷⁶					
	others ?		Br ⁷⁶					from γ excitation curve
(th n, γ) 17.5 ^s Se	~7		47A1					
				Se-n- γ	σ	47A1		
				Se ⁷⁶ -n- γ		48G2, 47D10		
				Se- γ		49G4		
				Not d 40 ^b As		49F10		

34 SELENIUM Se

78				79				80			
34		44		34		45		34		46	
	23.61%		49H3	τ	6.5×10^{-17}		49P14		49.96%		49H3
	23.52		48W9		$> 7 \times 10^6$				49.82		48W9
					1f β energy	$> 30 \text{ keV}$	50g1				
I	0 ?	Mic	48S7					I	0	B	3401
Levels	0.046	}	Br ⁷⁸					Levels	?		Br ⁸⁰
	0.108										
	0.27		As ⁷⁸								

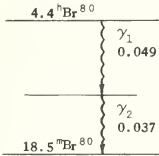
34 SELENIUM Se

83 34 49				84 34 50			
τ_1	67^s	47A1		τ_2	25^m 30	50K1 40L3	
β^-	3.4 a	47A1		β^-	1.5 a	46PP	
γ		47A1		γ	0.17 a 0.37 a 1.1 a	} 46PP	
Fission		50g2		Fission		46SP 46PP	
Se-n- γ	chem, σ	47A1		Se-d-p	chem	40L3	
				Se-n- γ	chem, σ chem	47A1 40L3	
p 2.4^h Br		47A1		p 2.4^h Br		50K1	
No long lived Se other than Se ⁷⁹ produced in fission		50w3, 50g1					

35 BROMINE Br

Neutron Cross Sections of Natural Element			75 35 40			76 35 41		
σ_s coh	5.7	48S12	τ	1.7 ^h	48W8	τ	15.7 ^h	48H27
σ_a	$E_n = 0.025\text{ev}$ 6.4 9.1	48P3 48H2	K	$\sim 81\%$	48W8	β^+	3.15 s	48H27
σ_s	7	37G1	β^+	$\sim 19\%$ 1.6 a	48W8	γ	2 a	48H27
E_o	Resonance <115ev	48H16	No γ		48W8	e^-	0.18 s	48H27
σ_t	$E_n = 2.5\text{Mev}$ 2.7	38A5	Se ⁷⁴ -d-n		48W8	As- α -3n	chem	48H27
			Se ⁷⁴ -p- γ		48W8			
			p 127 ^d Se ? 125 ^d activity found after Se ⁷⁴ -p 48W8					
77 35 42			78 35 43			79 35 44		
τ	57.2 ^h 58	48H27 48W8	τ	6.4 ^m 6.3	37S2 48W13		50.57% 50.51 50.5	48H3 48W9 48W3
K	95%	48W8	β^+	2.3 a	37S2	I	3/2 S Mic	32T2, 40T2 47T16
β^+	5% 0.36 a, s 0.36 s	48W8 48H27	γ	0.046 sc 0.108 sc	39V2 39V2	μ	2.0999 I M	49Po 49Z2, 47P16 47B24
γ	0.7	48H27				q	+0.28	47T15
						Level	0.2	Kr ⁷⁹
Se ⁷⁴ - α -p		48W8	As- α -n	chem	37S2	σ^1s (th n, γ) 4.4 ^h Br 8.9 48H5		
Se ⁷⁶ -d-n		48W8	Se-d-n	chem	37S2	(th n, γ) 18 ^m Br 8.1 47S33		
As- α -2n	chem	48H27	Se-p-n	chem	38B4	(th n, γ) 18 ^m Br 3.0 49H5		
			Br- γ -n	rel σ	38B5, 48W13	($\sim 1\text{Mev}$ n, γ) 4.4 ^h Br 2.8 47S33		
			threshold = 10.7		49M17	($\sim 1\text{Mev}$ n, γ) 18 ^m Br 0.014 49H5		
			Br-n-2n		37S2	Other fast n values 0.030 49H5		
			threshold = 9-13		38S14			

35 BROMINE Br

80			
35		45	
τ_1	4.4 ^h 4.5	38B4 37S2	τ_2 18.5 ^m 37S2
		γ_1 0.049 sc 39V2 $\alpha=\infty$ 40G6 chemical effects $\alpha=\infty$ 49H15 chemical effects $\alpha=57$ 40D3 assuming $\alpha=\sigma, K/L=7.3$ 44B7 0.047 cc 41S4 $\alpha=1$ K/L=10 41S4 (assuming no conversion of other γ)	
Se ⁸⁰ -p-n chem 46W8 threshold ~ 3.1 38B4 Se-d-2n 46W8 Se-a-p 46W8 Br-d-p chem 37S2 Br-g-n rel σ 46W13, 39B5 Br-n-2n 37P2 Br-n-g chem 37S2 σ 49H5, 47S33	γ_2 0.037 sc 39V2 $\alpha=0.64$ K/L=6.8 44B7 0.037 a 40G6 $\alpha=1$ 40G6 0.037 cc 41S4 $\alpha \sim 2$ 40D3	β^- 2.0 a 46C25 complex 2.3 a 37S2 (46B27) 2.0 s 36A1 β^+ 3% ~ 0.7 a 47B6 ~ 0.8 s 46W8 1.0% 1.0 s 49D19 β^- and β^+ ft values $\sim$ equal 49D19 γ >0.6 a 40D3 <0.5 a 37S2	
Relative amounts of isomers produced by different reactions 39B5		Se-p-n chem 36B4 threshold ~ 2.9 36B4 Br-d-p chem 37S2 Br-g-n rel σ 46W13, 39B5 threshold = 10.2 49M17 Br-n-2n 36S13, 37P2 Br-n-g rel σ , chem 49F15 chem 37S2 σ 49H5, 47S33 d 4.4 ^h Br 39S3, 40D3, 41S4	
81			
35		46	
49.43% 49H3 49.49 46W9 49.5 46W3			
I	3/2 S 32T2, 40T2 Mic 47T16		
μ	2.2633 49P0 I 49Z2, 49B7, 47T16 M 47B24		
q	+0.23 47T16		
σ 's (th n, γ) ^{81}Br 2.3 47S33 (~ 1 Mev n, γ) ^{81}Br 0.017 49H5 Other fast n values 46WH			

35 BROMINE Br

82									
35 47									
τ		35.5 ^h 33.9 36		49T6 37S2 35K1		K <5% No X-ray found 41R1			
		35.5 ^h Br ⁸²				β^- 0.465 s 41R1			
		0.067 γ_5 ? γ_6 ~0.048				γ_1 0.547 s 41R1			
		Stable Se ⁸²				γ_2 0.787 s 41R1			
						γ_3 0.14% 1.7-2.0 γ_n 49M8			
						γ_4 1.35 s 41R1			
						γ_5 0.067* ac 44B7			
						γ_6 ~0.048* ac 44B7			
						γ 's photo conv. rel. int. 49S20			
						0.553 0.547 0.68			
						0.613 0.608 0.78			
						0.685 0.692 0.42			
						0.772 0.766 1.00			
						0.826 0.823 0.13			
						1.045 1.031 0.18			
						1.317 1.312 0.14			
						*Assuming K conversion. No e ⁻ e ⁻ or β e ⁻ coincidences observed 44B7			
Se-p-n chem		38B4, 41R2							
Se-d- Σ n chem		37S2							
Br-n- γ chem		37S2							
σ		47S33							
Br-d-p chem		37S2							
threshold ~3		44C1							
Rb-n- α chem		37S2							
Fission chem		50f1, 48SP, 49G13							

35 BROMINE Br

86 35 51			87 35 52			88 35 53		
			τ	55.6 ^s 55.0 56.1	48H33 47R2 49S14	τ	15.5 ^s	49S14
			β^-	55% ~2 a 45% ~8 a	40S3 49S15 49S15	β^-		49S14
			Delayed neutron emitter		47S7			
			$\overline{E}_n$	0.25 0.3	48H33 46B22			
			γ	>3 a	49S15			
			Delayed n's in ~2% of disintegrations		50I2			
			Fission	chem	40H12, 48SP	Fission	chem	49S14
			p 78 ^h Kr		43B1, 43S1	p 3 ^h Kr		49S14
89 35 54								
τ	4.51 ^s 4.3	47S10, 46PP 46S28	No Br with $\tau > 3^d$ found in fission			50KI		
β^-		46PP, 47S10						
Delayed neutron emitter		47S10						
$\overline{E}_n$	0.43 a	46PP						
Fission	chem	47S10						
Mass 87-90 from fission fragment range		47S10						

36 KRYPTON* Kr

Neutron Cross Sections for Natural Element			77 36 41			78 36 42		
σ_a	$E_n = 0.025\text{eV}$ 0.045	44W11	τ	1.1^h	48W7		0.342% 0.36%	47L2 47D9
σ_t	24	42R3	K	$\sim 70\%$	48W7			
σ_s	6.7	50H5	β^+	$\sim 30\%$ 1.7 a	48W7			
			γ		48W7			
			$\text{Se}^{74}\text{-}\alpha\text{-n}$	chem	48W7			
						(th n, γ) 34^hKr	$\sigma^1\text{s}$ 0.26	50h2
79 or 81 36			79 36 43			80 36 44		
τ	13^s	40C6	τ	34.5^h 34	40C6 48W7		2.228% 2.25	47L2 47D9
γ	0.187 sc	40C6	K	98%	48W7			
			β^+	2% 1.0 a ~ 0.6 a 70% ~ 0.9 a 30%	48W7 50h2 50h2			
			γ	0.2 a	50h2			
						Level	~ 0.5	Br^{80}
Br-p-n		40C6	Kr-d-p	chem	41C2			
			$\text{Se}^{76}\text{-}\alpha\text{-n}$	chem	48W7			
			Br-d-2n	chem, f	44C1			
			yield		46C9, 44C1			
			threshold =	5.3	46C9, 44C1			
			Kr-n- γ	chem, σ	50h2			
			Br-p-n	chem	40C6			

* "chem" on the Krypton pages indicates separation which was carried out by physical means.

38 KRYPTON* Kr

81 or 79 36			81 36 45			82 36 46		
τ	55 ^s	40C8				11.50%	47L2	
						11.57%	47D9	
γ	0.127 sc	40C6						
			Level	0.8	Rb ⁸¹	Levels	?	Br ⁸² , Rb ⁸²
Br $\rightarrow$ p-n		40C8						
Se $\rightarrow$ a-n ?		39K1						
83 36 47			84 36 48					
τ	1.88 ^h	40L3	11.48%		47L2	57.02%	47L2	
	1.9	46R7	11.44		47D9	57.14	47D9	
γ	0.029 sc	} 41H1	I	9/2 S	49K21, 38K2			
	0.046 sc		μ	-0.968 M	46K5			
	K/L = 1		q	+0.15 S	49K21, 38S10			
Se $\rightarrow$ a-n	chem	41C2				(th n, γ) 4.4 ^h Kr	0.096	50h2
Kr $\rightarrow$ d	chem	41C2				(th n, γ) 10 ³ Kr	0.063	50h2
Kr $\rightarrow$ γ		45W3				(~1Mev n, γ) 4.4 ^h Kr	1.9mb	49H28
Kr $\rightarrow$ n γ		45W3				(~1Mev n, γ) 10 ³ Kr	<8mb	49H28
Kr $\rightarrow$ n-n		46R7						
Fission	chem	46PP						
d 2.4 ^h Br		40L3						

* "chem" on the Krypton pages indicates separation which was carried out by physical means.

Nuclear Data, National Bureau of Standards Circular 499

82

36 KRYPTON* Kr

85				86			
36 49				36 50			
τ	4.36 ^h 4.5 4.4 4.6	49K13 50h2, 37S2 48W7 48R7		τ	$\sim 10^7$	47T6, 50h1	
β^-	1.0 a 0.75 a 0.85 a	50h2 49K13 43B2		β^-	0.74 a	50h1	17.43% 17.24
γ	0.17 a 0.37 a	50h2 50h2		No γ		50h1	47L2 47D9
Fission	ms chem	49K13 50h2					
Se- α -n	chem	48W7					
Kr-d-p	chem	41C2		Fission	ms chem	47T6 50h1	
Kr-n- γ	σ	50h2					
Rb-n-p	chem	43B1		Kr-n- γ	σ	50h2	
Str-n- α	chem	43B1					
d ^{85}Br		43B1, 43S1					
							σ 's (th n, γ) ^{78}Kr 0.061 50h2 ($\sim 1\text{MeV}$ n, γ) ^{78}Kr 2.4mb 49H28
87				88			
36 51				36 52			
τ	78 ^m 74 75	49K13 37S2 43S1		τ	2.77 ^h 3 2.8	49K13 40H4, 39L11 40G5	
β^-	3.2 a ~ 4 a	49K13 43B2		β^-	~ 0.5 a 2.4 ? a 2.4 a 2.5 cc KU	49K13 49K13 48J20 42W1	
				γ		49K13	
Neutrons emitted following ^{86}Br disintegration		Br^{87}		Distribution of nuclear recoils indicates β 's and neutrinos emitted in same direction		46J3	
(th n, γ)	σ 's < 470	50h2, 45S17					
Fission	ms chem	49K13 43B1, 43S1		Fission	ms chem	49K13 40G5, 40H10	
Kr-d-p	chem	37S2					
Rb-n-p	chem	43B1					
Kr-n- γ	σ	50h2					
d ^{86}Br		43B1, 43S1		p 17.8 ^m Rb		40G5, 40H10	
							p 15.4 ^m Rb 40G5, 40H10 p 53 ^d Br 40G5, 50d1

* "chem" on the Krypton pages indicates separation which was carried out by physical means.

36 KRYPTON* Kr

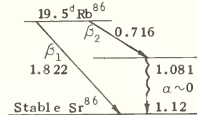
[illegible]

* "chem" on the Krypton pages indicates separation which was carried out by physical means.

37 RUBIDIUM Rb

Neutron Cross Sections for Natural Element			80 37 43		81 37 44	
σ_s coh	3.8	49S12			τ	5.0 ^h 49R1
σ_s bound	5.5	49S12				
σ_a	$E_n = 0.025\text{ev}$ 0.70	49P3			K $\sim 70\%$	49R1
σ_t	12	42L1			$\beta^+ \sim 30\%$	0.9 a 49R1
					γ	0.8 a 49R1
					e^-	0.2 s 49R1
					K X-ray	49R1
					Br- α -2n	ms, chem 49R1
					Br- α -4n	chem 49R1
					Kr daughter not observed	49R1
82 37 45			82 ? 37 45 ?		83 37 46	
τ_1	6.3 ^h 6.5	49R1 40H11	τ_2	20 ^m 40H11		
K $\sim 85\%$		49R1				
$\beta^+ \sim 15\%$	0.9 a	49R1				
γ	1.0 a	49R1				
X-ray		49R1				
Note γ 's of Br ⁸²						
Br- α -n	ms, chem	49R1	Br- α -n	chem	40H11	
Br- α -3n	chem	49R1		Not produced by		
Kr-d-2n	chem	40H11	Kr-d		40H11	

37 RUBIDIUM Rb

84 37 47			85 37 48					86 37 49			
τ	$\sim 40^d$	47B8	72.8%					36N5	τ	19.5^d 18	48W13, 41H2 37S2
β^+		47B8	I	5/2	S	33J1, 33K1 36M1					
K		49G13			M	40M11		β_1^-	1.822	s 48Z2	
K X-ray		49G13	μ	1.349		49P0 49B7, 49C2 I M		Stable Sr^{86}	1.12	a 48J7	
			Levels ?	0.17 0.37 0.510		$\text{Sr}^{85}, \text{Kr}^{85}$ Kr^{85} Sr^{85}		β_1^-	80% 1.822 67% 1.8 1.60	s 48Z2 a 48J7 s 42H1	
				$\sigma^{\text{r}}\text{'s}$		(th n, γ) 19.5^dRb 0.7 ($\sim 1\text{Mev n}, \gamma$) 19.5^dRb 0.023	47S33 49H28	β_2^-	20% 0.716 33% 0.56	s 48Z2 a 48J7	
Br-n- γ		47B8						$\beta\gamma$ angular correlation		49F16	
Sr-d- α		47B9						Indicates I (Rb^{86}) = 2			
								Rb-n- γ	chem	37S2, 38S6	
									σ	47S33	
								Rb- γ -n		44H5	
									rel σ	48W13	
								Sr-d- α	chem	41H2	
								Fission	chem	50F2	

87						88					
37 50						37 51					
	27.2%	36N5	τ	$6.0 \times 10^{10} \text{ y}$ 6.3×10^{10} 5.8×10^{10}	49K28, 48H41 38J8 46E2	τ	17.8^m 17.5 18		40G5 42W1 39H4		
I	3/2	S 33J1, 33K1 Z 36M1 M 40M11	β^- or e^-	0.13 0.25 0.144 0.56 <0.01	s 41O3, 39L1 35K4 s 46S1 cc 48F10 a 48H41	β^-	5.0 5.1 2.5	a cc cc	40G5 (46B27) 42W1 42W1		
μ	2.742	49Po I 49B7, 49Z2 M 39K7	γ	0.034 0.053 0.082 0.102 0.129	sc sc sc sc sc	γ			49K13		
			βe^- coincidences		48H41						
	σ 's					(th n, γ)	σ 's	< 200	45S17		
	(th n, γ) 17.6 ^m Rb	0.12 47S33									
	(~1Mev n, γ) 17.6 ^m Rb	1.8mb 49H29									
						Rb-n- γ	chem o		37P2, 37S2 47S33		
						Fission	chem		39H3, 40G5, 42W1, 40H10		
							d 3^b Kr		39L11, 40H10		

37 RUBIDIUM Rb

89 37 52			90 37 53			91 37 54		
τ	15.4 ^m 15.5	40G5 40H10	τ	short	50d2	τ	short	40H9, 50d1
β^-	4.5	a 40G5 (46B27)						
Fission	chem	43H4	Fission	chem	50d2	Fission	chem	50d1
	d 2.6 ^m Kr p 53 ^s Sr	43H4 40G5		d 26 ^s Kr p 26 ^s Sr	50d2 50d2		d 9.6 ^s Kr p 57 ^s Y	50d1 50d1
92 37 55			93 37 56			94 37 57		
τ	short	50b2, 50d1	τ	short	50d1, 50d2, 50b2	τ	short	50d1, 43H9
Fission	chem	50b2, 50d1	Fission	chem	50d1, 50d2, 50b2	Fission	chem	50d1, 43H9
	d 2.4 ^s Kr p 3.5 ^h Y	50b2, 50d1 50b2, 50d1		d 2.3 ^s Kr p 10 ^h Y	50d1, 50d2, 50b2 50d1, 50d2, 50b2		d 1.4 ^s Kr p 16.5 ^m Y	50d1, 43H9 50d1, 43H9

37 RUBIDIUM Rb

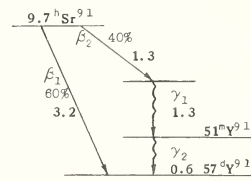
95 37 58	96 37 59	97 37 60
		τ short 50d1 Fission chem 50d1 d $1-2^5\text{Kr}$ 50d1 p 17^hZr 50d1 See also 50g2
>90 37 τ 80^S 40H4 Fission chem 40H4		

38 STRONTIUM Sr

Neutron Cross Sections for Natural Element			84 38 46	
σ_s coh	4.1	49S12	0.56%	36N3
σ_s bound	9.5	49S12	0.55	48W9
$E_n = 0.025\text{ev}$				
σ_a	1.2	49P3		
	1.5	49H2		
σ_s	9.5	37G1		
85 38 47			86 38 48	
τ_1	70 ^m	40D5	9.86%	36N3
			9.75	48W9
γ	~0.17 sc	40D5		
		K		40D1
		No β^+		49T14
		γ	0.510 sc	49T14
			0.8 a	40D5
		Auger e's from Rb L and M shells		
			Level	1.08 Rb ⁸⁶
				49T14
			σ 's	
			(th n, γ) 2.7 ^h Sr	1.3 47S33
			assuming 15% internal conv.	
Rb-p-n	chem	40D5		
		Rb-p-n chem		40D5
		Rb-d-2n chem		49T14, 42O3

38 STRONTIUM Sr

87			88					
38 49			38 50					
τ	2.75 ^h	40D5	7.02% 6.96	38N3 48W9	82.56% 82.74	38N3 48W9		
γ	0.37 sc 0.386 sc $\alpha = .18, K/L \sim 7$	40D6 41H1 41H1	I μ	9/2 S -1.1 S	38H5 38H5	I 0 S		
Sr K X-ray		40D5	Levels	0.37 others ?	2.75 ^h Sr ⁸⁷ Rb ⁸⁷	Levels 1.85 2.76	Y ⁸⁸	
Sr-d-p	chem	40D5	(~2.8 Mev n, n) 2.7 ^h Sr	0.3	40R4	(th n, γ) 53 ^d Sr (~1 Mev n, γ) 53 ^d Sr	5mb 2.1mb	47S33 49H28
Sr-n- γ		47S11						
Sr ⁸⁷ -n-n	σ	40R4						
Zr-n- α	chem	40S8						
Sr-e ⁻ -e ⁻		45W2						
Sr-X		45W2						
Sr-p-p(?)		40D5						
Rb-p-n	chem	40D5						
d 80 ^h Y		40D5						

89			90			91		
38 51			38 52			38 53		
τ	53 ^d 55 54.5	50N3 38S8 48G6	τ	25 ^y 23	50G3 50N4	τ	9.7 ^h 10	50F3 48H4
β^-	1.50 s 1.463 s 1.5 s	49S10 49L6 50N3, 47R1	β^-	0.537 s 0.531 s 0.61 s 0.6 a	49J1 49B11 48M8 50G3			
β spectrum shape consistent with $\Delta I = 2$, yes		49L6, 49S10	β spectrum shape consistent with $\Delta I = 2$, yes		49B11, 49J1			
No γ		49S10, 38S8, 50N3	No γ		50G3, 48PP			
(th n, γ)	σ 's < 110	45S17	(pile n, γ) 9.7 ^h Sr	σ 's ~ 1	49S11			
Fission	ms	48H25	Fission	ms	48H25			
Sr-n- γ	chem	38S8						
Sr-d-p	chem	38S8						
Zr-n- α ?	chem	40S8						
Y-n-p		38S3						
Fission	chem	49G13, 50N3						
d 15 ^h Rb		40G5, 46G6, 40H10	d 25 ^h Kr		46PP	d 9.8 ^s Kr		
			p 61 ^h Y		50N4, 46PP	p 80% 57 ^d Y 40% 51 ^m Y		
						Zr-n- α chem 43S3 Fission chem 40H4, 46PP, 48SP, 49G13 46PP 50F3 50F3		

38 STRONTIUM Sr

92 38 54	93 38 55	94 38 56
τ 2.7^h 41G4 β^- 41G4 Fission chem 41G4, 43H9, 50b2 d 2.4⁵Kr 50b2, 40H4 p 3.5^hY 50k5, 41G4, 43H9	τ 7^m 39L10 β^- 39L10 Fission chem 39L10, 43H9 d 2.3⁵Kr 42H8, 39L10 p 10^hY 43H9	τ ~2^m 43H4 Fission chem 43H4, 50d1 d 1.4⁵Kr 43H9 p 16.5^mY 43H9
95 38 57	96 38 58	97 38 59
		τ short 50d1 Fission chem 50d1 d 1-2⁵Kr 50d1 see also 50g2

39 YTTRIUM Y

Neutron Cross Sections for Natural Element								
σ_a	$E_n = 0.025\text{ev}$ 1.38	49P3						
σ_s	<14	37G1						
σ_t	~4	42B4						

39 YTTRIUM Y

88				39 49			
τ_1			105 ^d 104		4939, 40D5 4702	τ_2	2.0 ^h 3938
				β^+ 0.19% 0.83 48P13 γ_1 ~1% 43Q4 2.76 s 48P13 γ_2 ~99% 43Q4 0.908 s 48P13 $\alpha = 2.7 \times 10^{-4}$ 48P13 0.9 4605 0.95 41R3 γ_3 1.853 s 48P13 $\alpha = 1.3 \times 10^{-4}$ 48P13 1.89 s 41D4 1.92 cc 41R3 1.87 γn 41S5 1.9 4605 $\gamma\gamma$ angular correlation consistent with $I = 2, 1, 0$ 48B18 β^+ 1.65 a 4605 1.2 cc 37S3			
Y-n-2n	ms		48H25	Sr-p-n	chem		40D5
	chem		42H2, 4605	Y-n-2n	chem		4605
Sr-p-n	chem		40D5	Sr-d-n	chem		39S8
Sr-d-2n	chem		40P1, 43Q4		Not produced by		
threshold = 6, yield			46C9	Y-fast n's			49S9
				Sr-d			
				Rb-a			
89				90			
39 50				39 51			
100%			39D5	τ	61 ^h 65		46B25 50N4
I	1/2	S	49C17	β^-	2.180 s 2.25 s 2.23 s 2.35 s		49L6 49B11 49J1 48H6
μ	-0.14	S	49C17	β spectrum shape consistent with $\Delta I = 2$, yes			49J1, 49L6, 49B11
				No γ			49B11, 50G3
(th n, γ) 61^h Y	1.24	47S33		Y-d-p	chem		37S3
(th n, γ)	1.38	49P3		Y-n- γ	chem		37S3, 38S3
(~1 MeV n, γ) 61^h Y	7mb	49H28		σ			47S33
				Zr-n-p			40S8
				Zr-d- α			38S3
				Nb-n- α			38S4
				Fission	chem	50N4, 50G3, 49G13	
				d 25Y Sr	ms		48H25

39 YTTRIUM Y

91				92			
39		52		39		53	
τ_1	51 ^m 50	50f3 41G4		τ_2	57 ^d 61	44J4, 40H9 46G6	
IT		50f3		β^-	1.53 ^s 1.54 ^s 1.55 ^s	49L6 49O3 49W17	
γ	0.61 a $\alpha \sim 0.1$	50f3 50f3		β^-	3.5 3.6 3.4	a a a	43H9, 39L10 50h3 43B2 41Q4
See decay scheme of Sr ⁹¹				γ	0.7-1.1 a 0.6	a a	46PP 41Q4
				β^- spectrum shape consistent with $\Delta I = 2$, yes 49L6, 49O3, 49W17			
				γ very weak	0.2	a	49L6
				very weak	1.22	a	49L6
				γ 's in cascade			49L6
				No γ			50b4
51 ^m Y produced by				57 ^d Y produced by			
Zr-n-p	chem	43S3		Zr-n-p	chem	43S3	
Fission	chem	50f3, 41G4, 43H4		Fission	ms	48H25	
					chem	49G13, 50f3, 41Q4	
40% d 9.7 ^h Sr		50f3					
p 57 ^d Y		50f3		60% d 9.7 ^h Sr		50f3, 41Q4, 43S3	
				Fission			
				Zr-n-p	chem	50h3, 46SP, 49B10	
					chem	43S3	
				Mass assignment from range of fission fragment 48K9			
				d 2.7 ^h Sr 43H4, 50h3			

93				94			
39		54		39		55	
τ	10.0 ^h 11.5	50b6 39H10		τ	16.5 ^m 20	49B10 43H4	
β^-	3.1 a	50b6		β^-	5.4 a	49B10	
γ	0.7 a	50b6		γ	1.4 a	49B10	
Mass assignment from range of fission fragment 48K9				Mass assignment from range of fission fragment 48K9			
Fission	chem	50b6, 49G13		Zr-n-p	chem	43S3	
				Fission	chem	50d3	
d 7 ^m Sr		43H4		d 2 ^m Sr		43H9	
Not p 65 ^d Zr		50s15					
See Zr ⁹³							

95			
39		56	
τ	<1.5 ^h		50s15

39 YTTRIUM Y

96 39 57	97 39 58	
	T short 50d1	
	Fission chem 50d1	
	d ^{1-25}Kr 50d1	
	p $^{17\text{n}}\text{Zr}$ 50d1	
	See also 50g2	

40 ZIRCONIUM Zr

Neutron Cross Sections for Natural Element			87 40 47			
σ_s coh	4.9	49S12	τ	2.0 ^h	49S9	
σ_s bound	7.8	49S12				
$E_n = 0.025\text{ev}$			K		49S9	
σ_a 0.22		49P3	β^+	2.0 a	49S9	
0.4		49H2	γ	0.35 a	49S9	
σ_s 8.2		(49WH)		0.65 a	49S9	
			X-ray		49S9	
Resonances found by 47H25 probably due to Hf impurity 49B2						
Graphs Available						
σ_t 0.025-100ev		47H25, 47GIF	Sr ⁸⁴ - α -n		49S9	
0.020-1.60Mev		49B26, 50A4				

89 40 49			90 40 50		
τ_1	4.5 ^m	40D5	τ_2	80.1 ^h 78	43O1 40D5
K or IT		48H36	β^+	1.07 a ~1 a	43O1 40D5
e^-	0.555 s	48H36	No γ		40D5
			Levels		
			$\left. \begin{array}{l} \sim 0.04 \\ 0.25 \\ 1.66 \\ 2.03 \end{array} \right\} ?$		
			$\sigma's$		
			(th n, γ)	0.11	49P3
Y-p-n chem		40D5	Zr ⁹⁰ - γ -n		49B3
Zr-n-2n		48H36	threshold = 11.9		49B3
Zr ⁹⁰ - γ -n		49B3, 49H17	Zr-n-2n chem		40S8
threshold = 12.48		49H17	Y-d-2n		43O1
threshold = 12.1		49B3	Y-p-n chem		40D5
			Mo-n- α chem		40S8
			Zr ⁹¹ - γ -n		
			threshold = 7.2		49H17
			(only n's observed)		

40 ZIRCONIUM Zr

⁹¹			⁹²			⁹³		
40	51		40	53		40	53	
	11.23%	48W9		17.11%	48W9	7	>4x10 ⁻⁶ %*	49B44
	10.8	49H39		17.1	49H39		very long *	49C20
I	5/2 S	49A6					>40 **	48L4
							>100 **	50S15
			Level	~0.7	Y ⁹²	Level	~0.7	Y ⁹³
(th n,γ)	σ's 1.52	49P3	(th n,γ)	σ's 0.25	49P3			
							* From fission yield	
							** From decay of 10 ⁿ Y	

94			95				
40	54		40	55			
17.40%	48W9	T	65 ^d	50b1, 43H9, 46G6	β_1	0.400 s	49L17
17.5	49H39		65.5	46P1		0.39 s	50n1
			63	4088		0.42 a	50b1
						0.4 a	48M14
		Tentative decay scheme		5013			
Level	1.4	Y^{94}			β_2	2% 0.887 s	49L17
						2% 1.0 s	50n1
						5% 1.0 a	50b1
					γ_1	0.708 sc	49L17
						0.73 sc	50n1
					γ_2	0.216 sc	49H31
						$\alpha=\infty$	49H31
						0.24 sc	5013
						0.23 sc	50n1
					γ_3 ? weak	0.92 s	50n1
						0.8 a	50b1
						0.91 a	coin 48M14
					This line belongs to 35 ^d Nb daughter (?) 48M1		
(th n, γ)	0.08	49P3	Fission	ms 46PP			
(th n, γ) 65 ^d Zr	0.06	49L16		chem 49G13, 46PP, 46SP, 43H8, 40G4, 46G6			
	0.43	47S33		4088			
			Zr-n- γ	chem			
					Zr-n- γ	σ	47S33
					Zr-d-p	chem	50J1, 4088
					Zr-n-2n	chem	4088
					Mo-n- γ	chem	4088

40 ZIRCONIUM Zr

96 40 56		97 40 57		?	
2.8%	46W9	τ	17.0 ^h 40G4, 50K3, 40S8	τ	6 ^m 47833, 4088
2.9	49H39				
		β^-	2.2 a 50K3 1.1 cc 40S8		
		γ	~ 0.8 a 50K3		
		Fission	chem 40G6, 40H3, 41A3		
(th n, γ)	0.10 49P3	Zr-n- γ	chem 40S8, 49F16		
(th n, γ) 17 ^h Zr	0.045 49L16		σ 47833		
	0.60 47833	Mo-n- α	chem 4088		
(pile n, γ) 17 ^h Zr	0.2 49L16		Not produced by	Zr-n- γ	47833, 4088
		Nb-n-p		$\sigma(\text{atomic}) = 0.016$	47833
		d 1-2 ^s Kr	50d1		
		contested by	50g2		
		p 76 ^m Nb	40G4, 41H5, 50b3		
No Zr ^{>97} found in fission with τ between 2 ^m and 100 ^y		49C20			
No Zr with $\tau < 5^m$ found by ny on separated Zr isotopes		49B42			

41 NIOBIUM Nb
(Columbium)

⁹³ 41			⁹⁴ 41 53		
τ	30 ^m	49B29	τ_1	6.6 ^m	4086
β^-		49B29	τ_2 >>100 ^y for K capture 4802		
			6.6^mNb⁹⁴ ~99.9% ~0.1% γ0.0415 >>100^yNb⁹⁴ β 1.3 Stable Mo⁹⁴		
			β^- ~0.1% 1.3 48019 γ 0.0415 sc 49C1 Nb K _α X-ray 4802		
Mo-d-α	chem	49B29	6.6 ^m Nb produced by		
Sample enriched in heavy Mo			Nb-n-γ	4802	Mo ⁹⁶ -d-α produces no detectable
Not observed in fission			σ	49H5	Geiger activity 49B29
			Nb-d-p	46K1, 46W2	

⁹⁵ 41 54					
τ_1	90 ^h	50s3, 49H31	τ_2	35 ^d	49H31, 43E8
	73-78	50J1		38.7	45P1
90^hNb⁹⁵ γ₁ 0.216 35^dNb⁹⁵ β 0.146 γ₂ 0.758 Stable Mo⁹⁵ 5/2⁻ ?			β^-	0.146 s 49H31 0.15 s 50n2 0.14 a 48M1	
			γ_1	0.216 sc 49H31 $\alpha \sim \infty$ 49H31 0.24 sc 50L3 0.23 sc 50n1	
			γ_2	0.758 s 49H31 $\alpha \sim 0.002$ 49H31 0.75 s 47R1 0.77 s 50n2 0.92 a coin 48M1	
			$\beta\gamma$ coincidences 48M1 $\gamma\gamma$ coincidences also observed 48M1		
No Nb K X-ray		49B29	35 ^d Nb produced by		
90 ^h Nb produced by			Fission	chem	50e4
Fission	chem	50e4	Mo ⁹⁷ -d-α	chem	49B29
Mo ⁹⁷ -d-α	chem	49B29	90 ^h yield >> 35 ^d yield		
Mo-d-α		50J1	Mo-d-α		50J1
Zr-d		50J1			
	d (1.4%) 65 ^d Zr	49H31		d (98.6%) 65 ^d Zr	49H31
	d (2%) 65 ^d Zr	50e2		d (98%) 65 ^d Zr	50b1, 50e2
				d 65 ^d Zr	46G6

41 NIOBIUM Nb
(Columbium)

96 41 55				97 41 56				?	
τ	23.3 ^h		49K19	τ	76.0 ^m 75	48P3 40G4, 50K3		τ	42 ^d 45W2
β^-	0.67	a	49K19	β^-	1.4	a	50K3		
γ	1.03	a	49K19	γ	0.78	a	50K3		
				Level	~0.8		Zr ⁹⁷		
Zr ⁹⁶ -p-n	chem		49K19	Fission	chem	40G4, 41H5		Nb-e ⁻	45W2
				Mo- γ -p	rel α , chem	47H4, 48P3			
				Mo-n-p	chem	40S8		Mo ⁹⁵ -d- α	49B29
					d 17 ⁿ Zr	40G4, 40S8, 41H5		Not produced by chem	
?									
τ	21.6 ^h		46W2	No Nb found in fission with τ between 10 ^m and 10 ^h , except 76 ^m Nb ⁹⁷					
β^-	1.2	a	46W2				49C20		
γ	0.6	a	46W2						
Nb-d-t			46W2						
threshold ~ 5-6			46W2						
Excitation curve similar to that of 10.1 ^h Nb			46W2						
Not produced by Zr ⁹² or Zr ⁹¹ -d			49K18						
Mo ⁹⁴ -d- α	chem		49B29						
Nb-slow n's			46W2						

42 MOLYBDENUM Mo

Neutron Cross Sections for Natural Element				
σ_s	coh	5.2	49S12	
σ_s	bound	7.4	49S12	
σ_a		$E_n = 0.025\text{ev}$		
		2.40	49P3	
		3.01	49H2	
σ_s		6.7	37G1	
σ_t	MoO ₃	18.5	46D13	

91				92			
42 49				42 50			
τ_1	15.5 ⁿ 17	49D10, 48W13 39B5, 39S3, 49K19		τ_2	75 ^S 73	49D10 48W13	
ℓ^+	3.7 2.65	a cc	49D10 40S8	ℓ^+	2.6	a	49D10
No γ		49D10		γ	0.3	a	49D10
Mo ⁹² -n-2n		49K19		Levels	1.1 1.5		Nb ⁹² Tc ⁹²
Mo-n-2n	chem	37H4, 40S8					
threshold ~12-13		38S14					
Mo ⁹² - γ -n	chem	49D10					
threshold = 13.6		45B12, 49D10					
threshold = 13.28 for							
15 ^m Mo and 75 ^m Mo		48H17		Mo ⁹² - γ -n	chem	49D10	
Mo- γ -n	relc	48W13		Mo- γ -n	relc	48W13	
Mo-d-p		48W2					
Nb-d-2n		48W2					
Not produced by				Not d 15.6 ^m Mo		49D10	
Mo ⁹⁴ -fast n's		49K19					
							(pile n, γ) 6.7 ^m Mo <0.001 47S33

42 MOLYBDENUM Mo

93				94			
42		51		42		52	
τ_1	6.75 ^h	49K27	τ_2	< 2 ^y	49B44	9.35%	49H3
	6.7	46K1				9.1	46W3
	7	44D9					
IT		49K27	γ		49B44		
γ	0.3	} 49K27	e^-		49B44		
	α very large		Nb K _a X-ray		49B44		
	0.7, $\alpha = 0.005$						
	1.7, $\alpha = 0$						
γ 's in cascade		49K27					
Mo K _a X-ray		49K27	Level	2.4 ?	Tc ⁹³	Levels	? Tc ⁹⁴
Nb-p-n	chem	46K1, 44D9					
Nb-d-2n	chem	46K1, 46W2					
Zr ⁹⁰ - α -n		49K27					
Mo-d-p		46W2					
Zr ⁹¹ - α -2n		49K27					
Mo ⁹⁴ -n-2n		49K27					
Not found from			Mo-n- γ		49B44		
Mo ⁹² -n- γ		49D10, 49B44					
$\sigma < 10^{-5}$		49B44					
Mo ⁹⁴ -n- γ		49D10					
Mo ⁹⁴ - γ -n		49D10					
Mo ⁹² -d-p		49K27					

95			96			97		
42		53	42		54	42		55
	15.78%	49H3		16.56%	49H3		9.60%	49H3
	15.7	46W3		16.5	46W3		9.5	46W3
I	1/2 ? S	34G2				I	1/2 ? S	34G2
	5/2 or 7/2 S	50A3					5/2 or 7/2 S	50A3
Levels	?	Tc ⁹⁵ , Nb ⁹⁵	Levels	?	Tc ⁹⁶ , Nb ⁹⁶	Level	0.78	Nb ⁹⁷
(th n, γ)	σ 's	13.4 49F3	(th n, γ)	σ 's	1 49P3	(th n, γ)	σ 's	2.3 49P3
			Mo- γ -n		49H17			
			threshold = 7.1, n's observed					

42 MOLYBDENUM Mo

[illegible]

42 MOLYBDENUM Mo

103 42 61	104 42 62	105 42 63
		τ $\sim 5^m$ 47834 short 43B3 β^- 43B3 Fission chem 43B3 p 4.4^hRu 43B3
No fission Mo with mass > 102 has $\tau > 2^m$ 49B45		

43 TECHNETIUM Tc

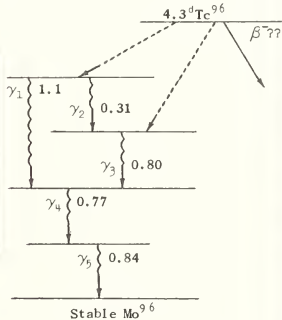
92 ? 43				92 43 49				93 43 50					
τ	47 ^m		48K26	τ	4.5 ^m		48M18, 49B45	τ	2.7 ^h	39D1, 48M18, 48K26			
K			48K26	K	20%		49B45	K	93%		48K26		
e ⁻	5%	0.54	a	48K26	β^+	3.5	a	49B45	β^+	0.85	a	49B45	
γ	15%	1.5	a	48K26	γ	1.5	a	49B45	γ	7%	0.83	a	48K26
Mo K _a X-ray			48K26	$\beta^+/\gamma \sim 1$			49B45	γ	2.44	a	49B45		
									2.0	a	48K26		
								$e^-/\beta^+ = 0.05$			48K26		
								Mo K _a X-ray			48K26		
Mo ⁹² -p-n	chem, rel σ		48K26	Mo ⁹² -d-2n	chem		49B45	Mo ⁹² -p- γ	chem, rel σ		48K26		
Mo ⁹² -d-2n	chem, rel σ		48K26	threshold ~ 10			49B45	Mo ⁹² -d-n	chem, rel σ		48K26		
				chem, rel σ			48K26	Mo-d-n	chem		39B4		
				Mo ⁹² -p-n	chem, rel σ		48K26	Not produced by			48K26		
				No Mo daughter			49B45	Nb- α			48K26		
								Not p 6.7 ^h Mo			49B45		

94 43 51							
τ_1	53 ^m		47Q3	τ_2	< 53 ^m		48H5
IT			48H5	K	65%		47Q3
γ	0.0334	sc	48H5	β^+	2.47	s	47Q3
K X-ray			49M44		2.5	a	48M19
				γ	0.380	s	} 48H5
					0.873	s	
					1.48	s	
					1.85	s	
					2.74	s	
					0.9	a	48M19
				Mo K X-ray			48H5
Mo-p-n			48H5				
Mo ⁹⁴ -d-2n			48M19				
				d 53 ^m Tc			48H5

43 TECHNETIUM Tc

				43 52					
τ_1	20.0 ^h	48E3, 48M19		τ_2	62 ^d 52		39C2, 48B45 47E1		
K		48E3, 48M2	Decay scheme					β^+	0.8% 0.4 cc 48H17
γ strong	0.762 0.78 0.8	sc a a	48M2 48E3 48M19					γ_1	~3% 1.017 sc, s 48H17
	0.932	sc	48M2					γ_2	~30% 0.81 sc, s 48H17 0.8 a 48M6, 47E1
γ	1.071	sc	48M2					γ_3	40% 0.570 sc, s 48H17
X-ray		48E3, 48M18						γ_4	70% 0.201 sc, s 48H17 $\alpha=0.044$ 48H17 0.2 48M6, 47E1
Level	0.95	Ru ⁹⁵						$\gamma_3\gamma_4, \gamma_2\gamma_4$	coincidences 48H17
								γ_4	twice as intense as γ_2 48M26
Mo ⁹² - α -p	chem	48E3						Mo K X-ray	39S4
Mo-p-p-n	chem	48E3							
Mo ⁹² -d- β -n	chem	48M19							
Mo-d-n	chem	39S4							
	d 1.65 ^h Ru	48E3							

43 96 53

	τ	4.3^d 4.2		47G4, 47E1 48M6		
Decay scheme	48M2	K		47E1		
		No β^+		48M2		
		$\beta^- \text{ ??*}$	0.82 0.64	s a	48M2 47E1	$\gamma\gamma$ coincidences 48M2 Order of γ_4, γ_5 unknown 48M2
		γ_1 weak	1.119	sc, s	48M2	γ 's of 0.815, 0.770, 0.840 Mev found from spectrometer measurements. (Attributed to Mo^{99} .) 47S12
		γ_2 weak	0.312	sc	48M2	
		γ_3 strong	0.806 0.8	sc, s a	48M2 48M6	Mo X-ray 47E1
		γ_4 strong	0.771	sc, s	48M2	
		γ_5 strong	0.842	sc, s	48M2	
		γ	0.9	a	47E1	Mo^{96} -d-2n chem 48M6 Nb- α -n chem Mo-p-n chem Mo-d-n chem } 47E1
		* Possibly due to scattered electrons			48M2	

43 TECHNETIUM Tc

97				98 ?			
43		54		43			
τ_1	90 ^d 91 95	39C2, 48M6 41H1 47E1	τ_2	> 10 ^{3y} * > 15*	49B42 41H1	τ	2.7 ^d 2.8 50g21 48M19
IT		41H1	* From decay of parent			β^-	0.75 a 1.3 a 50g21 48M19
γ	0.097 sc 0.097 ac a very large 0.108 ac a large	41H1 48M6 48M6 47E1 47E1				γ	1.0 a 0.9 a 50g21 48M19
Tc K X-ray		41H1					
Mo ⁹⁷ -d-2n	chem	48M6				Mo ⁹⁸ -d	chem 48M19
Mo-d-n	chem	37C3, 39C2				Ru-n	chem 50g21
Mo-p-n	chem	47E1, 47G4					
d 2.8 ^d Ru p long Tc		47M5, 50s28 49B42	d 90 ^d Tc	49B42			

98 ?				99			
43		56		43			
τ	41 ^m	49B42	τ_1	5.9 ^h 6.6	50g4 39S4	τ_2	$\sim 3 \times 10^{5y}$ 9.4 $\times 10^5$ 50s4 47M15
K		49B42	IT		39S4	β^-	0.30 s 0.3 a 0.32 a 49K34 50I4, 50s4 47M15
γ		49B42	γ_1	0.0018 pc	49M45		
			γ_2	0.1412 sc $\alpha = 0.1$ K/L = 8.1	49M45 49M45	No γ	49K34, 47M15
			$\gamma_1\gamma_2$ coincidences		49M45		
			No $\gamma\gamma$ or γe^- coincidences		48M15		
			Tc K X-ray		39S4		
Mo ⁹⁸ -d	chem	49B42	Fission	chem	40S2, 39H8, 48SP 49B42 48B21	Fission	ms chem 47I4 50I4, 50s4 47M15
			Mo ⁹⁸ -d-n	chem		Mo-n- $\gamma\beta$	
			Ru-n-p	chem			
			d ($\sim 10\%$) 68 ^h Mo p long Tc ⁹⁹	39S4, 41H7 39S4, 41H7		d ($\sim 90\%$) 68 ^h Mo d 5.9 ^h Tc	39S4, 41H7 39S4, 41H7

43 TECHNETIUM Tc

100 43 57			101 43 58			102 43 59		
τ	80 ^S	48M18	τ	15.0 ^m 14.5 14.0 16.5	48B42 48P3 41M3 48M33	τ	<25 ^S <1 ⁿ	49B44 41H7
β^-	2.3 a	48M18	β^-	1.3 a	42M4	β^-	3.7 a ~5 a	49B44 41H7
γ	0.6 a	48M18	γ	1.2 a	40S8	γ		41H7
				0.3 a	42M4			
			Level		Mo ¹⁰¹			
Mo ¹⁰⁰ -d-2n		48M18	Fission Ru- γ -p	chem rel yield	41H7 48P3	Fission		41H7
			d 14.6 ^m Mo	3984, 40S8		d 12 ^m Mo		41H7
105 43 62			<101			<101		
τ	short	43B3	τ	36.5 ^h	39D1	τ	18 ^S	44D9
			β^-		39D1	β^-		44D9
Fission		43B3	Mo-p-n		47G4, 39D1	Mo-p-n		38D2
d ~5 ^m Mo		43B3						
p 4.4 ^h Ru		43B3						

44 RUTHENIUM Ru

Neutron Cross Sections for Natural Element						95 44 51		
σ_a	$E_n = 0.025\text{ev}$ 2.5 6.2	49P3 49H2				τ	1.65 ^h 1.6	48E3 48M33
σ_s	5.6	37G1				K		48E3
σ_t	7.3	47GIF, 50Ad				β^+	1.1 a	48E3
Resonances						γ	0.95 a	48E3
E_o 9.4 ev Others		47GIF, 50Ad 47GIF, 50Ad				K X-ray		48E3
Graphs Available								
σ_t	0.015-500 ev	50Ad, 47GIF				Mo ⁹² - α -n Ru-n-2n Ru- γ -n	chem	48E3 48E3 48M33
						p 20 ^h Tc		48E3
96 44 52			97 44 53			98 44 54		
5.68%		44E1	τ	2.8 ^d	48M33, 46S11	2.22%		44E1
			K		46S11			
			γ	0.23 a, ac	46S11			
			Tc K X-ray		46S11			
			X/ $\gamma \sim 4$		46S11			
						Level	1.0 ?	Tc ⁹⁸
(th n, $\gamma\beta$) 90 ^d Tc	σ^t s 10mb	46B29						
			Mo ⁹⁴ - α -n	chem	48E3			
			Ru-d-p		46S11			
			Ru-n- γ		46S11			
			Ru-n-2n		48E3			
			Ru- γ -n		48M33			
			p 90 ^d Tc		47M5, 50s28			

44 RUTHENIUM Ru

99 44 55		100 44 56		101 44 57	
12.81%	44E1	12.70%	44E1	16.98%	44E1
		Level 0.6	Tc ¹⁰⁰	Level 0.3	Tc ¹⁰¹
102 44 58		103 44 59		104 44 60	
31.34%	44E1	τ 42 ^d 41 40 45	46S11 46B28 50g5 48M33	18.27%	44E1
		β^- ~50% 0.350 s ~50% 0.665 s	48H36 48H36		
		97% 0.2 a 3% 0.8 a	50s5 50s5		
		γ 0.239 sc 0.312 sc	48H36 48H36		
		0.56 a 0.54 a	50g5, 46G25 50s5		
		No $\beta\gamma$ angular correlation	49G21		
(th n, γ) 42 ^d Ru	σ 's 1.2 47S33	Fission chem 42N3, 50g6, 49G13 Ru-d-p chem 46B28, 46S11 Ru-n- γ chem 48H36, 50s5 σ 47S33 Ru- γ -n 48M33 Ru-n-2n 48E3 Mo- α -n chem 48E3 p 57 ^m Rh 48H36, 50g5	(th n, γ) 4.4 ^b Ru	σ 's 0.7 47S33	

44 RUTHENIUM Ru

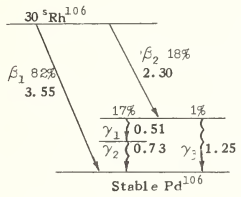
105				106				107			
44		61		44		62		44		63	
τ	4.4 ^h		46B28	τ	1.0 ^y	50g5		τ	4 ^m	43B3, 50g6	
	4.5		50s6, 50s7		290 ^d	49G4					
β^-	1.3	a	46B28	β^-	0.041 s	49M46		β^-	~4	a	43B3
	1.5	a	43B3								
	1.4	a	50s7								
γ	0.75	a	50s7								
	0.7	a	46B28								
No $\beta\gamma$ angular correlation			49G21								
Ru-n- γ	chem		46S11, 46B28								
	σ		47G33								
Ru-d-p	chem	50s8, 46S11, 46B28		Fission	ms	48H25		Fission			43B3
Fission	chem	49G13, 43B3, 41S6, 48SP			chem	50g7, 49G13					
	d short Mo		43B3								
	d short Tc		43B3								
	p 36.5 ^h Rh		46B28, 46S11		p 30 ^s Rh	50g5			p 24 ^m Rh	50g6, 43B3	

Neutron Cross Sections for Natural Element			99		
			45	54	
σ_a	$E_n = 0.025 \text{ ev}$ 150 171	49P3 49H2	τ	5^h	49E4
σ_s	~ 6	49M31	β^+	0.6	49E4
σ_t	155 145	44F12 49M31	γ, e^-		49E4
Resonance					
E_o	σ_o	Γ			
1.21 ev	2750	0.21			49M31
1.30	>2500	<0.26			46B26
1.28		0.14			49G9
Graphs Available					
σ_t	0.0044-330 ev 0.015-5 ev	49M31 50Ad, 47GI F, 47S31	Ru-p-n Ru- α -p		49E4 49E4
100			101		
45 55			45	56	
τ	19.4 ^h 21	48L3 50s29	τ	4.3 ^d 4.7 5.9	48L3 49E4 50s30
K		48L3	K		48L3, 49E4
β^+	5% 3.0 s 25% 1.3	48L3 49E4	No β^+		48L3
γ	1.2 a 1.8 a 1.55	48L3 50s29 49E4	γ	0.35 a, s $\alpha \sim 0.10$? 0.13 sc 0.08 sc	48L3 48L3 49E4 49E4
e^-	0.6 s	48L3	K X-ray		48L3, 49E4
Ru K X-ray		50s29, 49E4	e^- possibly from 0.35 γ		48L3
Levels	0.09 1.8	Pd ¹⁰⁰			
Ru-d-n	chem	50s29	Ru-d-n chem	50s30	
			Ru-p-n	49E4	
			Ru- α -p	49E4	
d 4 ^d Pd		48L3	d 9 ^h Pd	49E4, 48L3	
102			102		
45 55			45	57	
τ	215 ^d 210	47H5 48M33, 41M2	τ	215 ^d 210	47H5 48M33, 41M2
K		50s31	K ?		50s31
β^+	1.3 a 1.13 cc	50s31 45H1	β^+	1.3 a 1.13 cc	50s31 45H1
β^-	1.04 cc	45H1	β^-	1.04 cc	45H1
$\beta^-/\beta^+ = 1.2$		41M2			
γ	~ 0.46 a probably annihilation	50s31 50s31	γ	~ 0.46 a probably annihilation	50s31 50s31
Ru K X-ray		50s31	Ru K X-ray		50s31
Rh-n-2n	chem	41M2	Rh-n-2n	chem	41M2
Ru-d-n		50s31	Ru-d-n		50s31
Rh- γ -n		48M33	Rh- γ -n		48M33
Fission	Not produced by	50s10	Fission	Not produced by	50s10

		45	58		
τ	57 ^m	50g5	100%	43C1	
	52	47F3			
	45	45W3			
IT		47F3, 47H5, 48G19, 50g5			
e ⁻	0.034 sc	48H36	Levels found in production of		
	only line found	48H36	57 ^m Rh by Rh- γ - γ		
	0.03 a	50g5	1.26	45W3	
	0.042 a	47F3	1.64		
	0.0399 sc	48G19	2.02		
	0.0427 sc	48G19	2.37		
			2.71		
			3.05		
Rh K X-ray		47F3, 47H5, 48G19, 50g5			
			σ 's		
			(th n, γ) 4.3 ^m Rh	12	47S33
Fission		50g5	(th n, γ) 44 ^s Rh	137	47S33
Rh-n-n	σ	47F3	(~1Mev n, γ) 4.3 ^m Rh	0.016	49H5
Rh-e ⁻		45W3	(~1Mev n, γ) 44 ^s Rh	0.103	49H5
Rh- γ - γ		45W3	(Ra-Be n, n) 57 ^m Rh	~ 1	47F3
Rh-p-p	relo	48H36	For other fast n values see	48W	
Rh-d-pn		48H36	(50Mev d, 2n) 17 ^d Pd	0.0024	48L3
			(50Mev d, 4n) 9 ^b Pd	0.24	48L3
			(50Mev d, 5n) 4 ^b Pd	0.28	48L3
	d 17 ^d Pd	47M12			
	d 42 ^d Ru	48H36, 50g5			

104						105					
45			59			45			60		
τ_1	4.34 ⁿ 4.37 4.3	39R2 39C3 47F3	τ_2	44 ^s 42	39P2 39C3	τ	36.5 ^h 37 34	50s6, 50s11 46B2 41N2			
IT		39P2	f^-	2.6 s 2.5 a 2.3 cc	47H5 40H9 39C3	f^-	0.78 a 0.60 a 0.6 a	46B28 50s11 48K1			
e^-	0.070 sc 0.087 ac 0.070 ac 0.046 sc 0.066 sc 0.086 sc	47H5 47F3 43A2 4003 4003 4003	γ	0.041 a 0.18 a 0.95 a	} 47C11	γ	0.33 a α large	50s11 50s11			
						Level	0.7	Ru ¹⁰⁵			
γ	0.080 a $\alpha \sim 0.65$ ~ 0.05 a	43A2 43A2 43S4									
Rh K X-ray		43A2									
Rh-n- γ Pd- γ -p Ru-p-n	σ relo 44D9	47S33 47H4 44D9	Rh-n- γ Ru-p-n Pd- γ -p	σ relo	47S33 36L1 47H4	Ru-d-n Rh-t-p Pd- γ -p Fission		50s11 48K1 48P3 46PP			
p 44 ^s Rh		47F3, 39P2	d 4.3 ^m Rh		47F3, 39P2		d 4.4 ^h Ru	46B28, 46S11			

45 RHODIUM Rh

106				107			
45		61		45		62	
τ		30^s	50g5	τ	24^m 26	43B3 50g6	
				β^- 82% 3.55 s 47P7 3.5 a 49J3 3.9 a 50g5 β^- 18% 2.30 s 47P7 2.3 a 49J3 2.8 a 50g5 γ_1 0.51 s 47P7 0.3 a 50g5 γ_2 0.73 s 47P7 0.8 a 50g5 γ_3 1.25 s 47P7			
Fission	chem	46G6, 50g5	Angular correlation of γ 's suggests I = 0, 2, 0	Fission	chem	43B3	
	d 1.0 ^y Ru	50g5	48B18		d 4 ^m Ru	50g6, 43B3	
108 ?				109			
45		63		45		64	
τ	9^h	50b4	τ	$<1^h$	50s12	No Rh with τ between 10^d and 100^y found in fission	50s10, 50s13
β^-	~ 1.3 a	50b4					
γ	0.8 a	50b4					
Fission	chem	50b4					

46 PALLADIUM Pd

Neutron Cross Sections for Natural Element			100		101				
			46	54	46	55			
σ_s coh	5.0	49S12	τ	4.0 ^d	48L3	τ	9 ^h	48L3	
σ_s bound	4.8	49S12							
$E_n = 0.025\text{ev}$			K		48L3	K	$\sim 90\%$	48L3, 49E4	
σ_a	6.6	49P3	γ	0.09 a	48L3	ρ^+	$\sim 10\%$	48L3	
	8.8	49H2		1.8 a	48L3		$\sim 10\%$	49E4	
σ_s	3	37G1	X-ray		48L3	No γ , no e^-		48L3	
Resonances			Relative abundances of Pd ⁹⁸			X-ray		48L3	
E_0	0.14	49G9	Pd ⁹⁹ , Pd ¹⁰⁰ , Pd ¹⁰¹						
24ev		49G9		<0.0007%	49D7				
Attributed to Pd ¹⁰⁸									
			Rh-d-5n	chem	48L3	Rh-d-4n	chem	48L3	
						Ru- α -n		49E4	
			p 19 ^h Rh		48L3	p 4.3 ^d Rh		49E4, 48L3	
102			103		104				
46 56			46	57	46	58			
0.8%		36S4	τ	17 ^d	46B19, 47M12	9.3%		36S4	
			K		46B19, 47M12				
			No γ , no e^-		47M12				
			Rh K X-ray		48G19				
						Levels	?	Rh ¹⁰⁴	
						(6.0Mev p,n)	σ 's	0.018	36E2
			Rh-d-2n	chem, σ	48L3				
			Rh-p-n		47M12				
			Pd-n- γ		46B19				
			p 57 ^h Rh		47M12				

46 PALLADIUM Pd

105 46 59			106 46 60			107 46 61		
22.6%		3684	27.1%		3684	τ	$7 \times 10^{15} \text{ y}$ $> 3 \times 10^8$ $> 8.6 \times 10^7$	49P17 50g8 5015
						β^-	$\sim 0.035 \text{ a}$	49P17
Levels	0.33 ?	Rh ¹⁰⁵ Ag ¹⁰⁵	Levels	0.73 or 0.51 1.25 ?	Rh ¹⁰⁶ Rh ¹⁰⁶ Ag ¹⁰⁶			
(6.6 Mev p, n)	σ 's 0.037	39E2	(6.6 Mev p, n)	σ 's 8.6 ^d Ag ¹⁰⁶ threshold = 3.9-4.3	0.0013 39E2 39E2			
			(6.6 Mev p, n)	24.3 ^a Ag ¹⁰⁶ threshold = 3.8	0.055 39E2 39E2	Fission	chem	49P17
108 46 62			109 46 63			110 46 64		
26.7%		3684	τ	13.1 ^h 12.7 14.1 13	46W13 46P3 46M33 50s12	13.5%		3684
			β^-	0.95 s 1.0 a	49S23 46H4			
			No γ		50s12			
			No delayed $\beta\gamma$ coincidences		49M26			
(th n, γ) 13 ^b Pd	σ 's 11	47S33	Pd-n- γ	ms	46R3	(th n, γ) 26 ^m Pd	0.39	47S33
(0.9 Mev n, γ) 13 ^b Pd	0.21	49B4	σ		47S33	(0.9 Mev n, γ) 26 ^m Pd	0.13	49B4
(6.6 Mev p, n) 2-3 ^a Ag	0.081	39E2	Pd- γ -n	rel σ	46W13, 46P3			
			Pd-d-p	chem, f	37K1			
			Ag-n-p		38F1			
			Ag-d-2p		46H4			
			Fission	chem	50s12, 49O13			
			p 39 ^a Ag		49S23, 41S6			

46 PALLADIUM Pd

III			II2		
46	65		46	66	
τ	26 ^m 17	41S6 37K1	τ	21 ^h 17	50s12 41S6
β^-	3.5 a	43B3	β^-	0.2 a	50s12
			No γ		50s12
Pd-d-p	chem	37K1	Fission	chem	49G13, 49SP
Pd-n- γ	chem	37K1			
	σ	47S33			
Fission	chem	40N3, 41S6, 48SP			
p 7.5 ^d Ag		37K1, 41S6	p 3.2 ^h Ag		40N3, 41S6, 50s12

47 SILVER Ag

Neutron Cross Sections for Natural Element				102		104			
				47	55 or 47	47	57		
σ_s coh	4.6	}	49S12	Resonances		τ	73^m	39E2	
σ_s coh(Ag ¹⁰⁷)	8.7			E_n	$\sigma_s \Gamma^{1/2}$				Γ
σ_s coh(Ag ¹⁰⁹)	2.3			5.1ev	300				47R6
				5.1	0.12				49G9
				5.6	~ 0.7				48C24
σ_s bound	6.6			Assigned to Ag ¹⁰⁹	49G9, 48C24	K		48L4	
	$E_n = 0.025\text{ev}$					β^+		48L4	
σ_a	60		49P3	23	1-4				
	89		49H2	16	~ 24				
				Assigned to Ag ¹⁰⁷					
σ_s	6		49WH						
				45	~ 700				
σ_t	65		46H33	90	Assigned to Ag ¹⁰⁹				
				> 115					
				> 300					
				$E_n = 1\text{Mev}$					
			σ_t	~ 6.5	See graphs				
Graphs Available									
σ_t	0.015-1,000ev		46H33, 47R6, 47G1F			Pd-p-n Sb-d	yield	39E2 48L4	
	0.02-1.6Mev		49B29, 50Ad						
	1-40Mev		50Ad						
	0.025-11Mev		47G1F						

47 SILVER Ag

106							
47		59					
τ_1	8.6 ^d 8.2	49G24 38P3		τ_2	24.5 ^m 24.3 25	38P3, 38D1 48M33 39E2	
K		44H1, 38F1		β^+	2.04	a	38F1
γ	0.505 s 0.72 ? s 1.06 s 1.63 s	} 42D3		No γ			38F1
	0.69 s 1.06 s						
$\gamma/X \sim 3$							
$e^-/X = 0.2$							
K X-ray		39E2		Pd-p-n	f		39E2
					threshold = 3.8		39E2
				Pd-1-n	chem		38P3
				Ag-n-2n	chem		38P3
					threshold = 5-7		38S14
				Cd-n-p			38P3
Pd-p-n	f	39E2		Ag- γ -n		48M33, 39B5	
	threshold = 3.9	39E2			threshold = 9.5		45B12
Rh- α -n	f	47B16, 44H1		Ag-e ⁻ -e ⁻ n	σ		48S3
Ag-n-2n	chem	} 38P3			threshold = 9.5		48S3
Cd-n-p	chem			Rh- α -n		47B16, 39K1	
Pd-d-n	chem				threshold ~ 11.5		47B16

107				108			
47		60		47		61	
τ	44.3 ^S 40	47B5 41H3			51.35%	48W9	
IT		40A1		I	1/2 S	49C3, 37J1	
γ	0.0939 sc $\alpha = 16, K/L = 0.92$ 0.093 sc 39V2, 41H1 $\alpha = 99, K/L = 1$	47B5 47B5 41H1 41H1		μ	-0.086 S	49C3	
				Levels	0.094 0.94	44 ^S Ag ¹⁰⁷ Cd ¹⁰⁷	
				Levels found in production of			
				44 ^S Ag by Ag- γ - γ		45W1	
					1.59 1.95 2.32 2.76 3.13		
				May be in Ag ¹⁰⁹ or Ag ¹⁰⁷			
				σ^S			
				(th n, γ) 2.3 ^S Ag	44	47S33	
				(th n, γ)	30	48H38	
				(~ 1 Mev n, γ) 2.3 ^S Ag	0.13	49H5	
Ag-n-n		44F1		Other fast n values		49B4, 49WH	
Ag- γ - γ		45T2, 45W1		(10 Mev e ⁻ , e ⁻ n) 24.5 ^S Ag	5.4x10 ⁻⁴	48S3	
	threshold = 1.18	45W1		Graphs Available			
Ag-e ⁻ -e ⁻		45W1		(n, γ) 2.3 ^S Ag	0.003-6 Mev	48L7, 47G1F, 50Ad	
	d 6.7 ^b Cd	46H4, 47B5					

τ	2.33 ^m 2.3 2.4	48P3 48M33, 39B5 44F1		β^-	2.8	cc	36N2
				$\beta^+/\beta^- < 0.005$			47B8
				Ag ¹⁰⁷ -n- γ			44F3
				Ag-n- γ	σ		47S33
				Pd-p-n	yield		39E2
				Ag- γ -n			39B5
					threshold = 9.3		45B12
					rel σ		48P3, 48W13
				Ag-e ⁻ -e ⁻ n	σ		48S3
					threshold = 9.3		48S3
				Ag-d-p	chem		40K2
				Cd-n-p	chem		38P3

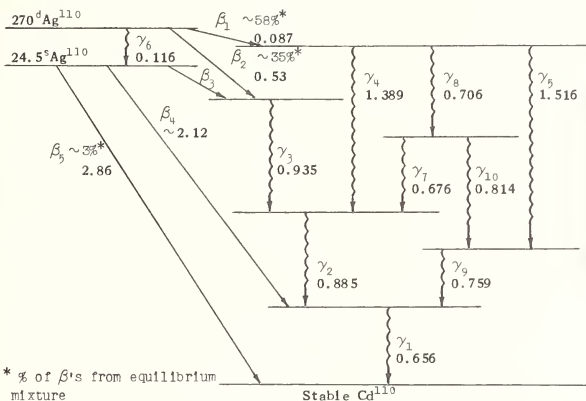
47 SILVER Ag

109					
47 62					
τ	39.2 ^S	47B5	48.65%	48W9	
IT		41H3	I 1/2	S 49C3, 37J1	
γ	0.087 sc 46H4, 49S23 $\alpha = 11.5, K/L = 1.3$ 49S23 0.0890 sc 47B5 $\alpha = 19, K/L = 1$ 47B5		μ -0.159 S	49C3	
			For possible levels see	Ag ¹⁰⁷	
			σ 's		
			(th n, γ) 24.5 ^S Ag	97	47S33
			(th n, γ) 270 ^d Ag	2	47S33
			(th n, γ)	84	48B38
			(~4Mev n, γ) 270 ^d Ag	0.23	49H5
Ag-n-n	44F1		Other fast n values	49B4, 48WH	
Ag- γ - γ	45W1		(16Mev e ⁻ , e ⁻ n) 2.3 ^m Ag	7.9x10 ⁻⁴	48S3
Ag-e ⁻ -e ⁻	45W1		Graphs Available		
d 330 ^d Cd	46H4, 41H3		(n, γ) 24.5 ^S Ag	0.003-6Mev	46L7,
d 13 ^b Pd	49S23, 41S6				47G1F, 50Ad

110
47 63

τ_1	270 ^d	49G24	τ_2	24.5 ^s	47H4
	282	48C3		22	38P3
	225	38L4			

Decay scheme 50S1



* % of β 's from equilibrium mixture

Stable Cd^{110}

$\beta\gamma$ and $\gamma\gamma$ coincidences support decay scheme 50S1

High energy β not in coincidence with any γ 49M38

β_1 and β_2 in coincidence with γ 's 49M38

γ_1 and γ_2 in coincidence 49Y2
 γ_5 not in coincidence with any γ 49Y2

No delayed coincidences with delay between 3×10^{-8} s and 10^{-3} s 49M26

$^{270}\text{Ag}^{110}$ in equilibrium with $^{24.5}\text{Ag}^{110}$				
$\beta_1^- \sim 58\%$	0.087 s	50S1	γ_1 100% *	0.656 sc, s 50S1
	0.09 a	49M38		$\alpha = 2.5 \times 10^{-3}$ 50S1
	0.09 cc	49E1	100% *	0.66 sc 47R1
				0.66 a 49Y2
$\beta_2^- \sim 35\%$	0.530 s	50S1	γ_2 81% *	0.885 sc, s 50S1
	0.57 a	49M38		0.9 a 49Y2
	~0.59 cc	49E1	110% *	0.9 s 47R1
β_3^- weak	soft	50S1	γ_3 31% *	0.935 sc, s 50S1
	0.19 ? a	49M38		
β_4^-	~2.12 s	50S1	γ_4 33% *	1.389 sc, s 50S1
			20% *	1.4 s 47R1
$\beta_5^- \sim 3\%$	2.86 s	50S1	γ_5 17% *	1.516 sc, s 50S1
	>2 a	49M38		1.48 a 49M38
Possibly one or more very weak β 's			γ_6 weak	0.116 sc 50S1
				α large, K/L ~ 1.3 50S1
No β^+			γ_7 weak	0.676 sc, s 50S1
$\beta^+/\beta^- < 0.002\%$			γ_8 weak	0.706 sc, s 50S1
			γ_9 weak	0.759 sc, s 50S1
No K X-ray			γ_{10} v. weak	0.814 s 50S1
			γ	1.63 < E_γ < 2.3 49D23
			* relative %	

$^{24.5}\text{Ag}^{110}$			
β^-	2.6	a	48H6
	2.8	cc	KU 36G1

$^{24.5}\text{Ag}^{110}$ produced by

$\text{Ag}^{109} - n - \gamma$		44F3
$\text{Ag} - n - \gamma$	σ	47S33
$E_\gamma(\text{max}) = 6.5$		49K15
$\text{Cd} - \gamma - p$	rel σ	47H4
$\text{Cd} - n - p$		38P3
Not produced by		
$\text{Pd} - 6.5\text{MeV } p$		39E2

$^{270}\text{Ag}^{110}$ produced by

$\text{Ag}^{109} - n - \gamma$		46G15
$\text{Ag} - n - \gamma$	σ	47S33
$\text{Ag} - d - p$	chem	44H2

Resonance for production of ^{270}Ag by $n - \gamma$ same as that for production of $^{24.5}\text{Ag}$ 48G4

47 SILVER Ag

111 47 64			112 47 65			113 47 66		
τ	7.5 ^d 7.6	38P3 49D6, 50s24	τ	3.2 ^h	49D6, 38P3	τ	5.3 ^h	49D6, 47T13
β^- simple	1.06 s ~0.2 a 1.0 a	49H6 50S24 50S24	β^-	3.6 a 2.2 cc	50s12 38P3	β^-	2.1 a 2.2 a	49D6 47T13
No γ		38P3	γ	0.86 a	50s12	No γ		49D6, 47T13
Number of coincidences as function of delay time (see Cd ¹¹¹) indicates that Ag ¹¹¹ decays directly to ground state of Cd ¹¹¹ 49M26								
See Cd ¹¹¹ for Ag, Cd, In relationships								
Pd-d-n	chem	} 38P3	Cd-n-p	chem	38P3	Cd ¹¹⁴ - γ -p	chem, rel σ	49D6
Pd- α -p	chem		In-n- α	chem	38P3	Fission	chem	47T13
Cd-n-p	chem		Cd- γ -p	chem, rel σ	49D6, 47H4			
Cd- γ -p	chem, rel σ	49D6, 47H4	Fission	chem	50s12, 49G13, 48SP			
Fission	chem	49G13, 50s24						
Ag-t-p		47K2						
d 26 ^m Pd		41S6, 37K1, 50s24	d 21 ^h Pd		41S6, 40N3, 50s12			

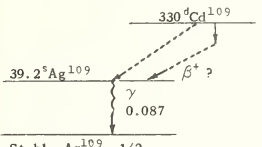
114 47 67			115 47 68					
τ	2 ^m	49D6	τ	20 ^m 22 ~20	49D6 47T13 47S34			
β^-	hard	49D6	β^-	~3 a ~2	49D6, 47T13 47S34			
			No γ		49D6			
Cd ¹¹⁴ -n-p	chem	49D6	Cd ¹¹⁶ - γ -p	chem, rel σ	49D6			
Fission		47S34	Fission	chem	47S34, 47T13			

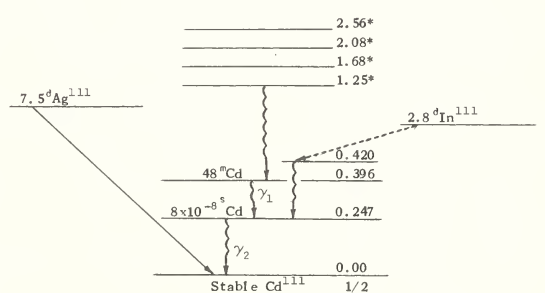
48 CADMIUM Cd

Neutron Cross Sections for Natural Element			105		106	
			48	57	48	58
σ_a	$E_n = 0.025\text{ev}$		τ	33^m		
	3170	49H2		37P2	1.22%	49H3, 48W9
	3500	49P3		48M33	1.215	48L5
σ_s	~ 6.5	(48WH)	β^+	1.5	49G24	
σ_t	2400	See graphs				
Resonances						
E_0	σ_0	Γ				
0.17ev	7200	0.115				
0.180	7800	0.122				
0.178	7250	0.110				
Assigned to Cd^{113}						
110ev						
Assigned to Cd^{116}						
$E_n = 1\text{Mev}$						
σ_t	~ 6.7	48H15				
Graphs Available						
σ_t	0.008-100ev	47GIF, 47R6	Cd-n-2n	chem	49G24, 37P2	
			Cd- γ -n		48M33	
	0.023-15Mev	50Ad, 47GIF	Pd- α	chem, rel σ	49G24	

107		108	
48	59	48	60
τ	6.7^h		
Proposed decay scheme	45B4		
β^+	0.31% 0.32 s	45B4	
γ_1	0.42% 0.846 s	45B4	
	$\alpha \sim 10^{-3}$	45B4	
	0.7 a	41H1	
γ_2	0.0939 sc	47B5	
	$\alpha = 16, K/L = 0.92$	47B5	
	$\tau = 44.3^s$	47B5	
	0.093 sc	39V2, 41H1	
	$\alpha = 99, K/L = 1$	41H1	
$K/\beta^+ = 320$, in agreement with Fermi theory		45B4	
Ag K X-ray		45E4	
$\text{Cd}^{106}\text{-n-}\gamma$	48H4, 48G15		
Ag-d-2n	chem	49C29, 41H3	
Ag-p-n	chem	39V2, 39D1, 49C29	
threshold ~ 2.4		39D1	
Pd- α	rel σ	49G24	
p 44.3s Ag	48H4, 47B5		

48 CADMIUM Cd

109			110		
48 61			48 62		
τ	330 ^d 470 158	46B2 49G24 41H3	12.43% 12.39 12.35	49H3 49L5 49W9	
					
Stable Ag^{109} 1/2			Levels	0.66 1.42 1.54 2.22 2.48 2.93	Ag^{110}
β^+ ?		48C23			
γ	0.087 sc $\alpha = 11.5, K/L = 1.3$ 0.089 sc $\alpha = 19, K/L = 1$ $\tau = 39.2^s$	46H4, 49S23 49S23 47B5 47B5 47B5			
$Cd^{108}-n-\gamma$		46G15, 46H4	$\sigma^{\prime}s$ (th n, γ) $49^{109}Cd$	0.2	48G2
$Ag-d-2n$	chem	49G24, 41H3	(6.9Mev p, n) $65^{109}In$	0.03	39B3
$Ag-\alpha-pn$		46H4			
$Ag-p-n$	chem	45B3			
$Pd-\alpha$	relor	49G24			
p $39.2^s Ag$		41H3, 46H4			

III			48 63		
τ	48.7 ^m 48.6	44W1 49H6	12.86% 12.75 12.78	49H3 38L5 49W9	
γ_1	0.149 s α large 0.146 sc $\alpha > 12, K/L \sim 1.8$	49H6 49H6 48H37 48H37	I	1/2 S	29S1, 33S2, 31S1
γ_2	0.247 s $\alpha \sim 0.1$ $K/L = 5.4$ $\alpha = 0.04, K/L = 6$ 0.238 sc $\alpha \sim 0.19, K/L > 10$ $\tau = 0.08^{\mu s}$ $\tau = 0.09$	49H6 49H6 40L7 49B8 48H37 48H37 49D26 49M26	μ	-0.65 S	33J2, 36B6
Fission	chem	40N3			
$Cd^{110}-n-\gamma$		48G2, 49M26			
σ		48G2			
$Pd^{108}-\alpha-n$		48H22			
$Cd^{112}-n-2n$		48H22			
$Ag-\alpha-pn$		45T2, 44W1	$\sigma^{\prime}s$ (6.9Mev p, n) $2.8^d In$ 8mb 39B3		
$Cd-\gamma-\gamma$		44W1			
$Cd-e^-e^-$		44W1			
$Cd-n-n$		48H37			

* Levels for production of 48^mCd by $Cd-\gamma-\gamma$ and $Cd-e^-e^-$

48 CADMIUM Cd

112 48 64			113 48 65		
23.79%	49H3		12.34%	49H3	
24.07	48L5		12.26	48L5	
24.00	48W9		12.30	48W9	
			I	1/2 S	29S1, 31S1, 33S2
			μ	-0.65 S	33I2, 36B6
			Possible relationships		
Level	0.86	Ag ¹¹²			
σ 's					
(6.9Mev p,n) ²³ In	0.02	39B3			
Cd- γ -n n's observed		49H17			
threshold = 6.4		49H17			
			(th n, γ) ~20,000	46M12, 47D2	
			Cd ¹¹³ responsible for large Cd thermal σ . Other main isotopes have < 1/40 this σ . 46M12, 47D2		
			σ 's		
			(6.9Mev p,n) 1.73 ^h In	0.02	39B3

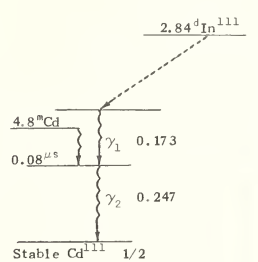
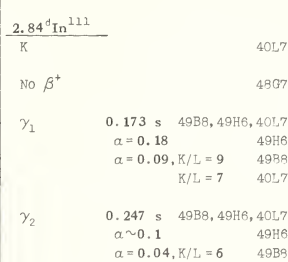
113 ? 48 65 ?			? 48			114 48 66		
τ	2.3 ^m	48H22	τ	5 ^y	49G24	28.81%	49H3	
						28.86	48L5	
						28.75	48W9	
			β^- or e^-	0.45	49G24			
			No γ		49G24			
						Levels	0.55	In ¹¹⁴
							1.27	
						σ 's		
						(th n, γ) 43 ^d Cd	0.14	47S1
						(th n, γ) 2.3 ^d Cd	1.1	47S1
						(6.9Mev p,n) 72 ^s In	~0.03	39B3
						(6.9Mev p,n) 50 ^d In	0.03	39B3
Cd ¹¹³ -n-n		48H22	Cd-d	chem	49G24	Cd-n- γ		
Cd-n- γ		47S1	Cd- fast n	chem	49G24	E_γ (max) = 8.7		49M14
σ (atomic) = 0.05	47S33					7.0		49K15
Not produced by						~7.9		49H9
Cd ¹¹² -n- γ		49G8						

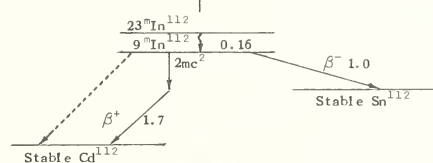
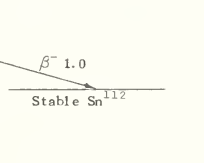
48 CADMIUM Cd

115					
48		67			
τ_1	43^d 44	50s27 50g18	τ_2	2.33^d 2.4	40L7, 50m6 48M33
			43^dCd^{115} β_1^- simple 1.67 s 49H7 1.75 a 50g18 γ_1 ~0.5 a 50s27 $\gamma_1/\beta_1 \sim 1$ 50s27 No delayed coincidences with τ between 3×10^{-8} s and 10^{-3} s 49M26		
43^dCd^{115} produced by Cd-d-p chem 39C4 Cd-n- γ chem, σ 47S1, 50s27 In-n-p chem 50s27 Fission chem 49G13, 50m7, 48SP			2.33^dCd^{115} produced by Cd-d-p chem 39C4 Cd-n- γ chem, σ 47S1, 39G2 Cd-n-2n chem 39G2 In-n-p chem 50s27 Cd- γ -n 48M33 Fission chem 49G13, 40N3, 48SP p 4.5^hIn 39C4, 49H7		
			2.3^dCd^{115} β_2^- 0.46 a $\beta\gamma$ 49M6 60% 0.56 a 50m6 β_3^- 1.10 s 49H7 1.13 s 40L7 γ_2 0.520 s 49H7 0.65 s 43M4 $\beta\gamma$ and $\gamma\gamma$ coincidences 49M6 No $\beta\beta$ coincidences 49M6		

116			117		
48		68	48		69
7.66%	49H3		τ	2.72^h	50m6
7.58	48L5			2.8	40L7
7.63	48W9		β^-	1.3 - 1.7 s	40L7
σ 's (th n, γ) 2.7^hCd 1.4 47S1 (6.9Mev p, n) 54^mIn 0.03 39B3 Resonance at 110ev 49C24			Cd-d-p chem 39C4 Cd-n- γ 37M3, 39G2 σ 47S1 Fission chem 40N3 p 1.95^hIn 40N3, 39G2, 40L7		

Neutron Cross Sections for Natural Element			107 ? 49		
$E_n = 0.025\text{ev}$			τ	33^m	49M20
σ_a 191	49P3				
σ_s 2.2	44B6		β^+	2 s	49M20
σ_t 194	44F12		γ		49M2
190	See graphs				
Resonances					
E_o	σ_o	Γ			
1.44ev*		~ 210			
1.44	26,400	0.085			
1.39	>15,000	<0.15			
3.8		~ 120			
3.7		46M18			
8.6		~ 300			
9.0		46M18			
* Scattering resonance also	47L21				
Graphs Available			Cd ¹⁰⁶ -d	chem	49M20
σ_t 0.017-1000ev	47H25, 46M18, 47GIF		Cd ¹⁰⁶ -p	chem	49M20
See also	49H16			Not produced by	
0.02-1.6MeV	49B28, 50Ad		Cd ¹⁰⁸ -p		49M20
			Cd ¹⁰⁸ -d		49M20
108			109		
49	59		49	60	
Activity of half-life < 1 ^h , $\beta^+ \sim 2, \gamma$, produced by Cd ¹⁰⁸ -d and assigned to In ¹⁰⁸ . This activity is daughter of 4.5 ^h Bn.			τ	4.3 ^h	49M20
Activity of half-life ~ 5 ^h , no β^+ , $\gamma \sim 0.65$, produced by Ag- α and assigned to In ¹⁰⁸ .				5.2	48G7
				6.5	47T2
			K		47T2
			β^+	0.75 a	49M20
			γ	0.5	48G7
			K/ $\beta^+ = 8$		49M20
			τ	65 ^m	48G7, 39E3
				66	47T4
				72	48L4
			β^+	1.7	48G7
				2.0 s	40L7
				2.2 a	48L4
			Ag- α -n	ms	48G7
				chem, f	47T4, 48G7
			threshold ~ 13.5		48G7
				~ 12	47T4
			Cd-p-n	chem, σ	39B3
			Cd-d-2n		40L7
			d 4.5 ^h Bn		48L4
			Ag- α -2n	ms, chem, f	49G7
				chem, f	47T2
			threshold ~ 13.5		48G7
				~ 13	47T2
			Cd ¹⁰⁶ - α -p	chem	} 49M20
			Cd ¹⁰⁸ -d-n	chem	
			Cd ¹⁰⁸ -p- γ	chem	

111							
49		62					
τ	2.84 ^d			49H6			
	2.7			39B3, 39C4			
							
Ag- α -2n ms 49G7				K 40L7			
chem, f 47T4, 48G7				No β^+ 49G7			
threshold = 15.5 47T4				γ_1 0.173 s 49B8, 49H6, 40L7			
~15 48G7				$\alpha = 0.18$ 49H6			
Cd ¹⁰⁸ - α -p chem 49M20				$\alpha = 0.09, K/L = 9$ 49B8			
Cd-p-n chem, σ 39B3				$K/L = 7$ 40L7			
Cd-d-n 39C4				γ_2 0.247 s 49B8, 49H6, 40L7			
In-n-Sn 40L7				$\alpha \sim 0.1$ 49H6			
				$\alpha = 0.04, K/L = 6$ 49B8			
				$K/L \sim 5$ 40L7			
				$\tau = 0.08 \mu s$ 49D28			
				0.09 49M26			
				Angular correlation of γ 's 49B19			
				See also Cd ¹¹¹			

112							
49		63					
τ_1	23 ^m		47T2	τ_2	9 ^m		47T4
	20		39B3				
							
IT 47T4				K 47T4			
γ 0.16 a 47T4				β^+ 1.7 a 47T4			
α large 47T4				1.7 cc 40L7			
0.16 sc 39B3				β^- 1.0 a 47T4			
In K X-ray 47T4				Cd K X-ray 47T4			
Ag- α -n chem, f } 47T4				Ag- α -n 47T4			
threshold ~12				In-n-2n 47T4			
In-n-2n } 47T4							
Cd-p-n chem, σ 39B3				d 23 ^m In 47T4, 48G3			
Cd-d-n chem 40L7							

49 INDIUM In

113						
			49	64		
τ_1	1.73 ^h 1.75	40L7 39B3			4.16% 4.23	49H3 49W9
γ	0.39 sc $\alpha = 0.7$ K/L = 5.4	40L7, 39B3 39B3 40L7	τ_2		$\sim 10^{14} \text{ yr}^*$	49C30
In K X-ray		39B3	I	9/2 M S	42H7 37B8	L capture* No K capture* pc 49C30 49C30
See Cd ¹¹³ for possible Ag, Cd, In, Sn relationships			μ	5.46 M 42H7, 49T1	49Po	
			Q	1.144 M	50M2	
				σ 's		
				(th n, γ) 72 ^s In 2.0	48G2	
				(th n, γ) 50 ^d In 56	47S33	
Cd-p-n chem, σ		39B3		(n, n) 1.73 ^h In similar to that		
Cd-d-n chem		40L7		for In ¹¹⁵ (n, n) 4.5 ^h In	48C19	
In- $\gamma\gamma$		45D2, 47D3		(6He p, n) 112 ^d Sn 0.03	39B3	
In-n-n σ		48C13		(γ, γ) 1.73 ^h In same as that		
				for In ¹¹⁵ (γ, γ) 4.5 ^h In	47D3	
d 112 ^d Sn		39B3				
						* Preliminary work

114
49 65

τ_1	50 ^d 49	49B52, 37L5 48W13, 39B3	Decay scheme				49B52, 49M50		τ_2	72 ^S	48W13, 39B3			
γ_1	0.192 s $\alpha = 4, K/L = 1.1$ $\alpha = \alpha, K/L = 1.0$ 0.191 sc 0.190 s 0.196 f $\alpha = 9$	40L7, 49B52 49B52 40L7 48C23 49M50 49M38 49M38							K 3% β^+ 0.01% β^- 97% γ_2 0.715 γ_3 0.548 γ_4 1.27	49B52 49M50 0.650 s 0.650 a 0.650 a 0.650 a	49B52 49M50 49B52 48C23 49M13 49B52 49M50 49B52 49M50 49M50 49M38			
In-n- γ	σ	49M38, 49M50 47S33 48W13	Stable Cd ¹¹⁴						γ_2 3%	0.715 s 0.722 s	49B52 49M50			
In- γ -n	relo	40L7	γ_2 and γ_3 in cascade				49B52, 49M38		γ_3 3%	0.548 s 0.552 s	49B52 49M50			
In-n-2n	chem		No $\beta^- e^-$ coincidences				49M38		$\gamma_4 \sim 0.03\%$	1.27 s 1.3 a	49M50 49M38			
In-d-p	chem		No $\beta^- \gamma$ coincidences				49M13, 49M38							
Cd-d-n	chem		$\gamma\gamma$ coincidences				49M13							
Cd-p-n	chem, σ	39B3	$\beta^+/\beta^- = 10^{-4}$				49B52							
p 72 ^S In														

49 INDIUM In

115

49 66

τ	4.50 ^h		47D3	95.84%	49H3
	4.53		40L7	95.77	48W9
			$\beta^- \sim 0.83$ 0.83 s 49B53 γ 0.338 sc 40L7, 49B53 $\alpha \sim 1, K/L \sim 5$ 40L7 $\alpha = 0.33$ 49B15 $\alpha = 0.337$ sc 49H7 $\beta^-/e^- = 0.13$ 49B53 X-rays account for all $e^- \gamma$ and $\gamma \gamma$ coincidences 49M6 Levels found in production of 4.5^hIn by $\text{In} \gamma \gamma$ and $\text{In} e^- e^-$		
Fission	chem	39G2, 40N3	1.04 49M7	β^-	(preliminary result) 49C30
In-d-d	σ	49M7	1.42 49M7	σ 's	
In- α - α	chem, σ	40R7	2.13 49W4	(th n, γ) 54^mIn	145 47S33
In- $e^- e^-$	σ	49W4	2.64 49W4	13^5In	52 47S33
In- $\gamma \gamma$		43W4, 49W4		($\sim 1\text{Mev}$ n, γ) 54^mIn	0.18 49H5
In-p-p	chem, σ	39B3		13^5In	0.063 49H5
In-n-n		39G2		Other fast n values	49B4, 49WH
	σ, f	48C19		($\sim 3\text{Mev}$ n, n) 4.5^hIn	0.36 48C19
Cd-d-n	chem	40L7		(5.8Mev p, p)	3×10^{-5} 39B3
d 2.3^dCd		39C4, 49H7		(2Mev d, d)	$< 10^{-6}$ 49M7
				(16Mev α, α)	3×10^{-4} 40R7
				(1.2Mev e, e)	$\sim 10^{-9}$ 49W4
				(γ, γ)	49M7, 47D3
Graphs Available $\sigma(n, \gamma) 54^m\text{In}$ 0.003-6Mev 46L7, 47GIF, 50A4 0.5-4Mev 48C19					

49 INDIUM In

116				117			
49		67		49		68	
τ_1	54.31 ^m 54.05 53.93	45R2 47G16 49S2		τ_2	13 ^s 35A1, 39C4		
β^-	0.85 s simple 0.7 a $\beta\gamma$	39C4 48M11		β^-	2.95 a 40L7 (46B27)		
γ	0.428 s 1.12 s 1.31 s 2.32 s < 1% above D- γ -n threshold 47W1 1-10% above Be- γ -n threshold 47W1 Other γ values cc	42D3 40C9		No γ	38M2		
Cd-p-n	chem, σ	39B3		Cd-p-n	44D9		
In-d-p		37L5		In-d-p	37L5		
In-n- γ	σ	47S33		In-n- γ	σ 47S33		
				Sn- γ -p	rel σ 47H4		
				Fission		46SP	
				Cd-d-n	chem	39C4, 40L7	
				Sn- γ -p	rel σ	47H4	
					d 2.7 ^b Cd	39G2, 40N3, 40L7	

118		119					
49		69		49		70	
τ	4.5 ^m	49D4		τ	17.5 ^m	49D4	
β^-	1.5	49D4		β^-	2.7	49D4	
γ		49D4		No γ		49D4	
Sn ¹¹⁹ - γ -p		49D4		Sn ¹²⁰ - γ -p		49D4	

Neutron Cross Sections for Natural Element			??			III ?		
			50			50	61 ?	
σ_s coh	4.6	49S12	τ	4.5 ^h 3	49M20, 48L4 39L4	τ	35.0 ^m	49H10
σ_s bound	4.9	49S12						
σ_a	$E_n = 0.025\text{ev}$ 0.58 0.71	49P3 49H2	K		49M20, 48L4	β^+	1.45	49H10
σ_s	4.3	(48H1)				X-ray		49H10
σ_t	4.6 ce	See graphs						
E_o	Resonances 6 ? ev 50 ? ev 100 ? ev	} 48H46						
σ_t	$E_n = 1\text{Mev}$ 6.5		$\text{Cd}^{106}\text{-}\alpha$	chem	49M20			
			Sb-d		48L4			
σ_t	Graphs Available 0.01-200ev 0.013-10,000ev 0.023-~14Mev 0-1.5Mev 1-300Mev	47G1F, 50Ad 48H46 47G1F 50Ad 50Ad	Not produced by			$\text{Cd-}\alpha\text{-n}$	chem	49H10
			$\text{Cd}^{108}\text{-}\alpha$		49M20	Enriched material used but details not given. Note Sn^{113}		
			$\text{Cd}^{110}\text{-}\alpha$		49M20			
			$\text{Cd-}\alpha$		39L4			
			p < 1 ^h In		49M20			
			p 65 ^m In		48L4			

112			113				
50	62		50	63			
1.01%	49H3	T_1	30-33 ^m	49N10	T_2	112 ^d	49N9
0.90	48W9		25	39L4		~100	39B3
0.94	48H44					70	39L4
		K ?		49N10	K		39B3
		β^+	1.2 a	49N10	γ	~0.09 a	49N9
		e^-		39L4	No γ	0.085 s	39B3
		X-ray		49N10	In K X-ray		47C4
							39B3, 47S33
See Cd ¹¹³ for diagram of possible relationships							
(th n, γ) 112 ^d Sn	1.1	47S33					
			Sn ¹¹² -n- γ	49N9	Sn ¹¹² -n- γ		49N9
			Cd- α -n	chem	39L4	Cd- α -n chem	39L4
						In-p-n chem, σ	39B3
						In-d-2n chem	47C4
						Sn-d-p chem	47C4
						Sn- α γ σ	47S33
						Sn- γ -n	48M33
						p 1.73 ^h In	39B3

114			115			116		
50	64		50	65		50	66	
0.68%	49H3		0.35%	49H3, 48W9		14.28%	49H3	
0.61	48W9		0.33	48H44		14.07	48W9	
0.65	48H44					14.36	48H44	
			I	1/2 S	49G2			
			μ	-0.86 S	49G2			
						Level	0.7 others ?	Sb ¹¹⁶ In ¹¹⁶
117			118					
50	67		50	68				
τ	14.5 ^d	49M51		7.67%	49H3	23.84%	49H3	
	14	48L4		7.54	48W9	23.98	48W9	
	13	39L4		7.51	48H44	24.21	48H44	
γ	0.175 sc	49M52	I	1/2 S	3383, 34T1			
	$\alpha \sim 1$	49M52						
	0.17 a	48L4	μ	-0.9948	49P0			
					I			
	0.159 a, s	49M51			49P11			
	0.162 a, s	49M51			S			
Sn X-ray		49P10, 49M52	Levels	0.156 ? ~0.5 ?	Sb ¹¹⁷	Levels	?	Sb ¹¹⁸
Cd ¹¹⁴ - α -n	chem	} 49M52						
Sn ¹¹⁶ -d-p	chem							
Sn ¹¹⁸ -n-2n	chem							
Sn ¹¹⁷ -n-n	chem							
Cd ¹¹⁶ -d-n	chem							
Sn ¹¹⁶ -n- γ		49M51						
Sb-d- α		48L4						
Cd- α -n	chem	39L4						
						σ 's		
						(th n, γ) $\gg 100^d$ Sn	0.02	49M51
						Sn- γ -n (n's observed)		49H17
						threshold = 6.5		

50 TIN Sn

119				120			
50		69		50		70	
τ	$\geq 100^d$	49M51	8.68% 8.62 8.45	49H3 49W9 49H44	32.75% 33.03 33.11	49H3 49W9 49H44	
γ	0.069 a, s	49M51	I 1/2 S 33S3, 34T1 μ -1.0410 I 49P0 S 49P11 34T1				
					Level 1.1?	Sb ¹²⁰	
Sn ¹¹⁸ -n- γ	σ	49M51			σ 's (th n, γ) 27 ^h Sn 0.22 (18Mev d, p) 27 ^h Sn 0.02 (18Mev d, 2n) 6 ^d Sb 0.1 (18Mev d, 2n) 17 ^m Sb 0.1 (18Mev d, 3n) 39 ^h Sb ~0.02	47S33 48L2	
Sn- γ -n		49M33					

121				122			
50		71		50		72	
τ	27.0 ^h 26.4	49N1 49L5	τ long 49K34	4.74% 4.78 4.61	49H3 49W9 49H44		
β	0.383 s 0.35 a ~0.4 a	49D15 49L5 49N11, 49L2	β 0.41 49K34				
No γ		49N6, 49L2, 49D15					
No e ⁻		49M51					
62 ^h Sn activity reported in 49PP probably due to 27 ^h Sn ¹²¹ activity			Sn ¹²⁰ -n- γ 49K34				
				(th n, γ) 40 ^m Sn	0.30	47S33	
Sn ¹²⁰ -n- γ	chem	49L5, 49N11, 49D15	41 ^m activity with $\beta \sim 2.5$, $\gamma = 0.25$ produced by				
Sn ¹²⁰ -d-p	chem, σ	49L2	Sn ¹²⁰ -d 49N6				
Sn ¹²² -n-2n		49L5	Assigned to Sn ¹²¹ 49N6				
Sb-n-p		49N6	Not produced by				
Sn ¹²² -slow n's	Not produced by	49L5	Sn ¹²⁰ -n- γ 49N1				
Sn ¹²⁴ -slow or fast n's		49L5	Sn ¹²⁰ -d-p 49L5				

50 TIN Sn

123 50 73				124 50 74				
τ_1	130 ^d 136	49L5, 49M51 49N1, 49O6		τ_2	39.5 ^m 41 40	49D15 49N11 49L5, 39L4	6.01% 6.11 5.83	49H3 48W9 48H44
β^-	1.42 s 1.3 a ~1.5 a	49B58 49L5 49N6		β^-	1.26 s 1.12 a 1.32 a ~1.7 a	49D15 49N9 49L5 49N6	$0.4-0.9 \times 10^{16} \gamma$ β^- 1.0-1.5	49F4 49F4
γ	0.394 s, a	49M51 49N9		γ	0.153 sc ~0.17 a ~0.4 a	49D15 49N6 49N9	Double β decay	49F4
weak								
No γ		49L5, 49N6						
No X-ray		49N6		Sb K X-ray		49N9, 49N6		
				β_e^- coincidences		49D15		
				$e^-/\beta = 0.11$		49D15		
				Sn ¹²² -n- γ		49L5, 49N9, 49D15	σ 's	
				Sn- γ -n		48M33, 49H17	(th n, γ) 10 ^m Sn	0.6 47S33
				threshold = 8.5		49H17		0.8 49S8
				rel σ		48W13	(th n, γ) 10 ^d Sn	0.15 47S33
Sn ¹²² -n- γ	chem	49L5, 49N9		Sn ¹²⁴ -n-2n		49L5		
Sn ¹²⁴ -n-2n	chem	49L5		Sn ¹²⁴ -d-t		49N6		
Sn ¹²² -d-p	chem	49L5						
Sb-n-p		49N6		Not produced by				
Sn ¹²⁴ -d-t		49N6		Sn ¹²⁰ -slow n's		49L5		
Fission	chem	50L8, 48O4, 48SF		Sn ¹²⁴ -slow n's		49L5		
				No Sb daughter with $\tau < 10^7$		49N6		

125 50 75				126 50 76				
τ_1	10.0 ^d 9.9 11	49L5 49B58 48H8, 46S13		τ_2	9.5 ^m 9.8 10	49N9, 49D27 49L5 47S21	70 ^m 80	42N3, 43H8 45S13
β^-	2.38 s 2.34 s 2.1 a 2.6 a	49N6 49B58 49L5 50S16		β^-	2.04 s 2.05 a $\beta\gamma$ ~2.2	49D27 49N9 47S21	60% 0.7 40% 2.7	50S16 50S16
γ ?		49N6		γ	1.17 s	49D27	~1.2	50S16
No γ		49B58						
				β^-	0.51 ? s 0.5 a	49D27 49N1	Any of these radiations may be due to 60 ^m Sb ¹²⁶	50S16
No X-ray		49N6		γ_1	0.326 sc, s 0.36 a $\beta\gamma$	49D27 49N1		
X-ray		47C4		γ_2	1.86 a $\beta\gamma$ >1	49N1 49D27		
Sn ¹²⁴ -n- γ		49N1						
Sn ¹²⁴ -d-p	chem	49L5		Sn ¹²⁴ -n- γ		49D27, 49L5, 49N9, 49S8		
Sn ¹²⁴ -fast n- γ	chem	49L5		Sn-d-p		39L4		
Fission	chem	50S16, 46S8, 43H8		Sn-n- γ		47S21, 39L4	Fission chem	42N3, 43H8
Sn-d-p	chem	47C4						
Sn-n- γ	chem	39L4						
	σ	47S33						
				Not produced by				
p 2.7 ⁷ Sb		49N1		Sn ¹²⁰ -slow n's		49L5		
No Sb daughter with $\tau < 50^7$		49N6		Sn ¹²² -slow n's		49L5	p 60 ^m Sb	46PP, 42N3, 43H8

51 ANTIMONY Sb

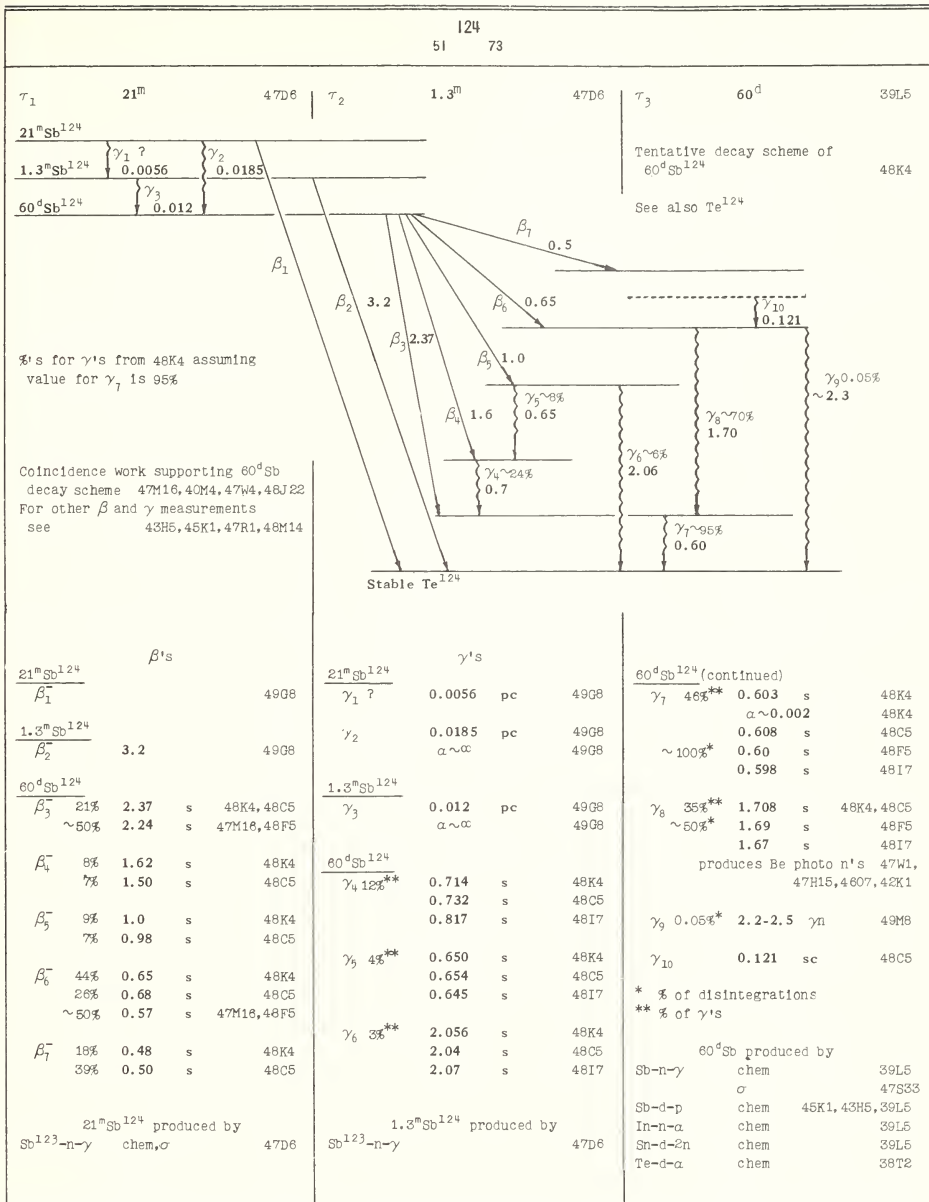
Neutron Cross Sections for Natural Element			116 51 65			117 51 66		
σ_s coh	3.7	49S12	τ	60 ^m	49T11	τ	2.8 ^h 3	47C4 39L5
σ_s bound	4.2	49S12						
σ_a	$E_n = 0.025\text{ev}$ 5.3 8.3	49P3 49H2	β^+	~ 1.45 s	49T11	K		47C4
σ_s	4.3	(48WH)	γ	~ 0.70 s	49T11	No β^+		49T11
σ_t	8.3	47R6				γ	0.156 sc α large	49T11 49T11
	Resonances					e^-	0.46 a	47C4
E_0 5.8ev	σ_{eff}^2 ~ 12	} 47R6				Sn K X-ray		47C4
15	~ 35							
21	~ 35							
σ_t	$E_n = 1\text{Mev}$ ~ 6.5	49B28						
	Graphs Available		In- α -3n	ms, chem, f	49T11	In- α -2n	ms, chem, f	49T11
σ_t	0.015-1000ev 0.020-1.6Mev 0.024-14Mev	47R6, 47GIF 49B28, 50Ad 47GIF	threshold ~ 27		49T11	threshold ~ 18		49T11
	References on fast n graphs and in 48WH					Sn-d-n	chem	47C4, 39L5
						Sn-p-n	chem	47C4

118				119			
		51	67			51	68
τ_1	5.1 ^h	47C4	τ_2	3.3 ^m 3.9 3.6	47L10 48L2 40R2	τ	39 ^h 48L2, 47C4
			β^+	3.1	a 48L2	K	47C4
γ	0.260 1.5	sc a 49T11 47C4	γ		48L2	No β^+	47C4
e^-	0.20	a 47C4				No γ	47C4
X-ray		47C4				Sn K X-ray	48L2, 47C4
						Level	Te ¹¹⁹
In- α -n	ms, chem, f	49T11	In- α -n	chem	39L3	Sn-d-n	chem 47C4
threshold	~13	49T11		chem, σ	40R2	Sn-p-n	chem 47C4
	chem	47C4	Sn-p-n		44D9	Sn-d-pSn	chem 48L2
Sn-d-n	chem	47C4		d e^d Te	48L2	Sn ¹²⁰ -d-Sn	σ 48L2
						d 4.5 ^d Te	48L2

51 ANTIMONY Sb

120						121					
51			69			51			70		
τ_1	16.6 ^m	48P3	τ_2	6.0 ^d	48L2		57.25%		48W9		
	17	37H4, 39L5									
	15.4	37P2									
β^+	1.5	cc	38A3	K	48L2	I	5/2	S	32B1, 34C3		
				γ	1.1	a	48L2	μ	+3.7	S	36B6, 34C3
				Sn K X-ray	48L2	q	-0.3		49M48		
				No β^+	48L2		~0		40T3		
						Level	0.61		Te ¹²¹		
Sn ¹²⁰ -d-2n	chem, σ	48L2					σ 's				
Sn-d-n	chem	39L5				(th n, γ) 2.8 ^d Sb	6.8		47S33		
Sb- γ -n	rel σ	48W13, 39B5, 48P3				(~1 Mev n, γ) 2.8 ^d Sb	0.09		49H5		
	threshold = 9.25	49M17							49B4,		
Sb-n-2n	44J5, 37P2	48L2	Sn ¹²⁰ -d-2n	chem, σ	48L2				48WH		
	threshold = 5.5-7	38S14	Sb-d ₁	chem	48L2						
Sb-d-t	chem	41K4									
Sn-p-n		44D9									

122						123					
51			71			51			72		
τ_1	3.5 ^m	47D6	τ_2	2.8 ^d	39L11		42.75%		48W9		
				2.63	40M4						
				2.5	35A1						
3.5^mSb¹²² 2.8^dSb¹²² ~0.14 β_1 1.94 β_2 1.36 γ 0.568 Stable Te¹²²											
IT						I	7/2	S	32B1, 34C3		
γ	~0.14	ac	47D6			μ	+2.8	S	36B6, 34C3		
Sb K α X-ray						q	-1.2		49M48		
						Levels	0.15		Sn ¹²³		
							0.39				
3.5 ^m Sb ¹²² produced by			β_1^-	1.94	s	48M6	σ 's				
Sb-n- γ	47D6			1.77	a	48M11	(th n, γ) 1.3 ^m Sb	~0.03	47D6		
				1.76	a	40M4	(th n, γ) 60 ^d Sb	2.5	47S33		
2.8 ^d Sb ¹²² produced by			β_2^-	1.36	s	48M6					
Sb-n- γ	39L5			1.19	a, $\beta\gamma$	48M11					
Sn-p-n	σ	44D9		~0.81	a	40M4					
Sn-d-2n	chem	39L5	γ	0.568	sc	48C5, 48K4					
Sb-d-p	chem	48L2		0.57	sc	47R1					
Sb- γ -n	rel σ	48W13	No β^+			47B8					



51 ANTIMONY Sb

[illegible]

51 ANTIMONY Sb

		132 51 81	
		τ $\sim 5^m$ 39A2	
		Fission chem 39A2	
		p 77^hTe 39A2	
133 51 82		134 51 83	
Sb parent, if any, of 21^hI has $\tau < 10^m$ 39A2	Sb parent, if any, of 51^mI has $\tau < 10^m$ 39A2	τ 28^d 46G6	
		β^- 1.86 a 46G6	
		Fission chem 46G6	

52 TELLURIUM Te

Neutron Cross Sections for Natural Element			?		
σ_a	$E_n = 0.025\text{ev}$ 4.53 5.87	49P3 49H2	τ	2.5^h	48L2
σ_s	5.3	37G1	β^+		48L4
E_o	Resonance > 300ev	49H16	e^-		48L2
			Sb-d	chem	48L2
118 52 66			119 52 67		
τ	6.0^d	48L2	τ	4.5^d	48L2
X-ray		48L2	γ	1.5 a	48L2
			e^-	0.2 0.5	48L2 48L2
Sb-d-5n	chem	48L2	Sb-d-4n	chem	48L2
p 3.3^mSb		48L2	p 39^hSb		48L2
120 52 68					
				0.090% 0.091 0.09	49H3 48W9 48W8

52 TELLURIUM Te

121									
52					69				
τ_1	143^d 125	46E3 40S1	τ_2	17^d ~ 16	46E3 46B6				
						$143^d Te^{121}$			
						γ_1	0.082 sc	42K2, 49H25	
							α large	49H25	
							K/L ~ 0.8	49H25	
						γ_2	0.213 sc	49H25	
							$\alpha_K \sim 0.13, K/L = 4.2$	49H25	
							0.211 sc	42K2	
							0.225 a	46B6, 46B8	
						γ weak	0.032 ⁵	} 49H25	
						these γ 's not yet assigned	0.035		
						Te K X-ray		46E3	
						X γ and e $^-$ γ coincidences		46B6	
						$17^d Te^{121}$			
						γ_3	0.615 sc	42K2	
							0.61 a	46E3	
							α small	46E3	
						Sb K X-ray		46E3	
122					123				
52 70					52 71				
2.47%	49H3	τ	$\sim 100^d$	49H25	0.89%	49H3, 48W8			
2.49	48W8	IT		49H25	0.85	48W8			
2.43	46W8								
Level	0.57	Sb^{122}	γ_1	0.0885 sc 49H25 K/L = 0.92 49H25 0.0883 sc 42K2	I	1/2 S 49M47			
σ 's					μ	$\frac{\mu(Te^{123})}{\mu(Te^{125})} = 1.208$	49M47		
(th n, γ) $\sim 100^d Te$	~ 1	49H25	γ_2	0.159 sc 49H25 $\alpha_K \sim 0.2, K/L = 7.7$ 49H25 0.157 sc 42K2					
					$Te^{122} - n - \gamma$	49H25			

52 TELLURIUM Te

124			
52		72	
		4.74%	49H3
		4.63	48W9
		4.59	46W8
Level scheme		49M35	
Short lived isomer		47H24	
No short lived isomer		49B9, 49M26	
σ's			
(th n, γ) 58dTe		~5	49H25

125			
52		73	
τ	58d ~60	49H27 48F2	7.03% 7.01 6.98
IT		48F2	
		I	1/2 S
Stable Te ¹²⁵ 1/2		μ	$\frac{\mu(\text{Te}^{123})}{\mu(\text{Te}^{125})} = 1.208$
γ ₁	0.109 sc α~1, K/L = 1.5, L/M ~3.5 49H25, 49H27 0.110 sc K/L = 1.2 49K14	Levels	Sb ¹²⁵
γ ₂	0.0354 α _K ~3, α _L ~0.41 49H25 49B49		
γ ₁ γ ₂ in cascade γ ₂ delay < 5x10 ⁻⁸ s 49B49 49B49			
Te ¹²⁴ -n-γ σ 49H25			
d 2.7dSb 48F2, 49H27			

126			
52		74	
		18.72%	49H3, 48W9
		18.70	46W8

52 TELLURIUM Te

127				128				
52		75		52		76		
τ_1	90 ^d	40S1		τ_2	9.3 ^h	40S1		
IT		40S1						
				τ for double β decay $> 1.3 \times 10^{19}$ 49I3				
γ	0.0885 sc	49H25		β^-	~ 0.8 a	40S1		
	K/L = 0.75	49H25			0.70 a	46PP		
	0.085 sc	41H1		No γ		46PP		
	$\alpha \sim \alpha_K/L = 0.75$	41H1						
	$\alpha > 5.7$	46W18						
Te ¹²⁶ -n- γ		49H25		Te-n- γ	chem	40S1		
Te-n- γ	chem	40S1			σ	47S33		
	σ	47S33		I-n-p	chem	40S1		
Te-d-p	chem	40S1		Te-n-2n		38T2		
I-n-p	chem	40S1		Fission	chem	39A2		
Fission	chem	39A2		Te-d-p	chem	40S1		
d (16%) 93 ^h Sb	46B19, 39A2			d (84%) 93 ^h Sb	46B19, 39A2			
129				130				
52		77		52		78		
τ_1	32 ^d	40S1		τ_2	72 ^m	40S1		
	35.5	46W13			70	39A2		
					67.3	46W13		
IT		40S1		β^-	1.8 s	47R1		
					1.75 a	46PP		
γ	0.106 sc	49H25			1.6 a	50n5		
	K/L = 1	49H25		γ	0.3 a	46PP		
	$\alpha > 1.9$	46W18			~ 0.8 a	46PP		
	0.102 sc	41H1						
	$\alpha \sim \alpha_K/L \sim 1$	41H1						
Fission	chem	50n5		Fission	chem	39A2		
Te- γ -n	rel σ	46W13		Te- γ -n		39B5		
Te-n- γ	chem	40S1			rel σ	46W13		
	σ	47S33		Te-n- γ	chem	40S1		
Te-d-p	chem	40S1			σ	47S33		
Te-n-2n		38T2		Te-n-2n		37H4, 38T2		
				Te-d-p	chem	40S1		
				d 4.2 ^h Sb	39A2			
				τ for double β decay $> 8.0 \times 10^{19}$ 49I3				
				σ 's				
				<th <math="" n,="">\gamma) 1.25^dTe < 0.008 47S33 </th>				\gamma) 1.25 ^d Te < 0.008 47S33
				<th <math="" n,="">\gamma) 25^mTe 0.22 47S33 </th>				\gamma) 25 ^m Te 0.22 47S33

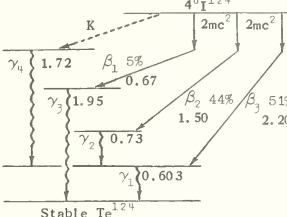
52 TELLURIUM Te

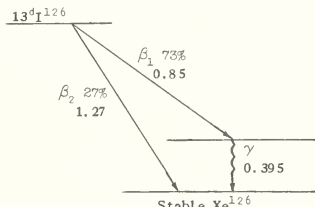
131						132					
52			79			52			80		
τ_1	1.25 ^d	39A2	τ_2	25 ^m	40S1	τ	77 ^h	39A2			
	1.2	40S1		30	39A2		66	39H9			
IT		40S1	β^-	> 1.8	a 48W18	β^-	0.28	a 50n6			
							~0.3	43B2			
γ	0.177 sc	41H1									
	$\alpha \sim 0.6$	41H1									
	$\alpha \geq 0.6$	48W18				γ	0.22	a 50n6			
	K/L = 2	41H1, 49H25									
Te-n- γ	chem	40S1	Te-n- γ	chem	40S1	Fission	chem	39A2, 46SP			
σ		47S33	σ		47S33	Mass assignment from range					
Te-d-p	chem	40S1	Te-d-p	chem	40S1	of fission fragment		48K9			
Fission	chem	39A2	Fission	chem	39A2						
			p 8 ^d I		39A2, 40S1	d ~ 5 ^m Sb		39A2			
						p 2.4 ^h I		39A2, 39H7			
133						134					
52			81			52			82		
τ	60 ^m	39A2, 45W5	τ	43 ^m	39A2						
β^-		39A2									
Fission	chem	39A2	Fission	chem	39A2						
Mass assignment from range			Mass assignment from range								
of fission fragment		48K9	of fission fragment		48K9						
p 21 ^h I		39A2, 39H7	p 52 ^m I		39H7, 39A2, 40P3						

52 TELLURIUM Te

?		
τ $\sim 1^m$ 43H8		
Fission chem 43H8		

Neutron Cross Sections for Natural Element			119 ? 53 66 ?		
σ_s coh	3.4	49S12	Graphs Available σ_t 0.01-1000ev 47GIF, 47W8, 47J4 See also 49H16 0.020-1.6Mev 49B28, 50Ad 0.02-3.5Mev 47GIF Other references on graphs and in 48WH Resonances $E_n = 0.025\text{ev}$ $\sigma_s \sim 4$ $E_n = 20.6\text{ev}$ $E_n = 20.3$ $E_n = 32$ $E_n = 42$ Two additional resonances between 25 and 50ev $E_n = 2.6\text{Mev}$ σ_t 5.4 39A5		
σ_s bound	3.8	49S12			
σ_a	6.1 9.1	49P3 49H2			
σ_t	11 10.3	47W8 47J4			
			τ	30^m	49M53
			β^+	4.0	49M53
			Sb- α	chem	49M53
			$E_\alpha > 100\text{Mev}$		
			p several days Te		49M53
120 53 67			121 53 68		
			τ	1.8^h	49M53
			β^+	1.2	49M53
			e^-	0.185	49M53
			Sb- α	chem	49M53
			$E_\alpha > 45\text{Mev}$		
			p 17^dTe		49M53
122 53 69					
			τ	4^m	49M53
			β^+	2.9	49M53
			Sb- α -3n	chem	49M53

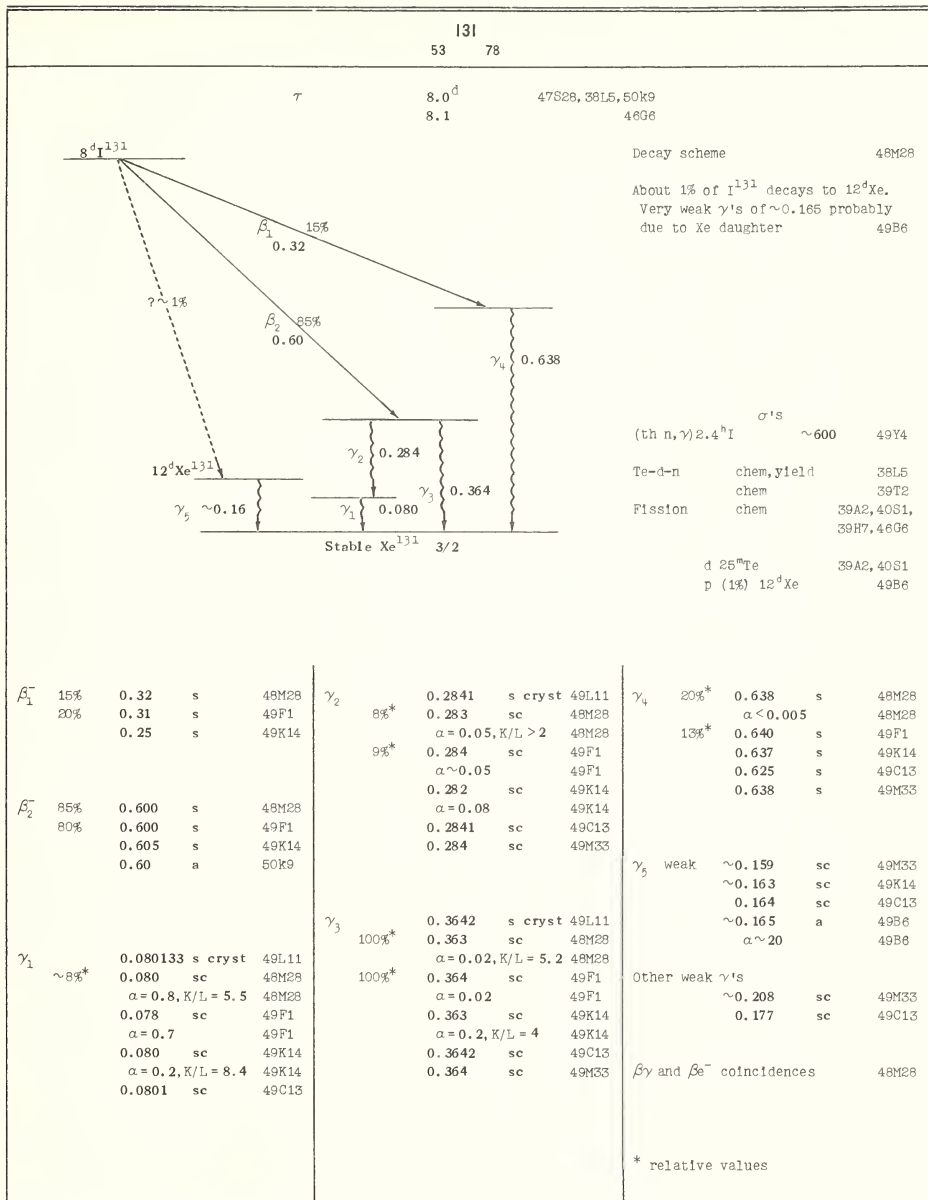
123 53 70			124 53 71			
τ	13^h	49M35, 49M53	τ	4^d 4.5	38L5, 44D9 49M53	
K or IT		49M35	Decay scheme			
γ	0.159 sc See also ~ 0.18 ac	49M35 Te ¹²³ 49M53	β_1^+ 5% β_2^+ 44% β_3^+ 51%	0.67 1.50 2.20	s s s	49M35 49M35 49M35
			Spectral shape consistent with $\Delta I=2$, yes			
			γ_1	0.603	sc	49M35
			γ_2	0.73	s	49M35
			γ_3	1.95	s	49M35
			γ_4	1.72	s	49M35
Sb ¹²¹ - α -2n	chem	49M35	Te X-ray	} 49M32		
Sb- α -2n	chem, f	49M53	$\beta\gamma$, $\gamma\gamma$ coincidences No βe^- coincidences			
			Sb- α -n	chem	49M35	
			Sb ¹²¹ - α -n	chem, yield	38L5	See also Te ¹²⁴
			Sb- α -3n	chem, f	49M53	
			Te-p-n	chem, f	44D9	
Not produced by I-fast n's		49M35				

125 53 72			126 53 73			
τ	$\sim 56^d$	46R4	τ	13.0^d 13.1	38L5 48M33	
K		47G5, 46R4				
Te K _a X-ray		47G5	β_1^- 73%	0.85	s	49M35
			β_2^- 27%	1.27	s	49M35
				1.1	a	38L5
Sb- α -2n	chem, f	49M53	γ	0.395	sc, s	49M35
Te-d	chem, yield chem	47G5 46R4		0.5	a	38L5
			I- γ -n			48M33
				rel yield		49P5
				threshold = 9.3		49M17
				9.45		49B3
			Sb- α -n	chem, yield		38L5
			Te-d-n	chem, f		49M53
			Te-p-n	chem		38L5
			I-n-2n			44D9
						38L5

				127		128				
				53	74	53		75		
				100%	37N2	τ	24.99 ^m	41H4		
I	5/2	S	39T3, 38M6							
μ	2.7944		49P0							
		I	49Z2, 48P9							
		S	39S15							
		Mic	49Q19							
Q	-0.75	Mic	48B23, 48S31, 48Q21, 48T11							
	-0.46	S	39M7, 39T3, 39S16							
				σ 's						
				(th n, γ) ^{25}I	6.3	47S33				
				(1 Mev n, γ) ^{25}I	0.11	49H5				
				Other fast n values	49B4, 48WH					
				Graphs Available						
				$\sigma(n, \gamma) ^{25}\text{I}$	0.03-6Mev	48M19, 47GIF, 50Ad				
						β_1^- 7%	1.59	s	46S10	
						β_2^- 93%	2.02	s	46S10	
							2.2	a	38L5	
						γ	0.428	46S10		
						I-n- γ	σ	47S33		
							f	47J4		
						$E_\gamma(\text{max})$	= 7.0	49K15		
						Te-d-2n	chem, yield	38L5		
						Te-p-n		44D9		

				129		130					
				53	76	53		77			
τ	2-4x10 ^{7y}		49P19	τ	12.5 ^h	12.5 ^h			39T2		
	long		47K4, 50I7		12.6				38L5		
I	7/2	Mic	49L9					β_1^- 40%	0.61	s	43R2
μ	2.72	Mic	49Q19 (49P0)					β_2^- 60%	1.03	s	43R2
Q	-0.43	Mic	49L9 (49P0)					γ_1	0.417	sc	43R2
β^-	~0.12		49P19					α_K	= 12x10 ⁻³		
γ or X-ray	~0.03		49P19					γ_2	0.744	sc	43R2
$\beta/\gamma \sim 1$			49P19					α_K	= 3x10 ⁻³		
Levels	0.3		Te ¹²⁹					γ_3	0.667	sc	43R2
	~0.8							α_K	= 4x10 ⁻³		
				σ 's							
				(th n, γ)	~15	49P19					
				(th n, γ) 12.5 ^h I	~8	47K4					
Fission	chem		47K4					γ_4	0.537	sc	43R2
								α_K	= 7x10 ⁻³		
				I-n- γ	chem, σ	47K4	Order of $\gamma_2, \gamma_3, \gamma_4$ unknown. See Cs ¹³⁰				
				Cs-n- α	chem	40W5	$\beta\gamma$ and $\gamma\gamma$ coincidence rates				
				Te-d-2n	chem, yield	38L5	support decay scheme				
								43R2			
								$a_L \ll a_K$ for all γ 's		43R2	

129				130				
53		76		53		77		
τ	2-4x10 ^{1y} long		49P19 47K4, 50L7	τ	12.5 ^h 12.6		39T2 38L5	
I	7/2	Mic	49L9					
μ	2.72	Mic	49G19 (49P0)			β_1^- 40%	0.61 s	43R2
Q	-0.43	Mic	49L9 (49P0)			β_2^- 60%	1.03 s	43R2
β^-	~ 0.12		49P19			γ_1	0.417 sc $a_K = 12 \times 10^{-3}$	43R2
γ or X-ray	~ 0.03		49P19			γ_2	0.744 sc $a_K = 3 \times 10^{-3}$	43R2
$\beta/\gamma \sim 1$			49P19			γ_3	0.667 sc $a_K = 4 \times 10^{-3}$	43R2
Levels	0.3 ~ 0.8		Te ¹²⁹			γ_4	0.537 sc $a_K = 7 \times 10^{-3}$	43R2
σ 's				Stable Xe ¹³⁰				
(th n, γ)	~ 15		49P19	I-n- γ	chem, σ	47K4	Order of $\gamma_2, \gamma_3, \gamma_4$ unknown. See Cs ¹³⁰	
(th n, γ) 12.5 ^h I	~ 8		47K4	Cs-n- α	chem	40W5	$\beta\gamma$ and $\gamma\gamma$ coincidence rates support decay scheme	
Fission	chem		47K4	Te-d-2n	chem, yield	38L5	43R2	
				$a_L \ll a_K$ for all γ 's				43R2



132				133				134 ?			
53		79		53		80		53		81 ?	
τ	2.4 ^h		39A2	τ	21 ^h		49B47	τ	50.8 ^m		49L19
	2.3		39H8		22	39A2, 40W5, 50K6			54		39A2
β^- ~50%	0.9	a	50n6	β^- 6%	~0.5	ac	49B47	β^-	~1.6	a	49L19
	~1.35	a	43B2		94%	1.4 ac	49B47		~3.9	a	49L19
						1.4 a	50S19				
~50%	2.2	a	50n6	γ 94%*	0.53	s	49B47	γ	> 2.3		49L19
γ ~50%	0.6	a	50n6		0.528	s	47P13				
	0.85	a	43B2		5%*	~0.85	s				
~50%	1.4	a	50n6		1%*	~1.4	s				
Level	0.22		Te ¹³²				49B47				
				* % of disintegrations							
				$\gamma\gamma$ coincidences in ~5% of disintegrations							
Fission	chem		39A2, 39H7, 48G6, 48SP	No evidence for metastable state with $\tau > 10^{-6}$ s				Fission	chem		39A2, 39H7, 48SP
				Fission chem 39A2, 39H7, 40W5							
d ⁷⁷ Te			39A2, 39H7		d ⁸⁰ Te	39A2, 39H7		d ⁸³ Te			39A2, 39H7, 40P3
					p ^{5.3} Xe	45W5					

135				136			
53		82		53		83	
τ	6.68 ^h		47P13	τ	86 ^s		49S27
	6.7		50G9, 50K6		108		40S3
	6.6		41S2, 40D7				
β^- 35%	0.47	s	47P13	β^-	6.5	a	49S27
40%	1.0	s	47P13	γ	2.9	a	49S27
25%	1.4	s	47P13				
	1.4	a	50K6				
	1.55	a	50S32				
γ	1.27	s	47P13				
	1.3	a	50S32				
	1.8	s	47P13				
	1.6	a	50K6				
1.1%*	2.4	γn	49L19	Fission	chem		41S2, 40W5, 48SP, 50K6
1.4 β not in coincidence with γ			47P13		p (~10%) ^{15.3} Xe		40G2, 45W5, 50G9
					p (~30%) ^{15.3} Xe		47P13
					p (~90%) ^{9.2} Xe		45W5, 40G2, 50G9
* % of disintegrations					p (~70%) ^{9.2} Xe		47P13
				Fission	chem		40S3

53 IODINE I

137 53 84			138 53 85			139 53 86		
τ	19.3 ^s 22 22.5 30	49S14 48H33 47R2 40S3	τ	5.9 ^s	49S14	τ	2.7 ^s	49S14
β^-		47S7, 48H33	β^-		49S14	β^-		49S14
Delayed n emitter		47S7						
E_n^-	0.56 a 0.7	48H33 46B22						
Delayed n's in ~7% of disintegrations		5012						
Fission	chem	47R2, 41S3, 43S1, 47S7	Fission	chem	49S14	Fission	chem	49S14
p 3.9 ^m Xe	49T4, 43S1, 49S14		p 3.3 ^m Cs	49T4, 49S14		p 8.5 ^m Ba	49S14	
No I found in fission with $\tau > 8^d$ except I^{129}								
		5017						

54 XENON* Xe

Neutron Cross Sections for Natural Element			124		125	
			54	70	54	71
σ_t	$E_n \sim 0.025\text{ev}$		0.095%	47L2		
	37	42R3	0.102	47D9		
			0.094	37N2		
σ_s	4.0	50H5				

* "chem" on the Xenon pages indicates separation which was carried out by physical means
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54 XENON* Xe

128			129			130		
54	74		54	75		54	76	
1.917%	47L2		26.24%	47L2		4.053%	47L2	
1.93	47D9		26.51	47D9		3.68	47D9	
1.90	37N2		26.23	37N2		4.07	37N2	
			I	1/2 S	34K2,34J1			
			μ	-0.9 S	34K2,34J1			
Level	0.43	I^{128}	Level	~ 0.5	Cs^{129}	Levels	0.51 ? 0.537 ? 1.20 ? 1.95 2.37	Cs^{130} I^{130}
131			132			132		
54	77		54	78		54	78	
τ	$\sim 12^d$	49B6	21.24%	47L2		26.93%	47L2	
	~ 14	47A4	21.04	47D9		27.12	47D9	
	11	44C11	21.17	37N2		26.96	37N2	
IT		49B6,44C11	I	3/2 S	34K2,34J1			
γ	~ 0.165	a 49B6	μ	+0.8 S	34K2,34J1			
	$\alpha \sim 20$	49B6	q	~ 0	38S10			
Xe K X-ray		49B6						
			Levels	0.080 ? 0.145 ? ~ 0.16 0.364 0.638	I^{131} Cs^{131} $12^d Xe^{131}$ I^{131} I^{131}	Levels	0.6 1.4 ?	I^{132}, Cs^{132} I^{132}
Fission	chem	47A4						
Xe-n-n		44C11						
	d ($\sim 1\%$) $B^d I$	49B6				(th n, γ) $5.3^d Xe$	0.2	43K5

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54 XENON* Xe

133			134		
54	79		54	80	
τ	5.271 ^d	49M25	10.52%	47L2	
	5.3	50e5	10.54	47D9, 37N2	
	5.4	41C2			
β^-	0.315	s 49T4			
	0.34	a 50e5			
	0.26	a 45W5			
	0.32	a 43S2, 43B2			
γ	0.085	a 50e6			
	0.083	a 43B2			
X-ray	0.031	a 50e6	Level	>2.3	I ¹³⁴ ?
	0.040	a 50e5			
Fission	ms	49T4, 49M25			
Cs-n-p	chem	45W5, 44C11, 45S2			
Ba-n- α	chem	45W5, 44C11			
Xe-n-2n		43R1	(th n, γ) 9.2 ^h Xe	0.2	44T3
Xe-n- γ		43R1, 44C11			
Te- α -n	chem	41C2			
Xe-d-p	chem	41C2			
d 21 ^h I		45W5			

135			136		
54	81		54	82	
τ_1	15.3 ^m	46B16	τ_2	9.2 ^h	50n7, 50g9
	15.6	43R1		9.4	40W5
	13	50n9		9.5	40D7
	10	40G2, 45W5		9.6	43R1, 41C2
			β^-		
				0.93	s 49T4, 47F13
				0.95	a 43B2
				0.9	a 45W5
				1.0	a 50h4
			γ_2	0.247	s 47F13
				0.25	a 45W9
				0.26	a 50n7
			Levels	?	I ¹³⁵
γ_1	0.52	s 47F13	Fission	ms	49T4
	0.54	ac 50n9		chem	40D7, 45W5
	~0.5	a 45W5	Xe-d-p	chem	41C2
	0.6	ac 43S2	Ba-n- α	chem	45W5, 43S2
Fission	chem	40G2, 45W5	Xe-n- γ		43R1
Xe-n- γ		46R7, 43R1		σ	44T3
Xe-n-2n		43R1	Xe-n-2n		43R1
	d (~10%) 6.7 ^h I	45W5, 40G2,		d (~90%) 6.7 ^h I	45W5, 40G2,
		50g9			50g9
	d (~30%) 6.7 ^h I	47F13		d (~70%) 6.7 ^h I	47F13
				p 2X10 ⁶ Cs	45W5, 50f5, 50e7

				8.93%	47L2
				8.98	47D9
				8.95	37N2
			β^-		
				0.93	s 49T4, 47F13
				0.95	a 43B2
				0.9	a 45W5
				1.0	a 50h4
			γ_2		
				0.247	s 47F13
				0.25	a 45W9
				0.26	a 50n7
			Levels	~1	Cs ¹³⁶
				2.9	I ¹³⁶
			Fission	ms	49T4
				chem	40D7, 45W5
			Xe-d-p	chem	41C2
			Ba-n- α	chem	45W5, 43S2
			Xe-n- γ		43R1
				σ 's	
				(th n, γ) 37 ^h Cs	0.15
				(~1MeV n, γ) 3.9 ^m Xe	0.001
					49H28

* "chem" on the Xenon pages indicates separation which was carried out by physical means

54 XENON* Xe

137 54 83			138 54 84			139 54 85		
τ	3.9 ^m 3.8 3.4	48S16 43S1 43R1	τ	17 ^m	40G5	τ	41 ^s ~30	50d1 40H4
β^-	~4	a 43B2	β^-		39H7	β^-		39H7
Neutrons emitted following 19 ⁵ I disintegration			I ¹³⁷					
Fission	ms chem	49T4 43S1	Fission	ms chem	49T4 40H4, 40G5, 43S2, 46PP	Fission	chem	40H5, 40H4
Xe-n- γ		43R1, 48S16						
	d 19 ⁵ I	49S14, 43S1, 49T4					p 85 ^m Ba p 9.5 ^m Cs	50d1, 39H3 39H3, 40H4
	p 37 ⁷ Cs	50t1, 50g16		p 33 ^m Cs	40H4, 40G5, 43S2			
140 54 86			141 54 87			142 54 88		
τ	16 ^s ~0.5 ^m	50d1, 46D14 40H4	τ	3 ^s 1.7	50d1 50o1			
β^-		40H4	β^-		50b2			
Fission	chem	40H4, 46PP	Fission	chem	50b2			
	p 12.8 ^d Ba	40H4, 50o1, 50d1, 50b2		p short Cs p 3.7 ^h La p 28 ^d Ce	50b2, 50d1 50b2 50o1, 50d1			

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54 XENON* Xe

143 54 89			144 54 90			145 54 91		
τ	$\sim 1^s$	50d1	τ	$\sim 1^s$	50d1	τ	0.8^s	50d1
Fission	chem	50b2	Fission	chem	50d2	Fission	chem	50d1
p 33^hCe		50b2, 50d1						
p 13.8^dPr		50o1	p 275^dCe		50d2	p 1.6^hCe		50d1
??								
τ	68^m	41C2	No Xe with $\tau > 5^d$ found in fission 50h1					
Xe-d-p		41C2						

* "chem" on the Xenon pages indicates separation which was carried out by physical means
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55 CESIUM Cs

Neutron Cross Sections for Natural Element			127 55 72			128 55 73		
σ_a	$E_n = 0.025\text{ev}$ 29	49F3	τ	5.5^h	49F9			
σ_t	~ 50	42L1	β^+	~ 1.2	a	49F9		
			$e^- \gamma$	0.35	a	49F9		
			No γ 's harder than annihilation γ 's			49F9		
			X-ray			49F9		
			I- α -4n			ms, chem	49F9	
			p ^{34}dXe			49F9		
129 55 74			130 55 75			131 55 76		
τ	31^h	49F9	τ	30^m	49F9, 48R4	τ	9.6^d	49Y1
							10	47Y1
							10.2	50k12, 47K5
No β^+		49F9	γ	0.51	49F9	K		50k12, 47K5, 47Y1
γ	~ 0.5	49F9	X-ray			No β^+		50f7, 47F9
e^-	0.33	a			49F9	No γ		50k12, 47K5
K, L X-rays		49F9				γ	0.145	a, ac
							$\alpha \sim 32$	47Y1
						e^-	0.115	49Y1
						Xe K X-ray		47Y1, 49Y1, 47K5, 50k12, 47F9
						Levels	0.26 0.5 ~ 1.2	Ba ¹³¹
							}	
I- α -2n	ms, chem	49F9	I- α -n		49F9, 48R4	Ba-n- $\gamma\beta$	ms	49K7
							d ^{12d}Ba	50k12, 47K5, 47Y1

55 CESIUM Cs

132			133		
55	77		55	78	
τ	7.1 ^d	44C11	100%	37N2	
K		44C11	I	7/2 S 37F3, 34J2, 31K1 Z 34C4	
γ	0.62 a	44C11	μ	2.563	49P0
e^-	0.6 a	44C11	I	49B7, 49C2	
			M	39K10	
			q	≤ 0.3	40S9
Possible level scheme					
Cs-n-2n			σ^1s (th n, γ) 3^hCs 0.016 47S33 (th n, γ) 2.3^hCs 26 47S33 (30Mev α , 2n) 19^hLa 0.03 48C3		

134			55 79		
τ_1	3.15 ^h 3	45S2 40K7	τ_2	2.3 ^y 1.7 >254 ^d	50G19 40K7 45S2
			3.15^hCs^{134} β_1 2.4 a 45S2 γ_1 0.128 s 49C1 0.15 s 47P10 0.16 a 47M21 $\gamma ?$ 0.7 a 45S2		
2.3^yCs^{134} produced by Ce-n- γ chem, σ 40K7 Cs-d-p chem 40K7 2.3^yCs^{134} produced by Ce-n- γ chem, σ 40K7, 38S8 Cs-d-p chem 40K7 Ba-d- α 43H10			2.3^yCs^{134} β_2 75% 0.658 s 47E2 95% 0.65 s 47S13 0.635 s 47P10 β_3 34% 0.090 a $\beta\gamma$ 49M38 25% 0.09 s 47E2 γ_2 28%* 0.568 s 47E2 0.566 s 48S1 γ_3 100%* 0.602 s 47E2 0.603 s 48S1 0.610 s 47P10 γ_4 ~1.35 s 48S1 γ_5 100%* 0.794 s 47E2 0.798 s 48S1 0.799 s 47P10		
Order of γ 's uncertain 48S1, 47E2 $\gamma\gamma$ coincidences 48S1 γ 1.63 < E < 2.3 in $7 \times 10^{-5}\%$ of disintegrations 49F5 No Xe K X-ray 48S1 $\gamma\gamma$ angular correlation indicates I = 4, 2, 0 48B18 * relative % of γ 's 47E2					

55 CESIUM Cs

135 55 80				136 55 81			
τ	2.1×10^6 y 5×10^6	49S3 49B5		τ	13.7^d 13 10.2	48G11 50g13, 50f8 44C11	
I	7/2 M	49D1		β^-	~ 0.35 ~ 0.28	a a	48G11 50f8
μ	2.72 M	49D1		γ	0.9 1.2	a a	48G11 50f8
$\begin{array}{c} 2.1 \times 10^6 \text{ y } ^{135}\text{Cs} \quad 7/2 \\ \beta^- \quad 0.21 \text{ No } \gamma \\ \text{Stable } ^{135}\text{Ba} \quad 3/2 \end{array}$				$\gamma/\beta = 2$		48G11	
Level in ^{135}Cs	0.25	Xe^{135}		$\beta\gamma$ coincidences			50f8
$\begin{array}{c} \sigma^1 \text{ s} \\ (\text{th n, } \gamma) ^{137}\text{Cs} \sim 15 \end{array}$							
Fission	chem	49S3		Fission	chem	50f8, 48SP	
				La-n- α	chem	48G11, 44C11	
d 9.2 ⁿ Xe 50e7, 50f5, 49S3, 45W5							
137 55 82				138 55 83			
τ	^{137}Cs 33	48E5 50g17		τ	^{138}Cs 32	50e8, 40H4 50g16	
I	7/2 M	49D1		β^-	2.68 2.65	s a	49T4 40G5 (46B27)
μ	2.84 M	49D1		γ	1.2	a	50g16
Proposed decay scheme	49P2						
$\begin{array}{c} ^{137}\text{Cs} \quad 7/2 \\ \beta_1^- \quad 5\% \quad 1.2 \\ \beta_2^- \quad 95\% \quad 0.51 \\ \gamma \quad 0.669 \\ \text{Stable } ^{137}\text{Ba} \quad 3/2 \end{array}$				β_1^-	5% 1.2 s 49P2 <5% 1.2 s 4903 unallowed shape? 4903, 49P2		
				β_2^-	95% 0.51 s 49L6 0.521 s 49P2 0.518 s 4903 100% 0.55 s 48T2 0.57 a 48E5		
				spectral shape indicates $\Delta I=2$, yes 4903, 49L6, 49P2			
Ba X-ray in 2.60 ^m activity 48T3				γ	0.669 sc 49P2 0.663 sc 4903, 48T2 $\alpha = 0.12$ 48T2 $\alpha_K = 0.08, K/L = 5.0$ 4903 0.12, K/L = 4.8 49M1		
Fission	ms, chem chem	46H5 48SP, 46PP		Fission	ms chem	49T4 39H7, 40G5, 40S5, 48SP 43S2	
d 3.9 ^m Xe 50t1, 50g16				Ba-n-p			
					2.60 ^m delay Ba^{137}		
						d 17 ^m Xe 40G5, 40H4	

55 CESIUM Cs

139 55 84			140 55 85			141 55 86		
τ	9.5 ^m 10 7	49S15 39A1 40H4	τ	66 ^s 40	49S15 40H4	τ	short	50b2, 50o1, 50d1
Fission	chem	40H5, 39H3	Fission	chem	39A1, 40H4	Fission	chem	50b2, 50d1
d 41 ^s Xe	40H4, 40H5, 39H3		d 16 ^s Xe	50b2, 50d1, 50o1		d 3 ^s Xe	50b2, 50d1	
p 85 ^m Ba	40H4, 40H5, 39H3		p 12.6 ^d Ba	50b2, 50d1, 50o1		p 28 ^d Ce	50o1, 50d1	
						p 3.7 ^h La	50b2	
142 55 87			143 55 88			144 55 89		
τ	$\sim 1.2^m$	42H6	τ	short	50b2, 50o1, 50d1	τ	short	50d2
Fission	chem	42H6	Fission	chem	50b2	Fission	chem	50d2
p 6 ^m Ba	42H6		d 1 ^s Xe	50b2, 50d1		d short Xe	50d2	
			p 13.6 ^d Pr	50o1		p 275 ^d Ce	50d2	
			p 33 ^h Ce	50b2, 50d1				

55 CESIUM Cs

145				
55	90			
τ	short	50d1		
Fission	chem	50d1		
d	0.8^{85}Xe	50d1		
p	4.5^{6}Pr	50d1		
p	1.8^{6}Ce	50d1		

56 BARIUM Ba

[illegible]

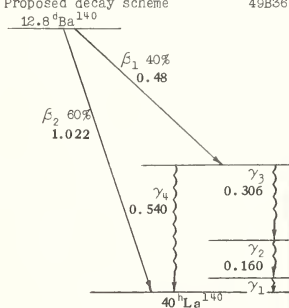
56 BARIUM Ba

133				134			
56		77		56		78	
τ_1	38.9 ^h 38.8 38	48Y1 43W3 48M33	τ_2	> 20 ^y 50k13, 47K5	2.42% 2.39	38N3 49H38	
IT		48Y1	K	50k13, 47K5			
γ	0.276 sc $\alpha = 2.45, K/L = 3.2$	41C3	γ	0.085 a, cc 48Y1 $\alpha = 0.34 K/L = 10$ 48Y1 0.320 a, cc 48Y1 $\alpha = 0.02$ 48Y1 0.36 a 47K5			
			Cs K X-ray	47K5	Levels	Cs ¹³⁴	
			See Cs ¹³³		0.79 1.40 1.96		
Fission	chem	49G13, 48SP					
Cs-p-n		44D9	Ba-n- γ	chem 48Y1			
Cs-d-2n	chem	41C3	σ	47K5, 50k13			
Ba-n- γ	chem	48Y1	Cs-d-2n	chem 48Y1			
Ba- γ -n	chem	48M33	Ba-d-p	48Y1			
	p > 20 ^y Ba	48Y1	d 39 ^d Ba	48Y1			
			Not p active Cs	47K5, 50k13			

135				136			
56		79		56		80	
τ	28.7 ^h	48Y1		6.59% 6.56	38N3 49H38	7.81% 7.74	38N3 49H38
IT		48Y1	I	3/2 S 37B9, 32M6, 49A10			
γ	0.3	49R5	μ	0.837	41H14		
e ⁻	0.28 a	49R5, 48Y1					
Ba K X-ray		49R5, 48Y1	Level	0.76	La ¹³⁵	Levels	Cs ¹³⁶
Ba-d-p		48Y1					
Ba-n- γ		48Y1					
Ba ¹³⁵ -n- γ	chem	49R5					
	Not produced by						
Cs-d-n, 2n		49R5					
Cs-a-p		49R5					

56 BARIUM Ba

137				138			
56		81		56		82	
τ	2.60 ^m 2.63 2.5	49M1 48T3 48E5	11.32% 11.25	38N3 49H38	71.66% 71.83	38N3 49H38	
IT		48T3	I	3/2 S 37B9, 32M8, 49A10			
γ	0.669 sc 0.663 sc $\alpha = 0.12$ $\alpha_K = 0.08, K/L = 5.0$ 0.12, K/L = 4.8	49P2 49O3, 48T2 48T2 49O3 49M1	μ	0.936	41H14		
Ba K X-ray		48E5				Levels	0.88 1.2
e ⁻ X coincidences		48T3					La ¹³⁸ Cs ¹³⁸
See Cs ¹³⁷						σ 's	
						(th n, γ) 85 ^m Ba	0.5 47S33
						(~1 Mev n, γ) 85 ^m Ba	2.6mb 49H5
						Values at other energies	49B4, 48WH
Ba-n- γ	chem	40K7					
d 37 ^f Cs		48E5, 48T3					

139				140			
56		83		56		84	
τ	8.5 ^m 8.4	50d4 48S27	τ	12.8 ^d 12.5	50e9, 47S25 42G2		
β^-	2.27 s 2.2 a	48S27 50K8	Proposed decay scheme	49B36	β_1^- 40% 25%	0.48 s 0.465 s ~0.4 a	49B36 49L14 50e3
γ	0.165 sc 0.163 sc $\alpha = 0.20$ K/L = 6 0.6%* 1.05 a	49L14 48S27 48S27 48S27			β_2^- 60% 75%	1.022 s 0.990 s 1.05 s 1.0 a	49B36 49L14 50w5 50e3
*% of disintegrations					γ_1	0.076 not observed	
σ 's					γ_2	0.160 sc 0.160 s	49B36 49L14
(th n, $\gamma\beta$) 40 ^h La	3.8	45K17			γ_3	0.306 sc 0.310 s	49B36 49L14
(pile n, $\gamma\beta$) 40 ^h La	4.7	49Y3			γ_4	0.540 sc	49B36
Ba-d-p	chem	37P3, 40K7	Fission	ms chem	48H25 39H7, 42H6, 46PP, 48SP	0.535 s 0.54 s	49L14 50w5
Ba-n- γ	σ	47S33				0.52 a	50e3
Ce-n- α		43W1	d 66 ^s Cs	42H6, 50b2, 50d1, 50d2, 50o1			
Fission	chem	50K8, 39H7, 39H3	p 40 ^h La	39H4, 46PP			
d 9.5 ^m Cs		39H7, 39H3			$\gamma\gamma$ coincidences		49M13

56 BARIUM Ba

141 56 85			142 56 86			143 56 87		
τ	18^m	42H6, 50g12	τ	6^m	42H6	τ	<0.5 ^m	42H6
β^-	~ 2.8	48L10						
γ		50g12						
Fission	chem	50b2, 50c1, 50d1, 48SP	Fission	chem	42H6, 48SP	Fission	chem	42H6, 48SP
d short Cs p 3.7 ⁿ La	50b2, 50c1, 50d1 42H6		d 1-2 ⁿ Cs p 74 ⁿ La	42H6 42H6		d short Cs p 19 ⁿ La	50b2, 50c1, 50d1 42H6	
144 56 88			145 56 89					
τ	short	50d2	τ	short	50d1			
Fission	chem	50d2	Fission	chem	50d1			
d short Xe p 275 ^s Ce	50d2 50d2		d 0.8 ^s Xe p 1.8 ⁿ Ce	50d1 50d1				

57 LANTHANUM La

Neutron Cross Sections for Natural Element			133 57 76		134 57 77	
σ_a	$E_n = 0.025\text{ev}$ 8.8	49P3	τ	4.0^h	49N8	
σ_t	26 10	42R2 42B4	K		49N8	
			β^+ few %	1.2	49N8	
			e^-	0.26 s	49N8	
			γ	0.8 a	49N8	
			K X-ray		49N8	
σ_t	Graphs Available 0.01-1000ev	50Ad, 47GIF	CS- α -4n	ms, chem	49N8	
135 57 78			136 57 79		137 57 80	
τ	19.5^h	48C3	τ	9.5^m 9.0 10	τ	$>400^y$ >30
K		48C3	K $\sim 67\%$			48C3 48I5
γ	0.76 a	48C3	β^+ $\sim 33\%$	2.1 s 2.1 a 1.8 a		
X-ray		48C3	γ			
$X/\gamma = 50$		48C3	No γ			
			X-ray		49N8, 49R7	
CS- α -2n	ms chem, σ	49N8 48C3	Ba 135 -d-n			
			Ba 136 -d-2n			
			Ba-d-n	chem		
			CS- α -n	chem		
				chem, σ		
					d ^{36}Ce ms	48I5

57 LANTHANUM La

138				139			
57		81		57		82	
τ	17.5 ^h	43W2, 49B3	0.089%	4719	99.911%		4719
K		43W2	No observable activity	4719	I	7/2 S	34A2
γ	0.88 a	43W2			μ	2.760	49Po
Ba K X-ray		43W2				I	49C2, 49D13
						S	40W8
					Levels	0.163	Ba ¹³⁹
						1.05	
						0.184	Ce ¹³⁹
						0.8	
						1.8 } ?	
					σ 's		
					(th n, γ) 40 ^h La	8.4	47S33
						>7	46B25
					(th n, γ)	8.8	49F3
					(1Mev n, γ) 40 ^h La	5mb	49H23
La- γ -n threshold = 12.9		49B3			(20Mev d, 4n) 36 ^h Ce	0.002	
Ba-d-n chem		43W2			(40Mev d, 4n) 36 ^h Ce	0.06	
Ba-p-n chem		43W2			(60Mev d, 4n) 36 ^h Ce	0.04	
					(20Mev d, 2n) 140 ^o Ce	0.09	

57
140
83

τ	40.0 ^h 39.5	50b7, 43W2 46B25							
			β_1^-	70%	1.32	s	49B36	γ_5	1.6 s
				20%	0.90	s	4601		1.61 s
								77%	1.65 s
								74%	1.63 s
Proposed decay scheme		49B36	β_2^-	20%	1.67	s	49B36		
				70%	1.40	s	4601		
					1.45	s	47R1	γ_6	~2.5 s
									2.52 s
									2.3 s
									2.3 s
									2.49 γ n
									47W1, 47W9
								γ 's from conversion lines	49C22
									0.068, 0.109, 0.131, 0.155,
									0.173, 0.242, 0.266, 0.323,
									0.328, 0.434, 0.487, 0.524
								$\beta\gamma$ and $\gamma\gamma$ coincidences	48M14, 4601, 47M3
								Levels in La ¹⁴⁰	0.54 Ba ¹⁴⁰
									others ?
								σ 's	
								(th n, $\gamma\beta$) 28 ^d Ce	~3 49K4
								ϕ % of γ 's	
								$\phi\phi$ % of disintegrations	

40^hLa¹⁴⁰

Stable Ce¹⁴⁰

Fission	ms	48H25							
	chem	50b7, 48SP							
La-d-p	chem	43W2	γ_4	0.820	s	49B36			
La-n- γ	chem	42G1, 43W2		0.832	s	4601			
Ce-n-p	chem	43W2		0.87	s	47R1			
	d 12.8 ^d Ba	42H6, 50F4		0.83	s	46M6			

57 LANTHANUM La

141 57 84			142 57 85			143 57 86		
τ	3.7 ^h 3.5	50k7 42H6	τ	74 ^m 77	42H6 50k7	τ	19 ^m 15	50g10 43H8
β^-	2.8 a	50k7	β^-		50k7			
No γ ?		50k7	γ		50k7			
Fission	chem	50k7,42H6,48SP	Fission	chem	50k7,42H6,48SP	Fission	chem	39H4,39H5
d 3^5Xe		50b2	d 6^mBa		42H6	d 1^5Xe		50b2
d 18^mBa		42H6				d $<0.5^m\text{Ba}$		39H4,39H5
Probably p 28^cCe		42H6,50b8,50k7				p 33^hCe		50g10
144 57 87			145 57 88					
τ	short	50d2	τ	short	50d1			
Fission		50d2	Fission		50d1			
d $\sim 1^5\text{Xe}$		50d2	d 0.8^5Xe		50d1			
p 275^dCe		50d2	p 1.8^hCe		50d1			

58 CER IUM Ce

Neutron Cross Sections for Natural Element			135 58 77		136 58 78		
σ_a	$E_n = 0.025\text{eV}$ 0.65 0.64	49P3 49H2	τ	$\sim 16^h$	48C3	0.193% 0.195	47I9 49H3
σ_t	~ 3 ~ 15	42R2 42B4	β^+	~ 0.4	48C3		
σ_t	Other energies	49H16					
			La-d-6n		48C3		
			p 19.5 ^b La		48C3		
137 58 79			138 58 80		139 58 81		
τ	36 ^h	48C3	0.250% 0.265	47I9 49H3	τ	140 ^d	48C3, 48P1
K		48C3			K		48P1, 47M12
No β^+		48C3			γ	0.18 sc, ac 0.184 sc	48C3 48P1
γ	0.28 ac 0.75 a	48C3 48C3				0.8 a 1.8 a	48P1 48C3
La K X-ray		48C3			La K X-ray		47M12, 48P1
La-d-4n	σ	48C3			La-d-2n Ba-a-2n	chem, σ chem	48P1, 48C3 48P1

58 CER IUM Ce

[illegible]

58 CERIUM Ce

145 58 87			146 58 88			
τ	1.8^h	50b11	τ	14.6^m 11 15	46PP 46G7 43H8	
Fission	chem	46PP	Fission	chem	46PP, 46G7	
d 0.8^5Xe p 4.5^hPr		50d1 50b11, 50K10	p 25^mPr		46PP, 46G7	

59 PRASEODYMIUM Pr

Neutron Cross Sections for Natural Element			140			141		
			59	81		59	82	
σ_a	$E_n = 0.025\text{ev}$ 11.2	49P3	τ	3.6 ^m	45H2	100%		42H2, 46I2
				3.4	42D7			
				~1.5	49W2			
			β^+	2.5 a	45H2	I	5/2 S	29W1
				~2.4 a	49W2			
				2.4 cc	42D7			
			K ~60%		49W2			
			γ ~2%	1.2 a	49W2			
			X-ray	0.038 a	49W2	Levels	0.141	Ce ¹⁴¹
							0.315 ?	Nd ¹⁴¹
				1.05				
				σ^+s				
				(th n, γ) ¹⁹ Pr	13	46B25		
					8.5	46W16		
				(th n, γ)	11.2	49P3		
				(~1Mev n, γ) ¹⁹ Pr	11mb	49H28		
				(9Mev d, 2n) ^{2.4} Nd	0.9	} 49W2		
				(19Mev d, 2n) ^{2.4} Nd	0.3			
				(19Mev d, 3n) ^{3.3} Nd	0.08			
				(10Mev p, n) ^{2.4} Nd	0.03			
				(9Mev d, p) ^{19.3} Pr	0.1			
				(19Mev d, p) ^{19.3} Pr	0.06			
			Pr- γ -n	relor	49P5, 46W13			
			threshold = 9.4		49H17			
			9.8		49B3			
			Pr-n-2n		42D7			
			d ^{3.3} dNd		49W2			

142			143									
59			83			59			84			
τ		18.9 ^h			48K21	τ		13.8 ^d			50b13	
		19.2			46B25			13.7			49B56	
		19.3			42D7			13.5			48P1	
β^-	0.215 a $\beta\gamma$	49M12	γ	~0.17 a	49M12	β^-	0.932				49F18	
	0.35 a $\beta\gamma$	49J3					0.922				49B56	
	2.23 s	47P10		0.134 sc	} 48C23		0.920 s				49T12	
3 groups present		47P10		0.329 sc			0.93 s				48S28	
	2.14 s	42D7		0.490 sc		Absorption values in agreement:						
				0.624 sc		49M15, 46P1, 46B25, 44J4						
$\beta\gamma$ ~5		47P10		~1.3 s	47P10	No γ				50s20, 50b12, 48P1		
$\beta\gamma$ ~25		42D7										
$\gamma\gamma$ coincidences	49J3, 49M12			~1.65 s	47P10	No delayed coincidences				49B9		
No $\beta\beta$ coincidences	49M12			1.53 a coin	49J3							
No γ in coincidence with 2.2 β	49M12			1.74 a coin	49M12							
			γ 's do not produce Be- γ -n		47W1	Level	0.5			Ce ¹⁴³		
Pr-n- γ	chem	48K21	La- α -n		} 42D7	Fission	ms			46H5		
	σ	48W16, 46B25	Ce-p-n					Chem			43H8, 50b12	
Ce-d-2n		48P1	Pr-d-p				Ce-d-n				48P1	
										d ³³ Ce	50b9, 50b12, 50s21, 46PP, 46B25	

59 PRASEODYMIUM Pr

144				145				146			
59		85		59		86		59		87	
τ	17.5 ^m		50n10,50s23	τ	4.5 ^h		50k10	τ	24.6 ^m		46PP
	17		46G6,43H8		4.7		50b11		25		46G7
	18		43G14								
β^-	3.07	s	50n8	β^-	3.2	a	50k10	β^-	~3	a	46PP
	2.99	s	47P10								
	3.1	a	43B2,43H8, 46G6	No γ			50k10	γ	1.4	a	46PP
									hard		46G7
γ	0.135	sc	50n8								
weak	0.22	a	50s23								
weak	1.25	a	50s23								
Fission	ms		48H25	Fission	chem		50b11,50k10	Fission	chem		46G7,46PP
	chem		50n10,46SP								
d 275 ^d Ce			43H8,50n10	d 1.8 ^h Ce			50b11,50k10	d 15 ^m Ce			46G7

60 NEODYMIUM Nd

Neutron Cross Sections for Natural Element			139 60 79		140 60 80	
σ_a	$E_n = 0.025\text{ev}$ 45 54	49P3 49H2			τ	3.3 ^d 49W2
σ_t	65 72	42R2 42B4			K	49W2
					γ weak	1.2 49W2
					Probably belongs to Pr ¹⁴⁰ 49W2	
					K X-ray	49W2
			</			

60 NEODYMIUM Nd

144 60 84			145 60 85			146 60 86		
	23.87%	48I2		8.30%	48I2		17.18%	48I2
	23.91	48M27		8.35	48M27		17.35	48M27
Levels	0.135 1.25 others ?	Pr ¹⁴⁴				Level	1.4	Pr ¹⁴⁶
(pile n, γ)	σ 's <15	49H12	(pile n, γ)	σ 's <30	49H12	(th n, γ) ¹¹⁶ Nd (pile n, γ)	σ 's 1.4 <20	46B25 49H12
147 60 87			148 60 88			149 60 89		
τ	11.0 ^d 11.1 12.1	47M28, 50m1 46B25 47M22		5.72% 5.78	48I2 48M27	τ	1.7 ^h 2.00	47M28, 50m5 46B25
β^-	40% ~0.4 a 60% 0.90 a 0.76 0.8	47M28, 50m1 47M28, 50m1 47M22 46B25				β^-	1.5 a 1.6 a	47M28, 50m5 46B25
γ	40% ~0.58 a 0.45 a	47M28, 50m1 47M22				γ or X-ray		47M28, 50m5
e ⁻	0.03 a	47M28, 50m1						
X-ray	~0.040 a	47M28, 50m1						
Nd-n- γ	chem	50m1, 48K21, 47M28				Nd-n- γ	chem	47M28, 50m5 46B25, 49H12
Fission	σ chem	46B25 47M28, 50m1				Nd- γ -n, threshold = 7.4		49H17
p 4 ¹ Pm		50m3				p 47 ^h Pm		47M28, 50m5
			(th n, γ) ^{2h} Nd (pile n, γ)	σ 's 2.8 <45	46B25 49H12			

60 NEODYMIUM Nd

150						151		
		60	90			60	91	
5.60%	46I2	τ	$<8 \times 10^{10} \text{y}$	34L3	τ	short		50m5
5.69	48M27							
		β^-	~ 0.011	a	34L3			
(pile n, γ)	$\sigma^{\prime}s$	<45	49H12					
			Natural source Mass assignment	34L1 48K22	Nd-n- γ			50m5
					p 12 ^m Pm			50m5

61 PROMETHIUM Pm

143 61 82			144 61 83			145 61 84		
τ	$\sim 200^d$ $\sim 1^y$	42W2 48W14						
K		48W14						
γ	0.67 a	42W2						
						Levels	0.242 0.95	Sm^{145}
Pr- α -2n		48W14						
Nd-d-n		43K1						
Pr- α		42W2						
146 61 85			147 61 86			148 61 87		
τ	2.7^h	43K1	τ	4^y 3.7	50m3, 50b15 50S26	τ	5.3^d	43K1, 47P4
β^-	2	43K1	β^-	0.223 s 0.227 s	49P20, 48L8 49L23	β^-	~ 2.5 2	a 47P4 43K1
γ		43K1	No γ		50S26, 50m3, 47M28	γ	~ 0.8	a 47P4
			Level	~ 0.5	Nd^{147}			
				σ 's				
			(th n, γ)	5.3^dPm	60			47P4
Nd-d-n		43K1	Fission	ms	48H25	Pm^{147} (from fission)-n- γ		
Nd-p-n		43K1		chem	50m3	ms, σ		47P4
Nd- α -p		41L2	Nd-n- $\gamma\beta$	chem	47M28, 50m3	Nd-p-n		43K1
			d 11^dNd		50m3, 48H25	Nd-d-2n		43K1

61 PROMETHIUM Pm

[illegible]

61 PROMETHIUM Pm

155 61 94	156 61 95	
	τ $< 5^m$ 50W9	
	$p \sim 10^h \text{ cm}$ 50W9	

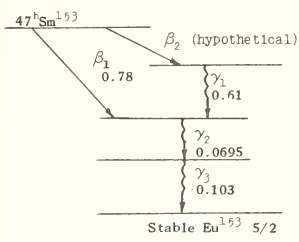
62 SAMARIUM Sm

Neutron Cross Sections for Natural Element			α activity of Sm		144 62 82	
$E_n = 0.025\text{ev}$ σ_a 8100 49H2 10,600 49P3 8800 Averaged over Maxwell distribution with $kT = 0.025\text{ev}$. From data of 47S31			Natural element α emitter 32H1, 36H4,33L1 τ (total Sm) $0.93 \times 10^{12} \text{y}$ 48L9 1.0×10^{12} 36H4 Radioactive isotope assigned to Sm^{152} 48D2		3.16% 2.95	48I1 48M27
Resonances E_o σ_o Γ 0.096ev 15,500 0.074 47S31 0.096 12,800 0.070 46B26 Assigned to Sm^{149} 47L19 10 2,800 47S31 10 49G9 Assigned to Sm^{152} 49G9 33 47S31 Graphs Available σ_t 0.02-70ev 47S31,47GIF 0.02-0.17ev 46B26,47GIF			α 2.14 photographic plate 46C1 2.2 cc 36H4 No α activity found from Sm-200Mev p 49T13			
145 62 83			146 62 84		147 62 85	
τ >150 ^d 48C9 >72 47I7 60 42K3 γ 0.242 sc 48C9 0.95 a 48C9 Sm-n- γ ms 47I7 Sm-d-p 42K3 Nd- α -n 42K3					15.07% 14.62	48I1 48M27

62 SAMARIUM Sm

148			149			150		
62	86		62	87		62	88	
	11.27%	48I1		13.84%	48I1		7.42%	48I1
	10.97	48M27		13.55	48M27		7.27	48M27
Level	~0.8	Pm ¹⁴⁸	Levels	0.25 ~0.5 ?	Pm ¹⁴⁹ Eu ¹⁴⁹			
				σ 's				
				(th n, γ) 65,000				
				Averaged over Maxwell distribution				
				kT = 0.025ev. From data of 47S31,				
				47L19, 48I1				
						Sm-n- γ		49K15
						E_{γ} (max) = 6.6		
151			152					
62	89		62	90				
τ	~10 ³ y	49M5		26.63%	48I1			
	~20	47I7		27.34	48M27			
β^-	0.074 s	49M5						
	0.079 s	49K5						
	0.06 a	48P7						
No γ ?		48P7	α activity assigned to this					
No γ		49M5	isotope			48D2		
γ	0.021 pc	49S35	See α activity box					
β spectrum may have forbidden shape		49M5	Levels ?			Eu ¹⁵² Eu ^{152,154}		
L X-ray		49S35	σ 's					
			(th n, γ) 47 ^h Sm			135 47S33		
						280 46B25		
Sm-n- γ	ms	47I7						
Fission	chem	49M5						

62 SAMARIUM Sm

153 62 91				154 62 92				
τ	47 ^h			46B25, 42K3, 50W6			22.53%	48I1
Proposed decay scheme 49M2							23.29	48M27
								
				β_1^-	0.78	a	48B5	
					0.73	a	50W6	
				γ_1 weak	0.61	a coin	48B5	
					~ 0.6	s	48M6	
					0.57	a	50W6	
				γ_2	0.0695	sc	48H18	Levels ?
					$\alpha \sim \infty$	K/L ~ 0.5	49M2	Eu ¹⁵⁴ Eu ^{152,154}
				γ_3	0.103	sc	48H18	
					0.102	sc	48C9	
					0.11	s	48M6	
					0.11	a coin	48B5	σ 's
Eu K, L X-rays 46B25, 48B5							(th n, γ)25 ^m Sm	5.5 47S33
(K X-ray) $\beta \sim 0.7$ 48B25				$\beta e^-, \beta X, 0.11\gamma\beta, 0.11\gamma X, XX$				
No coincidences delayed $> 1.5\mu s$ 48B5				coincidences			48B5	
Sm-n- γ ms 46H8				Sm-n-2n			} 42K3	
σ 46B25, 47S33				Sm-d-p				
Fission 50W6, 48SP				Nd- α -n				
Sm- γ -n 41L2				d $< 5^m$ Pm			50W6	
155 62 93				156 62 94				
τ	25 ^m		50W7	τ	$\sim 10^h$		50W9	
	21		42K3, 38P5					
β^-	1.9	a	50W7	β^-	~ 0.8	a	50W9	
	1.8		42K3					
γ	~ 0.3	a	50W7					
Sm-n- γ 41L2, 38P5, 36H1				Fission chem 50W9				
σ 47S33								
Sm-d-p 42K3								
Fission 50W7								
Assignment on basis of fission yield and decay energy								

63 EUROPIUM Eu

Neutron Cross Sections for Natural Element	146 63 83	147 63 84
$E_n = 0.025\text{ev}$ σ_a 4200 49P3 σ_t 4800 47S31 4120 42R2 Resonances E_0 σ_0 Γ -0.011ev 5570 0.08 47S31 Assigned to Eu ¹⁵¹ 46B26 0.465 5670 0.2 47S31 Assigned to Eu ¹⁵³ 46B26 3.3 47S31 Assigned to Eu ¹⁵¹ Additional resonances at 9.2, 22ev 47S31 Graphs Available σ_t 0.007-70ev 47S31, 47G16 50Ad		τ 53 ^d 50m9 40 43E6 γ 0.42 1.0 γ 's ~ equal intensity } 50m9 Sm-d-2n 50m9, 43K1
148 63 85	149 63 86	150 63 87
	τ 14 ^d 50m9 γ or X-ray 50m9 e^- ~0.5 50m9 Sm-d-n 50m9	τ 27 ^h 38P5 β^+ 38P5 Eu-n-2n 38P5

63 EUROPIUM Eu

151 63 88				152 63 89			
	47.77%	48H31		τ_1	9.2 ^h 9.3	38P5 46B25	τ_2 5.3 ^y 49H4
I	5/2 S	35S1		K		46B25, 47M23	K β^- 80% 0.9 a 49M5, 49H4 20% 1.7 a 49M5
μ	3.4 S	38S9		β^-	0.36 a 47M23 1.8 a 47M23 1.88 s 39T1		γ ~0.3 a 49M5 probably corresponds to soft γ 's of Eu ^{152, 154} 49M5 ~1.2 a 49M5 probably associated with K capture 49M5
q	~+1.2 S	38S10		γ	0.123 sc 0.163 sc 0.725 sc 1.0 a 47M23	39T1	K/ β =5 49H4(49M5)
				K/ β =0.6 0.22		46B25 49H4	σ 's (pile n, γ) 3200 49H4
	σ 's						Eu-n- γ ms, σ 49H4 Radiation of Eu ¹⁵² produced by Eu-n- γ not distinguishable from that of Eu ¹⁵⁴ . Above radiation assigned by comparison of radia- tion of mixture with that of fission product Eu ¹⁵⁴ . See also Eu ^{152, 154} .
(th n, γ) 9 ^h Eu	1400 47S33 1500 46B25			Eu-n- γ	ms, σ 49H4, 46H8 chem, σ 49K21, 41F3		
(pile n, γ)	5200 49H4			Eu-n-2n	38P5		
(th n, γ) long Eu	2500 46B25			Eu-d-p	chem 41F3		
(th n, γ) long Eu	per Eu atom 47S33 1500 per Eu atom						
152, 154 63 89, 91				153 63 90			
K		47M23, 46B25			52.23%	48H31	τ 5.4 ^y 49H4
β^-	0.75 s 48S24 0.751 s 48O9 1.57 s 48S24 1.57 s 48O9 1.4 a 48K7			I	5/2 S	35S1	β^- 50% 0.3 a 49H4(49M5) 40% 0.7 a 10% 1.9 a
γ	48O9 48S24 0.040 sc 0.122 sc 0.123 sc 0.247 sc 0.247 sc 0.286 sc 0.286 sc 0.342 sc 0.344 sc 0.408 sc 0.412 sc 0.442 s 0.772 s 0.959 s 1.082 s 1.402 s			μ	1.5 S	38S9	γ ~1.2 a 49H4, 49M5 0.3 and 0.7 β 's probably in coincidence with ~1.2 γ 49M5 K/ β < 0.05 49H4 Radiation of Eu ¹⁵⁴ produced by natural Eu-n- γ not distinguishable from that of Eu ¹⁵² . See also Eu ^{152, 154} .
				q	~+2.5 S	38S10	σ 's (pile n, γ) 5.4 ^y Eu 240 49H4
				Levels	0.102 Gd ¹⁵³ , Sm ¹⁵³ 0.172 Sm ¹⁵³ 0.78 Sm ¹⁵³		
γ	1.23 a 48O9 0.9 a 48K7 See also 48C26						
Eu-n- γ		48S24					Eu-n- γ ms, σ 49H4 Eu ¹⁵³ (fission)-n- γ 49M5
Eu-d-p	chem	41F3, 48K7					

63 EUROPIUM Eu

155 63 92			156 63 93			157 63 94		
τ	1.7^y 2	49H4 50W10	τ	15.4^d	50W9, 49H4	τ	15.4^h	50W8
β^-	80% 0.154 s 20% 0.243 s 2.23 a	49M5 49M5 50W10				β^-	75% ~ 1.0 a 25% ~ 1.7 a	50W8 50W8
γ	60%* 0.085 sc 40%* 0.099 sc 0.0844 critical a	49M5 49M5 50W10	β_1	~ 0.5	a 50W9	γ	0.2 a 0.6 a	50W8 50W8
*% of γ 's			β_2	2.5	a 50W9	Fission chem 50W8, 48SP		
0.154 β in coincidence with γ 49M5			γ	2.0	a 50W9	Mass assignment from fission yield and decay energy.		
No $\gamma\gamma$ coincidences 49M5			Eu ¹⁵⁵ -n- γ	ms	47I7			
No delayed β/γ coincidences 49M5			Eu-n- γ	ms	49H4			
σ 's			Fission	chem	50W9, 48SP			
(pile n, γ)			d 10^h Sm		50W9			
7,900 49H4								
14,000 47I7								
$\sim 30,000$ 49M5								
From expected and observed fission yields.								
Sm-n- $\gamma\beta$	ms	47I7						
Fission	chem	48SP, 50W10						
Eu-n- γ , n- γ		49H4						
158 63 95								
τ	60^m	50W8						
β^-	~ 2.6	50W8						
Fission chem 50W8								
Mass assignment from fission yield.								

64 GADOLINIUM Gd

Neutron Cross Sections for Natural Element			α activity of Gd or Tb		151 64 87	
σ_a	$E_n = 0.025\text{ev}$ 36,700	49H2	τ	$\sim 7^m$	49T13	
σ_t	48,000 42,000	47B15 47S31	α	4.2	49T13	
See also 48WH			τ	$\sim 4^h$	49T13	
Resonance			α	~ 4	49T13	
E_n	σ_a	Γ	α/K capture	$\sim 1\%$	49T13	
0.028ev	45,000	0.24				
0.044	32,000	0.10				
Graphs Available			Both activities produced by			
σ_t	0.002-0.2ev	47B15, 47GIF	Gd-200Mev p			49T13
	0.005-0.2ev	47S31, 47GIF	Dy-200Mev p			49T13
			Not produced by			
			Sm-200Mev p			49T13
			No α activity with $\tau < 10^{12}y$ found in natural Gd			48K27
152 64 88			153 64 89		154 64 90	
0.20%	48H31	τ	225 ^d	49K1	2.15%	48H31
0.2	41W13		154	49H11	2.86	41W13
			155	48H28		
		K		49K1, 48H28		
		γ	0.026* pc	49S35		
			0.100 sc	49K1		
			0.102 sc	48C9		
			others?	48H28, 48C9,		
				49H11		
			0.260 a	49H11		
		Eu K X-ray		49K1, 49H11	Levels ~ 0.3 ?	Tb ¹⁵⁴ , Tb ¹⁵⁴
		Levels	~ 0.2 ?	Tb ¹⁵³	~ 1.2	See also Eu ^{152, 154}
			~ 0.45 ?			
(th n, γ) 225 ^d Gd	<125	47S33	Gd-n- γ	ms, σ		
No activity found				chem	47I7	
					49K1	
			Eu-d-2n	chem	41F3, 48K7	
			* Probably in Tb ¹⁶¹		50S7	

64 GADOLINIUM Gd

155			156			157		
64	91		64	92		64	93	
14.78%	48H31		20.59%	41W13, 48H31		15.71%	48H31	
15.61	41W13					16.42	41W13	
Levels	0.085	Eu ¹⁵⁵	Level	2.0	Eu ¹⁵⁶	Levels	0.2	Eu ¹⁵⁷
	0.099						0.6	
(pile n, γ)	σ 's					(pile n, γ)	σ 's	
	69,000	47L19					240,000	47L19
158			159			160		
64	94		64	95		64	96	
24.78%	48H31		τ	18.0 ^h	48K3, 49B1	21.79%	48H31	
23.45	41W13			17.9	48K21	20.87	41W13	
				20.0	47S33			
			β^-	0.85 a	48K3			
				0.95 a	49B1			
				0.9 a	48K21			
			γ	0.055 a	49B1			
				0.38 a	49B1			
				~ 0.3 a	48K3			
				0.35 a	48K21			
			No delayed coincidences		49H26			
(pile n, γ) 18 ^h Gd	σ 's					(pile n, γ) 3.6 ^h Gd	σ 's	
	4.5	49B1					0.18	49B1
	4	47S33					0.1	49D17
Gd-n- γ		48K15	Gd-n- γ	chem, σ	49K1, 49B1	(pile n, γ) 6.7 ^d Tb	0.16	49B1
$E_{\gamma}(\text{max}) = 6.3$			Gd-d-p		48K3			
			Not produced by Tb-n-p		48K3			
			Not p 6.7 ^d Tb chem		48K21			

64 GADOLINIUM Gd

161			
64	97		
τ	3.6 ^m 3.3 4.5	49B1 49D17 46I3	No long lived Gd with half life between 0.3 ^y and 30 ^y found in fission 49M5
β^-	1.5 a ~2	48K21 49D17	Gd-n- γ emits conversion e ⁻ with mean half life <10 ⁻⁷ sec relative to the capture γ 's 48S32
γ	0.37 a	48K21	
e ⁻	~0.066	49D17	
Gd-n- γ	σ	49D17, 49B1	
p 6.75 ^d Tb		49K23	

65 TERBIUM Tb

Neutron Cross Sections for Natural Element			α activity of Tb or Gd			151 65 86		
σ_a	$E_n = 0.025\text{ev}$ 55	49P3	τ	$\sim 7^m$	49T13			
			α	4.2	49T13			
			τ	$\sim 4^h$	49T13			
			α	~ 4	49T13			
			$\alpha/\text{K capture}$	$\sim 1\%$	49T13			
			Both activities produced by					
			Gd-200Mev p	49T13				
			Dy-200Mev p	49T13				
			Not produced by					
			Sm-200Mev p	49T13				
152 65 87			153 65 88			154 65 89		
τ	4.5 ^h	48W12	τ	5.1 ^d	48W12	τ	17.2 ^h	48W12
K		48W12	K		48W12	K		48W12
K X-ray		48W12	e^-	0.15 a 0.4 a	48W12 48W12	β^+	2.6 a	48W12
			K, L X-rays		48W12	γ	1.4 a	48W12
						e^-	~ 0.22 a ~ 1.0 a	48W12 48W12
						K, L X-rays		48W12
Eu- α -3n	chem	48W12	Eu- α -2n	chem	48W12	Eu- α -n	chem	} 48W12
						Eu- α -3n	chem	
						Gd-p-n	chem	

65 TERBIUM Tb

[illegible]

65 TERBIUM Tb

161				
65	96			
τ	6.75 ^d 7.0	49B1 49K1	No long lived Tb with half life between 0.3 ^y and 30 ^y formed in fission.	49M5
β^-	0.52 a 0.5 a	49B1 49K1		
γ	0.026? pc 0.05 a	50S7 49B1		
no harder γ		49B1		
	~ 0.045 a	49K1		
5.5 ^d activity formerly assigned here probably mixture of 6.75 ^d Tb and 5.9 ^d Tb		49B1		
Level	0.37	Gd ¹⁶¹		
Gd-p		49B1		
Gd-d-n		49B1, 48K3		
Gd-n- $\gamma\beta$	chem, σ	49B1		
	d 3.6 ^m Gd	49K23		

66 DYSPROSIUM Dy

Neutron Cross Sections for Natural Element	α activity of Dy or Ho	155 66 89																	
$E_n = 0.025\text{ev}$ σ_t 1150 47B15 Resonances <table><tr><td>E_0</td><td>σ_0</td><td>Γ</td><td></td></tr><tr><td>-1.01ev</td><td>79,000</td><td>0.20</td><td>47S31</td></tr><tr><td>1.74</td><td></td><td></td><td rowspan="3">} 47S30</td></tr><tr><td>5.5</td><td></td><td></td></tr><tr><td>~20 ?</td><td></td><td></td></tr></table> Graphs Available σ_t 0.007-0.2ev 47GIF, 47B15 0.07-20ev 47GIF, 47S30 0.02-0.4ev 47GIF, 47S31 Produced by Dy-200Mev p 49T13 Not produced by Sm or Gd-200Mev p 49T13	E_0	σ_0	Γ		-1.01ev	79,000	0.20	47S31	1.74			} 47S30	5.5			~20 ?			τ 20 ^m 49T13 α 4.1 49T13
E_0	σ_0	Γ																	
-1.01ev	79,000	0.20	47S31																
1.74			} 47S30																
5.5																			
~20 ?																			
156 66 90	157 66 91	158 66 92																	
0.052% 49I2		0.0902% 49I2																	

66 DYSPROSIUM Dy

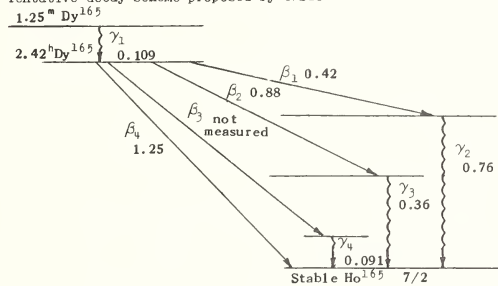
[illegible]

66 DYSPROSIUM Dy

165
66 99

τ_1	1.25 ^m	46F1	τ_2	2.42 ^h	47S14
	1.2	48H36		2.33	47S33, 46B25

Tentative decay scheme proposed by 47S14



Dy¹⁶⁴(n, γ) cross sections $\sim$ equal for both activities, indicating that only 1.25^mDy is formed directly. But growth of 2.42^hDy has not been observed. Part of 1.25^mDy may decay by β^- directly to Ho¹⁶⁵. 47I3

1.25 ^m Dy produced by			2.42 ^h Dy produced by		
Dy ¹⁶⁴ -n- γ		47I3	Dy-n- γ	ms	47I8
Dy-n- γ	σ	47G14, 46B25, 47S33	Dy ¹⁶⁴ -n- γ		47I3

β_1^-	0.42	s	47S14
β_2^-	0.88	s	47S14
β_3^-	not measured		
β_4^-	1.25	s	47S14
γ_1	0.109	sc	49C1
	0.102	sc	48H36
	0.18	ac	44F2
γ_2	0.76	s	47S14
	~ 1.0	s	46M6
γ_3	0.36	s	47S14
	0.37	s	46M6
γ_4	0.091	sc	47S14

~ 0.25 γ 's per disintegration 47S14

No delayed coincidences 49M26

σ 's		
(th n, γ) ^{165}Dy	5000	49K22

166 66 100				
τ	81 ⁿ	49K22		
β^-	0.4 a	49K22		
Dy-n- γ , n- γ	chem, σ	49K22		
p 27.3 ^h Ho		49K22		

67 HOLMIUM Ho

Neutron Cross Sections for Natural Element			α activity of Ho or Dy		159 67 92			
σ_a	$E_n = 0.025\text{ev}$ 67	49P3	τ	20 ^m	49T13			
σ_t	52 47	42B4 42R2	α	4.1	49T13			
			Produced by Dy-200Mev p		49T13			
			Not produced by Sm or Gd-200Mev p		49T13			
160 67 93			161 67 94		162 67 95			
τ	$\sim 20^m$	48W12	τ	60 ^d	48W12	τ	4.5 ^h	48W12
K ?		48W12	K ?		48W12	K, β^+		48W12
X-ray		48W12	e ⁻	0.16 a 0.6 a	48W12 48W12	e ⁻	0.3 a	48W12
			γ		48W12	γ	1.1 a	48W12
			K, L X-rays		48W12	K, L X-rays		48W12
Tb- α -3n		48W12	Tb- α -2n chem Dy-d-n, 2n, 3n chem Dy-p-n chem	} 48W12		Tb- α -n chem Dy-p-n chem		48W12 48W12

67 HOLMIUM Ho

163 67 96			164 67 97			165 67 98		
τ	7 ^d	48W12	τ	38.6 ^m 35 47	48W13 48W12 38P5	100%		34A1
K		48W12	β^-	0.7 a	48W12	I	7/2 S	35S2
e ⁻	0.4 a	48W12						
K, L X-rays		48W12				Levels	0.091 0.36 0.76	Dy ¹⁶⁵
						σ^1s (th n, γ) ²⁷ hHo	60 49 67	47S33 46B25 49P3
						(th n, γ) (38MeV, 3n) 7.7 ^h Tm (30MeV, 3n) 7.7 ^h Tm (38MeV, 2n) 9.6 ^d Tm (30MeV, 2n) 9.6 ^d Tm (19MeV, 2n) 9.6 ^d Tm (39MeV, n) 85 ^d Tm (30MeV, n) 85 ^d Tm (19MeV, n) 85 ^d Tm	1.1 5x10 ⁻⁴ 7x10 ⁻³ 0.1 10 ⁻³ 10 ⁻⁴ 3x10 ⁻³ 0.2	49W3
Dy-p-n	chem	48W12	Dy-p-n Ho-n-2n Ho- γ -n	chem rel σ	48W12 38P5 48W13			
166 67 99								
τ	27.3 ^h 27.7 26.8	46B25, 48K21 49C15 49G1						
β^-	1.8 a 1.88 s 1.64 a	49K22, 46B25 49G1 49C15						
γ	0.073 s 0.080 sc 0.081 sc	49K2 49G1 49C15						
1.5%	1.2 a 0.92 a	49G1 49C15						
No delayed coincidences		49M26						
Ho-n- γ	ms σ chem	47I2 46B25, 47S33 49C15, 48K21						
Dy-n- γ , n- $\gamma\beta$	chem	49K22						
d 81 ^h Dy		49K22						

68 ERBIUM Er

Neutron Cross Sections for Natural Element		161 68 93	
σ_a $E_n = 0.025\text{ev}$ 166 49P3 σ_t ~ 165 (extrapolation) 49B2 185 42B4 233 42R2 Resonance E_o σ_o $\sim 0.5\text{ev}$ ≥ 1700 49B2 Graph Available σ_t 0.03-0.7 ev 49B2			
162 68 94		163 68 95	
0.1% 41W8		1.5% 41W8	

68 ERBIUM Er

165 68 97	166 68 98	167 68 99
	32.9% 41W8 Levels 0.073 Ho¹⁶⁶ ~1.0 Ho¹⁶⁶ 1.7 Tm¹⁶⁶ others ?	24.4% 41W8 Levels 0.22 ? Tm¹⁶⁷ 0.95 ?
168 68 100	169 68 101	170 68 102
26.9% 41W8 Levels 0.21 ? Tm¹⁶⁸ 0.85 ?	τ 9.4^d 48K11 β^- 0.33 s 48K11 No γ 48K11 Er-n-γ chem 48K11	14.2% 41W8 (th n,γ)th Er σ's >7 46B25

171 68 103			172 68 104		
τ	7.5 ^h 5.7-7.1 5.1	48K11 48B25 38P5			
			β_1^- 22%	0.67 s	48K11
			β_2^- 72%	1.05 s	48K11
			β_3^- 6%	1.49 s	48K11
			γ_1	0.805 s	48K11
			γ_2	0.305 s	48K11
			γ_3	0.113 s $\alpha = 1.3$ 2.5 ^{μs} delay	48K11 48D5 48D5
			other γ 's ?		49C5
Er-n- γ	chem	38P5 48K11 48B25			
σ					
68 ?					
τ	2.5 ^s	49D16	Long and short lived conversion electrons assigned to Er from K, L, M differences		
IT		49D16			
e^-	~ 0.180	49D16			
Er-n- γ		49D16			
$\sigma(\text{atomic}) = 3$		49D16			

69 THULIUM Tm

Neutron Cross Sections for Natural Element			165 69 96		166 69 97		
σ_a	$E_n = 0.025\text{ev}$ 118	49P3			τ	7.7 ^h	49W3
σ_t	114 69	42B4 42R2			β^+	2.1 a	49W3
					K		49W3
					e^-	0.24 a	49W3
					$\beta^-?$	~ 1 a**	49W3
					γ	1.7 a	49W3
					Er K X-ray		49W3
					** Magnetic counter used		
					Ho- α -3n	chem, σ	49W1
					Er-p-n	chem	49W1

167 69 98			168 69 99		169 69 100		
τ	9.6 ^d	49W3	τ	85 ^d		100%	34A1
K		49W3	K				
e^-	0.21 a	49W3	e^-	0.16 a	49W3	I	1/2 S 34S3
γ	0.22 a 0.95 a	49W3 49W3	$\beta^-?$	0.5 a	49W3		
			γ	0.21 a 0.85 a	49W3 49W3		
Er K X-ray		49W3	Er K X-ray		49W3	Levels	? Yb ¹⁶⁹
Er L X-ray (20% of K)		49W3	Er L X-ray (20% of K)		49W3		
Ho- α -2n	chem, σ	49W1	Ho- α -n	chem, σ	} 49W1	σ 's (th n, γ) 129 ^d Tm	126 47S33
Er-p-n	chem	49W1	Er-p-n			(th n, γ) -	95 46B25
			Tm-n-2n			(32Mev α , 3n) 2.1 ^d Lu	118 49P3
							0.01 49W12

69 THULIUM Tm

170			171		
69 101			69 102		
τ	129 ^d 127 125	48K21 46B9 46B23	τ	630 ^d	48K21
129^dTm ¹⁷⁰ $\beta_1 \sim 10\%$ 0.886 $\beta_2 \sim 90\%$ 0.97 γ_1 0.084 Stable Yb ¹⁷⁰ $\beta\gamma$ coincidences 49G10, 49K2 No delayed coincidences 49M26			$\beta_1^- \sim 10\%$ 0.886 s 49F13 $\beta_2^- \sim 90\%$ 0.970 s 49G10, 49F13 0.97 s 49G5 0.98 s 48K21 γ_1 0.0839 sc 49F13 $\alpha_K = 0.4$ $\alpha_L = 2.75$ 49F13 $\alpha_M = 0.85$ 49F13 0.0855 sc 49S6* K/L = 0.71 49S5 0.0827 sc 49G10 $\alpha_K = 0.4^{**}$ 49G10 0.0826 s 49G3 $\alpha_L \sim 0.4$, K/L ~ 0.9 49G3 0.0843 sc 49C15 0.083 48K21 γ 's of 0.20 and 0.44 (49G3) not found 49G10, 49F13 * α 's given on assumption of only one β_1 **Independent of decay scheme but definition not clear.		
			β^- 0.10 s 48K21 No γ 48K21 Levels 0.113 2.5 ^{μs} delay 0.418 0.805 Er ¹⁷¹ d of an Er 48K11		
Tm-n- γ	chem	48K21			
Tm-d-p		48K18			

70 YTTERBIUM Yb

Neutron Cross Sections for Natural Element			167 70 97		168 70 98	
σ_a	$E_n = 0.025\text{ev}$ 36	49P3	<0.002%	49H8	0.14% 0.06	49H8 38D6, 41W9
σ_t	46 50	42R2 42B4				
					(th n, γ) ^{33d}Yb	σ 's 18,300 35,000 46B25 46A2
169 70 99			170 70 100		171 70 101	
τ	33d 33.5 32.5	46B9 47I13 48K18	3.03% 4.21	49H8 41W9	14.34% 14.26	49H8 41W9
K		46B9			I	1/2 S 38S10
γ sc	<u>46I7</u> 0.064 0.095 0.110 0.121 0.133 0.142 0.160 0.178 0.199 0.308	<u>49C23</u> 0.094 0.110 0.130 0.178 0.198 0.308	Levels 0.084 ~2.5	Tm ¹⁷⁰ Lu ¹⁷⁰	μ 0.45 S	38S11
Tm X-ray		46B9			Levels	? Lu ¹⁷¹
No $\beta\gamma$ delay		49M26				
Yb-n- γ	chem σ	48K21 46B25, 46A2				

70 YTTERBIUM Yb

172				173				174			
70		102		70		103		70		104	
21.88%		49H8		16.18%		49H8		31.77%		49H8	
21.49		41W9		17.02		41W9		29.58		41W9	
				I 5/2 S 38S10							
				μ -0.65 S 38S11							
				Q + 3.9 38S10							
Levels ? Lu ¹⁷²											
								(th n, γ) ⁴ Yb σ 's 74 46B25 24 46A2			
175				176				177			
70		105		70		106		70		107	
τ 4.2 ^d		46A2, 48K21		12.65%		49H8		τ 1.8 ^h		49M41	
4.1		46B9		13.38		41W9		2.4		46B9	
								1.9		46A2	
								β^- 1.3 a 46B9 1.2 cc 46A2			
								γ 0.15 49M41 0.13 μ s delay			
								No other γ follows the delay 49M41			
β_1^- 0.13 a 46B9											
β_2^- 0.50 a 46B9											
0.45 cc 46A2				σ 's							
				(th n, γ) 1.8 ^h Yb 6.7 46B25							
				(th n, γ) 1.8 ^h Yb 4.5 46A2							
γ 0.35 a 46B9								Yb-n- γ chem 48K21 σ 46B25, 46A2			
$\beta\gamma$ coincidences 46B9											
Yb-n- γ ms 47I8											
chem 48K21											
σ 46B25, 46A2											

70 YTTERBIUM Yb

70 ?			70 ?			
τ	6^S	49D16	τ	50^S	49D16	
e^-	~ 0.200	49D16	γ	0.025	49D17	
Yb K X-ray		49D17	e^-	0.010-0.020	49D16	
			Yb L X-ray		49D17	
Yb-n- γ		49D17	Yb-n- γ		49D17	
$\sigma(\text{atomic}) = 0.34$			$\sigma(\text{atomic}) = 0.4$			

71 LUTETIUM Lu

Neutron Cross Sections for Natural Element			170 71 99			171 71 100		
σ_a	$E_n = 0.025\text{ev}$ 108	49P3	τ	2.1^d	49W12	τ	8.5^d	49W12
σ_t	99 165	42R2 42B4	K		49W12	K		49W12
			γ	~ 2.5 a	49W12	e^-	0.17 a ~ 0.5 a	49W12 49W12
			e^-	0.1 a	49W12			
			K,L X-rays		49W12	K,L X-rays		49W12
			Tm- α -3n	chem, rel σ	49W12	Tm- α -2n	chem, rel σ	49W12
			Yb-d-2n, 3n		48W12	Yb-d-n, 2n, 3n		48W12
			Not produced by Yb- α , Tb-p		49W12	Not produced by Yb- α		49W12
172 ? 71 101?			172 ? 71 101?			172 ? 71 101?		
τ	3.40^d	49W12	τ	4.0^h	49W12	τ	500^d	49W12
K		49W12	β^+	1.2 a	49W12			49W12
$\beta^+ \sim 20\%$	1.8 a	49W12	γ	Possibly annihilation	49W12	e^-	~ 0.1 a ~ 0.16 a	49W12 49W12
K X-ray		49W12				K,L X-rays		49W12
Tm- α -n	chem, rel σ	49W12	Tm- α -n	chem, rel σ	49W12	Tm- α -n	chem, rel σ	49W12
Yb-p-n	chem	49W12	Yb-p-n	chem	49W12	Ta-d		49W12

71 LUTETIUM Lu

173 ?			174 ?			175		
71	102 ?		71	103 ?		71	104	
τ	6.7 ^d	49W12	τ	160 ^d	49W12		97.5%	39M3
K		49W12	K	~75%	49W12	I	7/2 S	35S3
γ		49W12	β^-	~25% 0.6 a	49W12	μ	2.6 S	36G3
e^-	0.13 a	49W12	γ		49W12	q	+5.9	36G3
	~0.6 a	49W12	e^-	0.16 a	49W12			
K, L X-rays		49W12	K, L X-rays		49W12	Levels	0.35 1.5	Hf ¹⁷⁵ , Yb ¹⁷⁵ Hf ¹⁷⁵
Yb-p-n	chem	49W12	Lu-n-2n	chem	} 49W12	σ 's		
			Hf-d- α	chem		(th n, γ) 3,7 ^h Lu	16	47S33
			Lu-d-p 2n	chem, σ			27	46B25
							45	46A2
d ~ 5 ^h Hf		49W12				(10Mev p, n) 70 ^d Hf	0.03	49W11
						(19Mev d, 2n) 70 ^d Hf	0.05	49W11
						(19Mev d, p) 3,7 ^h Lu	0.044	49W12
						(~1Mev n, γ) 3,7 ^h Lu	0.10	49H28

176			176			176		
71	105		71	105		71	105	
τ	3.75 ^h	49W12					2.5%	39M3
	3.67	46A2						
	3.7	46B9	τ				$2.4 \times 10^{10} \text{ y}$	39L13 (47F7)
β^-	1.04 a	48W12	I	≥ 7 S	39S14	K	67%	47F7
	1.15 a	46B9	μ	3.8 S	39S14	β^-	33% 0.40 a	43F2, 47F7
	1.25 cc	46A2	q	+6-8	39S14		0.22 a	39L13
No γ		46B9				γ	67% 0.26 a	47F7
						K X-ray		47F7
Lu-n- γ		46B9				σ 's		
	chem	48K21	(th n, γ) 6.7 ^d Lu	3640	47S33			
	σ	47S33, 46B25, 46A2		3600	46B25			
Lu- γ - γ	σ	47D4	(~1Mev n, γ) 6.7 ^d Lu	4400	46A2			
Lu-d-p	σ	49W12	(19Mev d, p) 6.7 ^d Lu	0.30	49H28			
Mass assignment from yield relative to 6.7 ^d Lu in d-p and fast n- γ reactions		49W12, 46A2		0.04	49W12			

71 LUTETIUM Lu

177
71 106

τ	6.70 ^d	49W12	β_1^- 18.3%	0.169 s	49D5
	6.8	46B9, 49C15			
	6.6	46A2, 43F2	β_2^- 16.7%	0.366 s	49D5
	7.0	49D5			
Proposed decay scheme		49D5	β_3^- 65%	0.495 s	49D5
				0.46 a	49C15
				0.440 a	43F2
				0.52 a	46B9
				0.47 a	46A2
			γ_1 weak	0.317 s	49D5
			γ_2	0.206 s	49D5
				0.209 sc	49C15
				0.20 a	46B9
			γ_3	0.112 s	49D5
				0.1131 sc	49C15
No delayed $\beta\gamma$ coincidences (3×10^{-7} to 10^{-3})		49B9			
Lu-n- γ	ms	47I8	Level in Lu ¹⁷⁷	0.15	Yb ¹⁷⁷
	σ	47S33, 46A2, 46B25			
	chem	46K21			
Lu-d-p	σ	48W12			
Hf-d- α		49W12			

72 HAFNIUM Hf

Neutron Cross Sections for Natural Element			170 72 98		172 ? 72 100 ?	
σ_a	$E_n = 0.025\text{ev}$ 103 157	49F3 49H2			τ	$>50^d$ 49W12
σ_t	175	42L1				3.4 ^d Lu shown to grow from long-lived Hf parent, but presence of 67 ^d Hf prevents identification. 49W12
E_o	Resonance ~1.0ev This resonance formerly attributed to Zr.	49B2				
σ_t	Graphs Available 0.02-1.5ev	49B2				p 3.4 ^d Lu 49W12
172 ? 72 100 ?			173 ? 72 101 ?		174 72 102	
τ	22.0 ^h	49W12	τ	~5 ^y 49W12		0.18% 44M2, 49H3
K or IT		49W12	K		49W12	
e^-	0.12 0.22	49W12 49W12	No e^-		49W12	
K, L X-rays		49W12	K, L X-rays		49W12	
Yb- α -2n, 3n chem		49W12	Yb- α -n, 2n, 3n chem Ta-d chem		49W12 49W12	
Not p 6.7 ^d Lu		49W12	p 6.7 ^d Lu		49W12	

72 HAFNIUM Hf

175 72 103			176 72 104			177 72 105		
τ	70 ^d	49W11	5.15%	49H3		18.39%	49H3	
			5.30	44M2		18.47	44M2	
K		} 49W11				I	1/2 or 3/2 S	35R1
γ	0.350 a							
	$\alpha \sim 0.4$							
	1.5							
Lu K, L X-rays			Levels	0.19 ?	Ta ¹⁷⁶	Levels	0.112	Lu ¹⁷⁷
			2 ?		Ta ¹⁷⁶		0.317	Lu ¹⁷⁷
			?		Lu ¹⁷⁶		others ?	Ta ¹⁷⁷
Lu-d-2n	chem, σ	49W11						
Lu-p-n	chem, σ	49W11						
Yb- α		49W12						

178 72 106			179 72 107		
27.08%	49H3	τ	19 ^S	46F1	
27.10	44M2				
		IT		46F1	I
		γ	0.15 sc	46H37	1/2 or 3/2 S
			$\alpha > 19$, K/L = 0.9		35R1
			0.19 a	46F1	
Levels	?	Ta ¹⁷⁸			
			Hf-n- γ	46H37, 46F1	

72 HAFNIUM Hf

180		181	
72	108	72	109
35.44%	49H3	τ	46 ^d
35.11	44M2		47
		β^-	0.405 s 49C11
			0.460 s 48H55
			0.41 s 49J5
		$\beta\gamma$ delay of 20.1 μ s	48B14
		$\beta\gamma$ delay of 22 μ s	48D5
		$\sim 0.5 \gamma$ in parallel with delayed γ .	
		No $\beta\gamma$ delay between 3×10^{-8} s and 10^{-3} s other than 22 μ s.	48D5
		γ_2 and γ_5 follow the delay, γ_3 and γ_4 do not.	49M26
		No delayed $\gamma\gamma$ coincidences	49H34
		Hard γ 's not in coincidence	49H34
		$\beta\gamma$ and $\gamma\gamma$ coincidences	49W20
		Delayed e ⁻ 's of γ_2 and γ_5 in instantaneous coincidence.	48H55
		Hf ¹⁸¹ produced by	49M6
		Hf-n- γ σ	49B9, 48B14
		Ta-n-p ?	47S33
			47N4
		γ_1	0.087 s 49J5
		Possibly in parallel with γ_3	
		γ_2	0.133 s 49H34
			0.130 s 49C11
			0.128 s 48H55
			0.134 s 49J5
		Highly converted. K/L < 1, exact value obscured by γ_3 .	49C11
		γ_3	0.136 s 49H34
			0.134 s 49C11
		γ_4	0.344 s 49H34
			0.337 s 49C11
		$\alpha \sim 0.02$, K/L = 4	49C11
		22%* 0.347 s, K/L = 5	49J5
		0.342	48H55
		γ_5	0.480 s 49H34
		78%* 0.471 s	49C11
		$\alpha \sim 0.02$, K/L = 3	49C11
		0.485 s, K/L = 5	49J5
		0.472 s	48H55
		* Relative values	

73 TANTALUM Ta

Neutron Cross Sections for Natural Element			175 73 102		176 73 103	
σ_s coh	6.1	49S12			τ	8.0 ^h 49W13
σ_s bound	7.0	49S12			K	49W13
σ_a	$E_n = 0.025\text{ev}$				No β^+	49W13
	21	49P3			β^- or e^-	~ 1 49W13
	36	49H2			γ	2 a 49W13
σ_s	4.9	(48WH)			e^-	0.12 a 49W13
σ_t	26	47H25				0.18 a 49W13
					K, L X-rays	49W13
	Resonances				Lu- α -3n	chem 49W13
E_o	$\sigma_o \Gamma^{-2}$					
4.1ev	~ 44	} 47H25				
10.0	~ 25					
13.0	~ 3					
22	~ 18					
37	~ 400					
	Graphs Available					
σ_t	0.025-600ev	47H25, 47G1F				
	See also	49H16				
	0.02-1.5Mev	49B28, 50Ad				
177 73 104			178 73 105		179 73 106	
τ	2.50 ^d	49W13	τ	15.4 ^d 49W13	τ	$\sim 120^d$ 49W13
K		49W13	β^- or e^-	1.5 49W13	e^-	0.120 49W13
γ	~ 1.4	49W13	No γ ?	49W13	Soft γ 's	49W13
e^-	0.1 a	49W13			K X-ray or γ	49W13
K, L X-rays		49W13				
Levels	?	W ¹⁷⁷				
Lu- α -2n, 3n	chem	} 49W13	Lu- α -n, 2n	chem 49W13	Lu- α -n	chem
Hf-p-n			Hf-p-n	chem 49W13	Ta-d-p-3n	chem
Ta-d					Ta-p-p-2n	chem
					Hf-p	
d 2.2 ^h W		49W13				d 21 ^d W 49W13

73 TANTALUM Ta

180 73 107			181 73 108								
τ	8.00 ^h 8.2	49W13 3801		100%	39D5, 48W9						
K		49W13, 3801	I	7/2	S	33M1, 33G2					
β^-	0.7	49W13	μ	2.1	S	35G1					
β^- or e^-	0.48	3801	q	$\sim +6$	S	43S15					
γ	1.3	49W13									
Hf K X-ray		49W13	Levels	? ?		Hf ¹⁸¹					
			$\beta\gamma$ delay of 20 ^{μs} in Hf ¹⁸¹								
			σ 's								
			(th n, γ) 117 ^d Ta	21		47S33					
				7	41H8 (48W)						
			(th n, γ) 16.4 ^m Ta	0.034		47S33					
Ta-n-2n		3801, 37P2	(19Mev d, 2n) 140 ^d W	0.05		49W14					
	chem	49W13									
Ta- γ -n threshold = 7.7		49M17									
Ta-d-pn chem		49W13									
Ta-p-pn chem		49W13									
threshold = 6		49B34									
182 73 109											
τ_1	16.4 ^m 16.2	48H37 47S2	τ_2	117 ^d 123.5 99	47S33, 43Z1 49C19 40H8	<u>49C19</u>	<u>49B21</u>	<u>49G14</u>	<u>47R1</u>		
IT		48H37	β^-	0.25 ? s	49B21	0.178		0.180			
γ	0.18 s K/L = 0.25	48H37		0.53 s	47R1, 49B21	0.197	0.198		0.209		
				0.50 s	47J1	0.212					
β^-	0.2 a	47S33	γ	<u>49C19</u>	<u>49B21</u>	0.220	0.222	0.220	0.22		
				<u>49G14</u>	<u>47R1</u>	0.227					
				0.0462			0.243				
				0.0583			0.255				
				0.0647			0.290?				
				0.0668			0.299?				
				0.0761	0.071		0.264	0.261			
16 ^m activity from Ta-fast n's with β^- of 0.6, e^- , and X		49W13		0.0837	0.084		0.290?				
				0.0931			0.301				
				0.0992	0.098		0.307				
				0.107	0.103		0.328	0.324			
				0.109			1.133	1.12	1.13		
				0.112	0.112		1.219	1.19	1.22		
				0.118			1.237	1.23			
				0.123	0.122						
				0.138	0.132						
				0.150	0.141	0.151					
				0.158	0.157						
				0.159	0.165						
				0.171	0.172						
							1.13, 1.22, and 1.24 γ 's most intense.				
							0.167, 0.165, and 0.222 γ 's also prominent			49B21	
Ta-n- γ chem, σ		47S33					βe^- coincidences			48S17	
							No delayed coincidences			49B9, 49M26	
										3801	
Not d 117 ^d Ta		47S2					Ta-n- γ			47S33	
							chem, σ			43Z1	
							Ta-d-p				

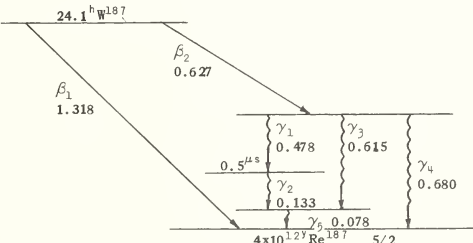
Neutron Cross Sections for Natural Element			177 74 103		
σ_s coh	3.3	49S12	τ	2.2^h	49W13
σ_s bound	5.7	49S12	K		49W13
σ_a	$E_n = 0.025\text{ev}$ 17.7 28.0	49P3 49H2	γ	~ 0.45 a 1.2 a	49W13 49W13
σ_s	5	(48WH)	e^-	0.13 a ~ 0.4 a	49W13 49W13
σ_t	23	47H25	K, L X-rays		49W13
Resonances					
E_0	$\sigma_0 \Gamma^2$				
4.0ev	~ 13	} 47H25			
7.4	~ 5				
18	$\sim 3,000$				
45	~ 400				
180	$\sim 10,000$				
Graphs Available					
σ_t	0.014-5000ev	47H25, 47GIF	Ta-d-8n	chem	49W13
	See also 49H16		Ta-p-6n	chem	49W13
	0.023-4Mev	47GIF			
	0.023-1.4	50Ad			
			p 2.5 ^d Ta		49W13

178 74 104			179 74 105		
<0.001% if stable form exists			τ_1	30^m	49W13
		49D7	K		49W13
			K, L X-rays		49W13
			No γ , no e^-		49W13
			τ_2	21.0^d	49W13
			K		49W13
			e^-	0.1 ~ 0.5	49W13 49W13
			K, L X-rays		49W13
			Ta-d-4n		49W13
			Ta-p-3n		49W13
			Ta-d-4n		49W13
			Ta-p-3n		49W13
			p 120 ^d Ta		49W13

74 WOLFRAM W

[illegible]

185			186		
74 111			74 112		
τ	73.2 ^d 74.5 76	48S18 40F1 49C7	28.64% 29.17 28.41 28.49 28.85	48W9 46I1 48W3 48M27 49H3	
β^-	0.428 s 0.43 s	48S24 48P2, 48S18			
No γ		48P2, 47C2			
γ	0.134 sc	49C7			
No delayed coincidences		49B9, 49M26			
			Levels ?	Re ¹⁸⁶	
			σ 's		
			(th n, γ) ^{24}W	34 57	47S33 41H8 (48WH)
			($\sim 1\text{Mev n, } \gamma$) ^{24}W	0.066	49H5
			Other fast n values		48WH, 49B4
Re-d- α	chem	40F1			
W-n- γ	chem	40F1, 40M5			
	σ	47S33			
W-n-2n	chem	40F1, 40M5			
W-d-p	chem	40F1			

187					
74 113					
τ	24.1 ^h 24.0 25.0	40F1 40M5 49C7			
					
Half life of metastable state;					
0.53 ^{μs}	49B9				
0.55 ^{μs}	49M29				
γ and soft β precede delay. Delayed radiation consists of e^- of 0.13-0.15 and γ of 0.1	48D5				
W-n- γ	σ	47S33, 41H8			
	$E_\gamma(\text{max}) = 7.1$	49K15			
W-d-p	chem	48P2			
			$\beta_1 \geq 12\%$ 30%	1.318 s 1.33 s 1.34 s	49L10 48P2 48H52
			$\beta_2 \geq 65\%$ 70%	0.627 s 0.63 s ~ 0.65 s	49L10 48P2 48H52
			γ_1	0.478 s 0.462 s	49L10 48H52
			γ_2	0.133 s 0.138 s 0.129 s 0.5 ^{μs} delay	49L10 49B23 48H52
			γ_3	0.615 s 0.652 s	49L10 48H52
			γ_4	0.680 s 0.696 s	49L10 49B23
			γ_5	0.078 s 0.086 sc	49B23 41V1
			$\beta^- \sim 0.38, \leq 23\%$; γ 's 0.204, 0.767 also found		49L10

75 RHENIUM Re

Neutron Cross Sections for Natural Element		?	
σ_a	$E_n = 0.025\text{ev}$ 84 49P3	τ	30m 40C5 $^{30-55}$ 44D9
σ_t	98 47GIF		
Resonances E_0 Γ $^{2.30\text{ev}}$ 47GIF ~ 27 ~ 3 49G9 Probably more than one 49G9			
Graphs Available σ_s 0.015-10ev 47GIF, 50Ad See also 49H18		W-p-n	chem 40C5, 44D9

182						183					
75			107			75			108		
τ_1	64.0 ^h	49W14	τ_2	12.7 ^h	49W14	τ	240 ^d		49W14		
K or IT		49W14	K or IT		49W14	K			49W14		
No β^+		49W14	γ	0.110 sc	} 49W14	No β^+			49W14		
γ	0.110 sc	} 49W14		0.129 sc		γ	0.081 sc	} 49W14			
	0.129 sc			0.222 sc			0.252 sc				
	0.222 sc			0.250 sc			1.0 a				
	0.250 sc			0.346 sc							
	0.346 sc			1.6 a							
	1.5 a		K, L X-rays		49W14	K, L X-rays			49W14		
K, L X-rays		49W14									
Ta- α -3n	chem, relo	49W14	Ta- α -3n	chem, relo	49W14	Ta- α -2n	chem, relo		49W14		
W-p-n	chem	49W14	W-p-n	chem	49W14	W-p-n	chem		49W14		

75 RHENIUM Re

184						185					
75			109			75			110		
τ_1	50 ^d	49W14,46S6	τ_2	2.2 ^d	49W14			37.07%		48W9	
	52	40F1									
	54	40C5									
No β^-		49W14	K or IT		49W14	I	5/2	S	31M1,31Z1		
K or IT		49W14				μ	3.3	S	38S10,38S9		
γ	0.043 sc	} 49W14	γ	0.043 sc	49W14	q	+2.8		38S10		
	0.159 sc			0.159 sc	49W14						
	0.205 sc		e^-	0.2 a	49W14	Level	0.75		Os ¹⁸⁵		
	0.285 sc			1.1 a	49W14						
	1.05 a	46S6	K, L X-rays		49W14						
	0.75	47C2									
	0.85 a	40F1									
	1 a	49W14,40C5									
K, L X-rays		49W14									
Ta- α -n	chem, rel σ	49W14	Ta- α -n	chem, rel σ	49W14						
Re-n-2n	chem	40F1,49W14	W-p-n	chem	49W14						
W-p-n	chem	40C5,48W12									
W-d-p		40F1									

186						187					
75			111			75			112		
τ	92.8 ^h	47G1						62.93%		48W9	
	91	48C23,49G3									
	90	40F1,39S5				τ		4×10^{12} ?		48N1,48S25	
β^-	~3% 0.64 s	} 49G3	I	5/2	S	31M1,31Z1	β^-	0.043 a		48N1	
	~30% 0.95 s		μ	3.3	S	38S10,38S9					
	~67% 1.09 s		q	+2.6	S	38S10					
	1.07 s	49B21									
	1.068 s	49L6									
Fermi plot straight											
No γ 's		47G1									
γ	0.138 sc	49B21	Levels	0.078		W ¹⁸⁷					
	$a_K = 0.029, K/L = 0.4$			0.211							
37%	0.132 sc	49G3		0.5 ^{μs} delay							
				0.680							
	0.214 s	49B21									
2.3%	0.275 s, a	49G3									
0.7%	0.7 a	49G3									
No delayed coincidences		49B9									
Re-n- γ	ms	47H7									
Re-d-p	chem	47G1									
W-d-2n	chem	40F1									
Re-n-2n	chem	40F1									
Re- γ -n	rel σ	48P3									
W-p-n	chem	40C5									

75 RHENIUM Re

188 75 113				
τ	18.9 ^h		47G1	
	18		40F1	
	16		48C23	
β^-	2.10	s	49B21	
	2.05	a	47G1	
γ	0.15	sc	49B21	
	0.154	sc	48C23	
	0.16	s	46M6	
	0.48	s	} 46M6, 49B21	
	0.64	s		
	0.95	s		
	1.40	s	49B21	
	1.43	s	46M6	
	1.39	a coin	48M1	
Re-n- γ	ms		47H7	
	chem		40F1	
Re-d-p	chem		47G1	

76 OSMIUM Os

Neutron Cross Sections for Natural Element			183 76 107		184 76 108	
σ_a	$E_n = 0.025\text{ev}$ 15	49P3			0.018%	37N3
σ_s	11	37G1				
σ_t	29 ce	47W8				
Resonances						
E_o	$\sigma_o \Gamma^2$					
6.5ev	~ 10	} 47W8			Levels	0.043 ?
8.8	35					0.159 ?
20	25					others?
28	8					
42	10					
86						
Graph Available						
σ_t	0.1-5000ev	47GIF, 47W8				
185 76 109			186 76 110		187 76 111	
τ	97 ^d 95	48K8 47G1	1.59%	37N3	1.64%	37N3
K		48K8, 47G1				
γ	0.75 a	48K8				
K, L X-rays		48K8				
$\gamma/X\text{-}1$		48K8				
			Levels	0.138 ? others?	Re ¹⁸⁶	
Re-d-2n	chem	46G3, 48K8				
Os-n- γ	chem, σ	48K8				

76 OSMIUM Os

188			189			190		
76	112		76	113		76	114	
13.3%		37N3	16.1%		37N3	26.4%		37N3
			I	1/2 S	36K3			
Levels	0.16 ?? others ?	Re ¹⁸⁸				Level	0.25 ?	Ir ¹⁹⁰
						(th n, γ) ^{15d} Os	σ 's 8	47S33
191			192			193		
76	115		76	116		76	117	
τ	15.0 ^d 16.1 17	48K8 48S18 41S7	41.0%		37N3	τ	32 ^h 30	47G1,41S7 47S33,40Z1
β^-	0.142 s 0.15 a 0.35 a 0.64 a Ir?	48S18 48M1 41S7 47W4				β^-	1.15 a 0.95 a 1.5 a	48M1 47G1 41S7
γ	0.039 sc 0.127 sc K/L=1.4 0.129 sc	48S18 48S18 49S28 47C5				e^-	0.14 a	48M1
K γ , L X-rays		48K8				γ	1.58 a 1.17 a	48M1 47G1
(X γ)/ β ~1		48K8				βe^- coincidences No delayed $\beta\gamma$ coincidences		48M1 49B9
Os-n- γ chem		41S7, 40Z1	(th n, γ) ^{32h} Os	σ 's 1.6	47S33	Os-n- γ chem		47G1,41S7 47S33
σ		47S33				Os-d-p chem		47G1
Os-fast n's, see Os ¹⁹³		41S7				Ir-d		47G1
						Os-fast n's		41S7
						^{32h} activity twice ^{15d}		41S7

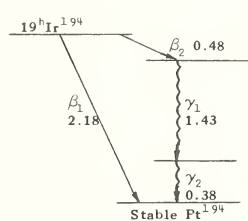
77 IRIDIUM Ir

Neutron Cross Sections for Natural Element				188 77 111	
σ_a	$E_n = 0.025\text{ev}$ 464 472	49P3 49H2			
σ_t	430	47R6			
Resonances					
E_0	$\sigma_0 \Gamma^2$	σ_0	Γ		
0.64 ev	5-20			47R6	
0.635	~530	0.25		47S31	
1.27	5-20			47R6	
1.35		~610	0.36	47S31	
1.29			0.10	49G9	
(assigned to Ir ¹⁹³)				49G9	
5.2	~55			47R6	
6.0				47S31	
8.7	~50			47R6	
25				47R6	
Graphs Available					
σ_t	0.055-15ev	47S31, 47GIF			
	0.22-1000ev	47R6, 47GIF			
	0.05-1.6ev	47W10			

189 77 112		190 77 113		191 77 114	
τ		10.7 ^d	47G1	38.5%	36S4
e^- or β^-		0.091 a	47G1	I 1/2 S	35V1
γ		0.2 ^c a	47G1	μ negative	39S17
X-ray			47G1	μ $\frac{\mu(\text{Ir}^{191})}{\mu(\text{Ir}^{193})} = -0.92$	39S17
				Levels ?	Os ¹⁹¹ , Pt ¹⁹¹
				σ 's	
				(th n, γ) 1.4 ^m Ir	~250 47G6
				(th n, γ) 70 ^d +1.4 ^m Ir	1000 47S33
				(19Mev d, 2n) 3 ^d Pt	~0.09 49W8
				(38Mev α , 3n) 4.0 ^b Au	~1.5 49W8
Os-d-n	chem	47G1			
Ir-n-2n		47G1			
Not produced by Ir-n- γ or Ir-d		47G1			

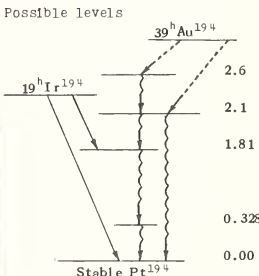
77 IRIDIUM Ir

192 77 115			
τ_1	1.42 ^m 1.5	48H37 37M4	τ_2 70 ^d 75 68 47S33 47G1 48M14
IT ?	47G6	β^- 0.67 s 0.62 s	47L6 47J1
γ	0.0574 sc 0.0555 sc	48C1 48H37	Conversion lines obscure end point.
Softer γ 's with $\sim$ half above energy possibly due to 2-quantum transitions	47G6	γ 48H3 0.137 0.208	47L6 47C12 43D1 0.269 0.294 0.306 0.315 0.466 0.477 0.586 0.601 0.610 0.651
Ir L X-ray	47G6	0.296 0.308 0.317	0.295 0.307 0.316 0.468 0.488 0.591 0.607 0.615
Suggested level scheme		47C12	0.651
$e^-/\beta^- = 0.29$		47W5	Ir-n- γ ms 48R3
0.32		48S17	σ 47S33
E_{γ} per $\beta^- = 0.6$		48M14	Ir-n-2n 37M4, 47G1
$\beta\gamma^-$ coincidences		48S17	Ir-d-p chem 48W1
No delayed $\beta\gamma$ coincidences		49B9, 49M26	Pt-d- α chem 48W1

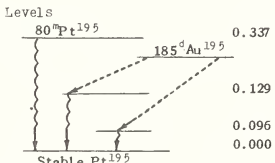
193 77 116			
61.5%	36S4	τ	19.0 ^h 20.7 19.5 47G1 47S33 41W7
I 3/2 S	35V1		β_1^- 2.18 s 41W7 2.1 a 47G1, 37M4
$\mu \frac{\mu(193^{191})}{\mu(193^{193})} = -0.92$	39S17	β_2^- 0.48 a $\beta\gamma$ 48M14	
Levels ?	Os ¹⁹³ , Pt ¹⁹³	γ_1 1.43 a coin 48M14 1.35 s 43M4 1.65 a 47G1	
σ 's		γ_2 0.38 a 47G1	
(th n, γ) 19^h Ir 130	47S33	$\gamma\gamma$ coincidences	48M14
(19Mev d, 2n) 4.3^d Pt ~ 0.07	49W8	No delayed $\beta\gamma$ coincidences	49B9
(36Mev α , 2n) 18^d Au ~ 0.1		Ir-n- γ ms 48R3	
(36Mev α , 3n) 39^h Au ~ 1		σ 47S33	
		Ir-d-p chem 48W1	
		Pt-d- α chem 48W1	

78 PLATINUM Pt

Neutron Cross Sections for Natural Element			190 78 112		191 78 113	
σ_a	$E_n = 0.025\text{ev}$ 8.1 13.3	49P3 49H2	$\sim 0.006\%$	49D8	τ	3.00 ^d 49W8
σ_s	12	(48WH)			K	49W8
σ_t	16.6 ce	47H25			γ	0.57 a, ac 49W8 1.5 a 49W8
E_o	Resonances				K, L X-rays	49W8
11.5ev	$\sigma_o \Gamma^{-2}$ ~ 55	} 47H25				
18.2	~ 30					
100 ?						
Graph Available						
σ_t	0.004-5000ev	47GIF, 47H25			Ir-d-2n chem, σ 49W8 Pt-n-2n chem 49W8	
					d 1 ^d Au	49W8

192 78 114			193 78 115		194 78 116	
	0.78% 0.8	47I12 38S4	τ	4.33 ^d 3.5	49W8 48H37	32.8% 30.2 47I12 38S4
			K		49W8	
			e^-	0.115 a 48M7, 49W8 0.112 s 48H37		
			γ	0.126 sc 48H37 K/L = 0.23 48H37 0.18 49W8 ~ 1.5 49W8		
Levels	many low ~ 2	Ir-192 Au-192	K, L X-rays (K X-ray) / (L X-ray) ~ 0.5 $\gamma\gamma$ or γX coincidences	49W8, 48M7 49W8 48M7	Possible levels 	
	σ 's (th n, γ) 3.3^d Pt 150 ? 47S33 40% may be due to Au-199 growth 47S33 (19MeV d, p) 4.3^d Pt ~ 0.05 49W8 (19MeV d, 2n) 4.0^h Au ~ 0.1 49W8		Pt-n- γ chem 48M7, 49W8 Pt-n-2n 48H37, 49W8 Pt-d-p chem } 49W8 Ir-d-2n chem, σ Ir- α -pn chem			
			d 16 ^h Au	49W8		

78 PLATINUM Pt

195				196			
78		117		78		118	
τ	80 ^m	41S8	33.7%	47I12	25.4%	47I12	
	78	48H37	35.2	36S4	26.6	36S4	
	87	48M33					
I^{π}		48H37	I	1/2 S	36J1, 37T3		
γ	0.337	48H37	μ	0.6 S	36S8		
	$\alpha = \alpha, K/L = 1.3$	48H37					
				Levels	0.358	Au ¹⁹⁶	
					0.688		
Hg-n- α	chem	41S8					
Pt-d-p		41S8					
Pt-fast n's		48H37, 41S8					
Pt- γ		48M33					
Not produced by Pt-n- γ		48H37, 41S8					
No active daughter		48H37					
				σ 's			
				(th n, γ) ¹⁸ Pt	1.1	47S33	
				(9Mev d, p) ¹⁸ Pt	16mb	42K7	
197		198		199			
78		120		78		121	
τ	18 ^h	48W13, 37M4	7.23%	47I12	29 ^m	41S8	
	19	41S8	7.2	36S4	31	37M4	
β^-	0.65 a	41S8					
	0.72 a	41K5					
No delayed $\beta\gamma$ coincidences		49B9					
				σ 's			
				(th n, γ) ²⁹ Pt	3.9	47S33	
				(~1Mev n, γ) ²⁹ Pt	0.06	49H5	
				Other fast n values		49B4	
				(9Mev d, p) ²⁹ Pt	29mb	42K7	
Pt-d-p	chem, σ	42K7		Pt-d-p	chem, σ	42K7	
Pt-n- γ	chem	37M4		Pt-n- γ	chem	37M4	
Hg-n- α	chem	41S8			σ	47S33	
Pt-n-2n		41S8		Hg-n- α	chem	41S8	
Pt- γ -n	rel σ	48W13		Not produced by Pt-fast n's		41S8	
				p ^{3,3} d Au	48M7, 37M4		

79 GOLD Au

Neutron Cross Sections for Natural Element			185-188 79					
σ_s coh	7.5	49S12	τ	4.3 ^m	49T13			
σ_s bound	~9	49S12						
σ_a	$E_n = 0.025\text{ev}$	See Au ¹⁹⁷	K		49T13			
			β^+		49T13			
σ_s	6.5 (48WH)							
	7.6	49C21						
σ_t	104	49C21, 44A2						
	100	47B15						
	99	47S31						
			α	5.2 ic	49T13			
			$\alpha/\text{K capture}$	$\sim 10^{-4}$	49T13			
	Resonances							
E_0	$\sigma_0 \Gamma^2$	Γ						
4.8ev	600	47H25						
4.8		49G9						
4.6	0.15	48C24						
>300	0.5	49H16						
	Graphs Available		Au-d	chem	49T13			
σ_t	0.015-0.3ev	47G1F, 44A2						
	0.01-0.13ev	47G1F, 47B15						
	0.03-10ev	47G1F, 47S31						
σ_a	0.03-3Mev	47G1F, 50Ad						

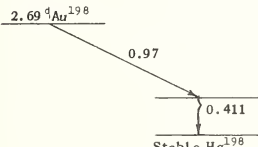
191 79 112			192 79 113			193 79 114		
τ	$\sim 1^d$	49W8	τ	4.0 ^h	49W8	τ	15.8 ^h	49W8
K		49W8	K		49W8	K		49W8
			β^+	1.9 a	49W8	e^-	<0.2 a	49W8
			γ	2-3 a	49W8	K, L X-rays		49W8
			e^-	0.4 a	49W8			
				1.5 a	49W8			
			K, X-ray		49W8			
Pt-d-3n	chem	49W8	Pt-d-2n	chem	49W8	Pt-d-3n	chem	49W8
Ir-a-4n	chem	49W8	Ir-a-3n	chem	49W8	Ir-a-2n	chem	49W8
p 3.0 ^d Pt		49W8				p 4.3 ^d Pt		49W8

194				195			
79		115		79		116	
τ		39.5^h	49WB 49S17	τ	185^d 180		49WB 49S17
Proposed decay scheme 49S17				Proposed decay scheme 49S17			
	γ_1 weak	0.466 sc	49S17		β^- 4.5%	0.30 s	49S17
	γ_2 70%	0.291 sc $\alpha = 0.054, K/L = 2$	49S17 49S17			0.34 a	49WB
	γ_3 30%	2.1 s	49S17		γ_1 59%	0.330 sc $\alpha = 0.087$ $K/L = 1.7$	49S17 49S17
	γ_4	1.48 sc $\alpha = 0.0026$	49S17 49S17		γ_2 95%	0.358 sc $\alpha = 0.087$ $K/L = 1.7$	49S17 49S17
	γ_5	0.328 sc $\alpha = 0.19, K/L = 2$	49S17 49S17		γ_3	0.175 $\alpha = 0.15, K/L = 3.4$	49S17 49S17
	β^+ 3%	1.8 a	49WB		γ	1.6 a	49WB
Ir- α -3n	chem		49WB	Ir- α -2n	chem		49WB
Pt-d-2n, 3n	chem		49WB	Pt-d-n	chem		49WB
Pt-p-n	chem		49S17	Pt-p-n	chem		49S17

196
79 117

τ_1	14.0^h 13	49WB 37M4	τ_2	5.55^d 5.60	49WB 49S17
K or IT		49WB			
X-ray		49WB			
e^-		37M4			
Au-n-2n	chem	37M4, 49WB	Pt-d-n, 2n	chem	49WB, 40L2
			Au-n-2n		49WB, 49S17
			Pt-p-n		49S17
			Au- γ -n	relo	48W13
			threshold = 8.0		49S17

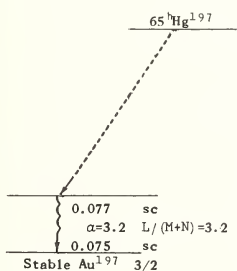
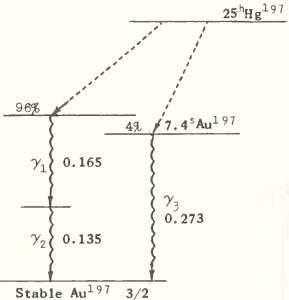
197				
79		118		
τ	7.4 ^s 7.5	48F12, 47F4 45W2	100%	35D2
IT		45W2	I 3/2 S 39E3	25 ^{Hg} ¹⁹⁷ goes to level in Au ¹⁹⁷ with $\tau = 8 \times 10^{-9}$ 49D22 49M42
γ	0.273 sc 0.25 a	48H24 45W2	μ 0.195 S 39E3	This level does not appear in decay of Pt ¹⁹⁷ 49D22
e ⁻ e ⁻ coincidences in 7.4 ^s activity but second γ not found		48H24	Levels	Levels in Au ¹⁹⁷ which combine with 7.4 ^s level 0.25 45W2 1.22 1.68 2.15 2.56 2.97
Au- $\gamma\gamma$		45W2		σ 's (th n, γ) 2.7 ^d Au 96 47S33 (~1 Mev n, γ) 2.7 ^d Au 0.12 49H5 Other fast n values 49B4, 48W1 (fast n, γ) graph 47G1F, 50Ad
Au-n-n		45W2		
d 25 ^{Hg}		47F4		

198				
79		119		
τ	2.69 ^d	49S18, 49S2		
		K $\leq 0.4\%$ from search for Pt X-ray 49R6	γ 18% 0.070 a 49S17 involved in $\gamma\gamma$ coincidences	
		β^- 0.966 s 49L7 0.956 s 49L6 0.975 s 49S17 0.955 s 49D20 0.970 s 49S33	γ 's of 0.157, 0.208 found 49L7, 48D3 Not found 49S17, 49S18, 49S19 See Au ¹⁹⁹	
Half life of 0.411 $\gamma < 4 \times 10^{-9}$ s $< 3 \times 10^{-9}$ s 49D12 49B39		γ 0.4112 cryst 48D3 0.411 sc 49S17, 49S19 0.415 sc 49S33, 49S18 0.410 sc 49D20 0.408 sc 48P2, 49L7	$\gamma\gamma$ coincidences found 49M35, 49S17 Not found 48J7, 49S19	No $\beta\gamma$ angular correlation 49D21, 49F16
No $\beta\gamma$ coincidences delayed from 3×10^{-7} to 10^{-3} s 49B9				
Au-n- γ σ 47S33 E $_{\gamma}(\max)$ = 7.3 49K15		a_K 0.028 a_L 0.013 a_W 0.003 49S17 0.026 0.012 0.003 49S33	Decay energy of 0.79 found by calorimetric measurement 47C13	
Pt-p-n chem 49S17		0.03 0.01 0.003 49S19	γ 's of 0.67 and 1.09 found in low intensity 49C24	
Au-d-p chem 48P2				
Hg-n-p chem 41S8		$\alpha = 0.048$ K/(L+M) = 2.7 49S18		

199				200 ?			
79		120		79		121 ?	
τ		3.3^d		37M4	τ	48^m	4188
Decay Scheme 49B21 3.3^d Au¹⁹⁹ β^- 0.32 30% 25% 45% γ_4 0.156 γ_5 0.207 γ_6 0.23 γ_3 0.070 γ_2 0.051 γ_1 0.024 Stable Hg¹⁹⁹ 1/2					β^-	2.5	a 4188
			β^- 0.32 s 49B21 0.32 a 49M32 0.38 a 48M7				
			γ_1 0.024 sc 49B21				
			γ_2 0.051 sc 49B21				
			γ_3 0.070 sc 49B21				
			γ_4 0.156 sc 49B21				
			Most strongly converted K/L~1 49B21				
			γ_5 0.207 sc 49B21				
			γ_6 0.230 49B21				
			K line overlaps L line of 0.156 γ .				
			No L line. 49B21		Hg-n-p chem	4188, 42M3	
Pt-n- γ/β chem 49B21			β/γ coincidences independent of		Tl-n- α	42M3	
Hg-n-p chem 4188			β energy. $\gamma\gamma$ coincidences observed 49M32				
			No delayed coincidences 49B9				
d 31 ^m Pt 37M4							
Not p 43 ^m Hg 49M32							

80 MERCURY Hg

Neutron Cross Sections for Natural Element				?		196	
						80	116
σ_a	$E_n = 0.025\text{ev}$			τ	0.7^m	49T13	
	349	49P3					0.16%
	360	49H2					0.155
							0.15
σ_t	400	46H26, 45B13					
Resonance							
E_o							
-2.0 ev		46H26					
				α	5.7	ic	49T13
							Level
							0.175
							Au ¹⁹⁶
							σ 's
							(pile n, γ)
							3100
							47I14
Graphs Available							
σ_t	0.01-0.25ev	47GIF, 45B13		Au-d		49T13	
	0.01-75ev	47GIF, 46H26		chemistry suggests Hg		49T13	
See also		49H16					

				197			
				80	116		
τ_1	65 ^h	48H24		τ_2	25 ^h		48H24, 42D8
	64	43F1, 42D8			23		43F1
							
						γ_1	0.165 sc
							0.161 sc
							K/L < 1
							42H4
							41V2
						γ_2	0.135 sc
							0.130 sc
							K/L < 1
							42H4
							41V2
						γ_3	4%
							0.273 sc
							7.4 ^s delay
						γ	weak
							0.38 a
							47F4
						Au K X-ray	43F1
Au K X-ray		43F1		25 ^h Hg ¹⁹⁷ goes to level in Au ¹⁹⁷			
				with $\tau = 8 \times 10^{-9}$	49D22	Hg-n- γ	σ
				7×10^{-9}	49M42	Hg-n-2n	chem
Au-d-2n	chem	43F1		This level does not appear in		Pt- α -n	41S8
Hg-n-2n	chem	43F1		decay of Pt ¹⁹⁷	49D22	Au-d-2n	chem
Au-p-n	48H24, 42D8			e^-e^- coincidences in 7.4 ^s activity		Hg-d-p	chem
				but second γ not found	48H24	Au-p-n	42D8, 48H24

80 MERCURY Hg

198 80 118				199 80 119			
10.02% 10.12 10.1		49H3 47I14 37N2		τ 43.5 ^m 44.4 43		48H48 48M33 37M4, 37H4	

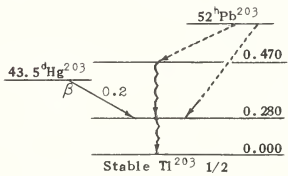
80 MERCURY Hg

203 80 123			204 80 124			205 80 125		
τ	43.5 ^d	48S30	6.84%	49H3		τ	5.5 ^m	40K8, 42M3
	51.5	43F1	6.69	47I14				
	50	41S8	6.7	37N2				
43.5^dHg^{203} $\swarrow$ 0.208 s 0.205 s 0.279 } sc $\alpha=0.27$ } K/L=3 0.286 } sc $\alpha=0.24$ } K/L=3 0.265 } sc 49S16 48S30 49S16 49S16 48S30 48S30 48K25						β^- 1.62 a 40K8		
Stable $\text{Tl}^{203} 1/2$								
$\beta\gamma$ coincidences		49S16	σ 's (th n, γ) 5.5^mHg 0.3 47S33 ($\sim 1\text{MeV}$ n, γ) 5.5^mHg 0.88mb 49H5 (9MeV d, p) 5.5^mHg 13.5mb 42K7					
No X-ray		43F1						
No delayed coincidences		49B9,						
		49M26, 49D22						
See also Tl^{203}								
Hg-n- γ	ms	49S16, 47I14				Hg-n- γ		43F1
	chem	43F1					σ	47S33
	σ	47S33				Tl-n-p		42M3
Hg-n-2n	chem	43F1				Pb-n- α		42M3
Hg-d-p	chem	40K8				Hg-d-p	σ	42K7
Tl-n-p		42M3				Not produced by		
No active Tl daughter 43F1						Hg-fast n's		42K7

81 THALLIUM TI

Neutron Cross Sections for Natural Element			198 81 117		
σ_a	$E_n = 0.025\text{ev}$ 3.27 3.29	49P3 49H2	τ	1.8^h	4901
σ_s	14	37G1	K		4901
σ_t	11.6	See graphs	γ	1.3 a	4901
			e^-	~ 0.4 a	4901
E_o	Resonances 230 ~990 ~4300	} 48R7	L X-ray		4901
			K X-ray obscured by e^- 's and γ 's		4901
σ_t	$E_n = 3\text{Mev}$ 5.2	48B28			
	Graphs Available				
σ_t	0.015-10,000ev	47W6, 47GIF, 50Ad	Au- α -3n	chem	4901
				d ~ 25 ^m Pb Probably d 7 ^m B1	49N5, 49K11 49N5
199 81 118			200 81 119		
τ	7^h	4901	τ	27^h	4901
K		4901	K		4901
γ	>1 a	4901	γ	~0.35 a 1.6 a	49N5 49N5
e^-	0.5 a	4901	e^-	~0.4 a ~0.35 a	4901 49N5
L X-ray		4901	K X-ray		49N5
K X-ray obscured by e^- 's and γ 's		4901			
Tl activities of 10.5 ^h and 44 ^h from Hg-d (40Ks) are possibly mixtures of Tl ¹⁹⁸ and Tl ²⁰¹					
Au- α -2n	chem	4901	Au- α -n	chem	4901
	d ~ 80 ^m Pb d 25 ^m B1	49N5 49N5		d 18 ^h Pb d 35 ^m B1	49N5 49N5
				d ~ 2 ^h B1 and 60 ^m B1 d 8 ^h Pb	49N5 49N5

81 THALLIUM Tl

202			203			204		
81	121		81	122		81	123	
τ	11.8 ^d 13	41F4 42M3, 40K8		29.52% 29.46 29.1	49H3 48W9 38N3	τ	2.7 ^y 3.5	45V1 41F4
K ?		42M3, 40K8	I	1/2	S 31S2, 32J2	β^-	0.783 0.770 0.87	s s cc 49S36 47P10 41F4
γ	0.40	a 42M3	μ	1.596	49P0 I 49P7, 49P8	No γ		41F4
X-ray	~0.068	a 42M3	Possible relationships		49S16	No delayed $\beta\gamma$ coincidences		49B9
						β spectrum has forbidden shape	49S36	
Tl-n-2n	chem	41F4				Tl-d-p	chem	41F4, 40K8
Hg-d-2n	chem	40K8				Tl-n- γ		41F4
						Tl-n- γ	σ	47S33
						Tl- γ -n (n's observed)		49H17
						threshold = 7.5		49H17

205			206			AcC ⁿ 207		
81		124	81		125	81		126
	70.48%	49H3	τ	4.23 ^m	40F4	τ	4.76 ^m	39S11,31IR
	70.54	49W9		4.4	40K8		4.77	40F2
	70.9	38N3						
I	1/2	S 31S1,32J2	β^-	1.65	a 41F4	β^-	1.47	a 39S12
				1.77	a 40K8		1.45	a 49E3
μ	1.612	49P0		1.8	a 46B7			
		I 49P7,49P8				γ in AcC + AcC ⁿ		
			No γ		41F4	0.5%	0.870	41S16

81 THALLIUM Tl

ThCⁿ
208
81 127

τ	3.1 ^m	31IR
Proposed decay scheme. 48R12		
3.1 ^m Tl ²⁰⁸	β^- complex 1.792 s 1.805 s $\beta\gamma$ 1.72 s $\beta\gamma$	48M29 48F9 47G37 Shape of β spectrum consistent with proposed decay scheme 48R12 Possible weak high energy β 48M29
γ $h\nu$	E_d 0.233 G 0.277 L 0.510 0.51 M 0.582 0.57 P 0.859* X 2.62 2.58	32E1 47J5
Rel γ Intensities	0.51 1.01 1.00	47J5
% K e ⁻ 's per dis- integration	2.50 2.73 0.20 3.2	1.77 2.26 1.7 1.7
% L e ⁻ 's per dis- integration	1.49† 1.75† 1.5 † 0.26 0.26 0.30 0.35	48M29 39F4 32E1
	0.35 ~0.42 0.65	48M29 39F4 32E1
Stable Pb ²⁰⁶		
3.2Mev γ not found 48B27, 46B36	† Includes L conversion of γ_L * Assigned to ThC ⁿ	48M29 d 60.5 ^m B1 ²¹² (ThC)

τ	2.2 ^m	48H10
β^-	1.8 a 48H10	37D3 38L7 37D3
		37D3
		37N4

d 47^mB1²¹³ 48H10
p 3.3^hPb 44F11, 46H7

d 19.7^mB1 (RaC)
p 22^hPb (RaD)

82 LEAD Pb

Neutron Cross Sections for Natural Element			198 82 116		199 82 117	
σ_s coh	11.5	49S12	τ	$\sim 25^m$ 49K11, 49N5	τ	$\sim 80^m$ 49N5
σ_s bound	11.6	49S12			K	49N5
σ_a	$E_n = 0.025\text{ev}$ 0.19 0.18 0.12	49P3 49H2 49W22				
σ_t	8.5 ce	See graphs				
σ_t	$E_n = 0.4-100\text{ev}$ ~ 13	See graphs				
E_o	Resonances 350kev 525 750	} 49B31				
σ_t	Graphs Available 0.003-10ev 50Ad, 47GIF, 47H28		Tl-p	49K11		
See also	49H16 0.2-14Mev 47GIF 1-300 Mev 50Ad 0.2-1.6 Mev 50Ad, 49B28, 49B31		p 1.8 ^h Tl	49N5, 49K11	d 25 ^h B1 p 7 ^h Tl	49N5 49N5
200 82 118			201 82 119		202 82 120	
τ	18 ^h	49N5	τ	8 ^h 49N5 ~ 5 46H15	τ	< 0.0004% 49D7 > 500 ^y 49N5, 47T3
K		49N5	K	46H15		
			γ	46H15		
			e ⁻	46H15		
			Tl-d-4n	46H15		
d 35 ^h B1	49N5		d 62 ^h B1 and 2 ^h B1	49N5		
p 27 ^h Tl	49N5		p 72 ^h Tl	49N5		

82 LEAD Pb

203			204				
82	121		82	122			
τ	52 ^h 54	46B7, 41F4 40K8, 42D8	τ	68 ^m 65 69	42M3 41F4 46B7	1.37% 1.5	48W9 38N4
K		42M3	IT	42M3, 41F4, 47T3			
γ	0.270 0.470 ~1.45	s 44L1, 42M3 s 44L1, 42M3 a 40K8, 41F4	68^mPb²⁰⁴ γ_1 0.905 $3 \times 10^{-7} s$ γ_2 0.374 Stable Pb²⁰⁴				
Pb or Tl K X-ray		42M3, 40K8	γ_1	0.905 $\alpha = 0.10$, K/L ~ 1.5 0.9 1.1	s a a	49S34 42M3 41F4	
See Tl ²⁰³ for probable decay scheme			γ_2	0.374 $\alpha = 0.05$, K/L ~ 2 $\tau = 3 \times 10^{-7} s$	s a a	49S34 42M3 41F4	68 ^m Pb ²⁰⁴ produced by Tl-d-n chem 41F4 Tl-d-3n 47T3 Pb-n-n 42M3, 39D3 Pb- γ 46B7
Tl ²⁰³ -d-2n		47T3	More than one e ⁻		40K8		d 12 ^h B1 49N3, 47T3 d 4 ^h Po 49K11
Tl-d-2n chem threshold > 7		41F4, 46H15 40K8					
Pb ²⁰⁴ -n-2n		47T3					
Tl-p-n		42D8					
Pb-n-2n		42M3					
Pb- γ -n		46B7					

205			206			207		
82	123		82	124		82	125	
			25.15% 23.6		48W9 38N4		21.11% 22.6	48W9 38N4
						I	1/2	S 32K1, 38C3
						μ	0.588	I 49P11
Levels	?	Bi ²⁰⁶ , Po ²¹⁰ (RaF)	Levels	0.87 ?	Tl ²⁰⁷ (Acc ^m)			
(α, β n) 5.7 ^h Po		1-2	47T3					
Pb- γ -n	n's observed	49H17						
	threshold = 6.9	49H17						

208 82 126			209 82 127			
52.38%	48W9		τ	3.32 ^h	41F4	
52.3	38N4			2.75	40K8	
			β^-	0.68 s	47R1	
				0.71 s	44L7	
				0.75 a	42M3	
				0.70 a	41F4, 40K8	
			No γ		44L7	
Levels	2.62	Tl ²⁰⁸ (ThC ^u)				
	3.2					
	3.5					
	3.7					
σ 's						
(th n, γ) ^{208}Pb	$\sim 1\text{mb}$	42M3				
	0.45mb	43L4				
($\sim 1\text{Mev}$ n, γ) ^{208}Pb	1.8mb	49H5	Pb-d-p	chem	41F6, 41F4	
(9Mev d, p) ^{208}Pb	14.1mb	42K7		chem, σ , f	42K7	
(40Mev α , pn) ^{208}Pb	8mb	47T3	Pb-n- γ	chem	42M3	
(40Mev α , 2n) ^{208}Pb			B1-n-p	chem	42M3	
	0.4	47T3				
(40Mev α , 3n) ^{208}Pb	1.2	47T3		d $3 \times 10^{-6} \text{ s}^{-1} \text{ Po}^{213}$	47E3, 47H2, 49M16	
RaD 210 82 128						
τ		22 ^y			31IR	
β^-	0.026 s	39L14				
	0.029 s	46S1				
γ	$\sim 10\% * 7.3\text{keV}$	46T4	γ	(7)* 7.8keV pc	49C4	
	$\sim 0\% 18-19$			(0.4) 25.8 pc		
	$\sim 1\% 23.2$			(3) 46.0 pc		
	0.4% 32		L X-ray (33)		49C4	
	0.2% 37		* Relative intensities of unconverted γ 's			
	0.2% 43					
	2.6% 46.7 $\alpha_L = 2.9$					
e ⁻	1%	37R5				
L X-ray	$\sim 30\%$	44T4	γ	47keV		
K X-ray	$\sim 1\%$	44T4		$\alpha_L: \alpha_M: \alpha_N = 1:0.26:0.08$	50C1	
				$\alpha_L = 16$	50C1	
46T4 gives summary of work of Curie Laboratory 1942-1945. For further details see 46F7, 45T6, 44M8, 44T4, and 43O4.						
* % of disintegrations from absorption and conversion e ⁻ measurements.						
				d $1.3 \times 10^{-4} \text{ s}^{-1} \text{ Tl}^{210}$ (RaC ^u)		
				d $1.5 \times 10^{-4} \text{ s}^{-1} \text{ Po}^{214}$ (RaC')		
				p $5.0 \times 10^{-4} \text{ s}^{-1} \text{ Bi}^{210}$ (RaE)		

AcB 211 82 129					
τ	36.1 ^m	39S11			
			$\beta_1^- \sim 20\% \sim 0.5$ 39S12 $\beta_2^- \sim 80\% 1.39$ 39S12 γ energies s, sc 38C4, 40F2, 42S9 γ intensities 42S9 % of disintegrations calculated from number of conversion e ⁻ 's, assuming quadrupole transitions 42S9 0.05±0.02 quanta of 829keV γ per disintegration 44M7		
γ energies in keV					
d 1.8x10 ⁻³ ²¹⁵ Po (ACA) p ²¹¹ Bi (AcC)					
ThB 212 82 130			RaB 214 82 132		
τ	10.6 ^h	31IR	τ	26.8 ^m	31IR
Proposed decay scheme 46S23					
			β^- 0.72 41C1 0.65 33Sar		
γ 's sc 37S7, 38S12 additional γ 's at 113 and 135 37S7, 38S12 Intensities 32E1, 46S23 d 0.16 ²¹⁶ Po (ThA) p ²¹² Bi (ThC)			γ keV 52.8 sc 44S30 1.6 γ 's per disintegration 42T3 241.0 sc 257.8 sc 294.2 sc 350.9 sc γ values in close agreement with above 34E1, 41H9		
All energies in keV β_1^- 88% 331 s 48M30 355 s 48F9 β_2^- 12% 569 s 48M30 589 s 48F9 γ_1 238 s 44S30 H _o (F)* = 1384 K/L = 7.1 44S30 1381 K/L = 8.3 39A6 1386 K/L = 6.7 32E1 K conv e ⁻ /disint. 0.288 48F9 0.313 48M30 H _o (I)** = 1750 44S30 1747 39A6 1751 32E1 B1 K X-ray 28M3			d 3.05 ²¹⁸ Po (RaA) p 19.7 ²¹⁴ Bi (RaC)		

83 BISMUTH Bi

Neutron Cross Sections for Natural Element			< 198 83		
σ_s coh	10.1	49S12	τ	1.7 ^m 2	49N5 48T1
σ_s bound	~10	49S12			
	$E_n = 0.025\text{eV}$				
σ_s	<0.01	46M20			
σ_s	~9	(48WH)			
σ_t	6.6 ce	See graphs			
	$E_n = 1\text{Mev}$				
σ_t	~4.5	See graphs	α	6.2 ic	49N5
Graphs Available					
σ_t	0.015-100 eV	48H46, 47GIF, 50Ad	Pb-d		49N5, 48T1
See also		49H16	Pb-p	chem	49N5
	0.020-0.50 MeV	49B31, 50Ad			
	0.020-1.4 MeV	50Ad			
	0.02-14 MeV	47GIF			

198				199				200			
83		115		83		116		83		117	
τ	7 ^m 9		49N5 48T1	τ	25 ^m 27		49N5 48T1	τ	35 ^m		49N5
K ?			48T1	K			49N5	K			48T1
α	5.83 ~ 5.5	ic ic	49N5 48T1	α	5.47 ~ 5.5	ic ic	49N5 48T1	No α observed			49N5
K/ α = 2x10 ³			49N5	K/ α = 8x10 ³			49N5				
Pb-d Pb-p	chem chem		49N5, 48T1 49N5	Pb-d Pb-p	chem chem		49N5, 48T1 49N5	Pb-d	chem		49N5
p 25 ^m Pb Probably p 1.8 ⁿ Tl			49N5 49N5	p 20 ^m Pb p 7 ⁿ Tl			49N5 49N5	p 18 ⁿ Pb p 27 ⁿ Tl			49N5 49N5

83 BISMUTH Bi

201 ? 83 118 ?				201 ? 83 118 ?				202 83 119			
τ	62^m ~ 100	49N5 48T1		τ	$\sim 2^h$	49N5		τ	2^h	49K11	
K		48T1		K		49N5		K		49K11	
α	5.15 ~ 5.5	ic ic	49N5 48T1								
$K/\alpha = 3 \times 10^{-4}$			49N5								
Pb-d	chem	49N5, 48T1		Pb-d	chem	49N5					
Pb-p	chem	49N5		Pb-p	chem	49N5					
p 8^hPb		49N5		p 8^hPb		49N5		d 40^mPo		49K11	
p 72^hTl		49N5		p 72^hTl		49N5					
203 83 120				204 83 121				205 83 122			
τ	12^h	49N5		τ	12^h	47T3		τ	$\sim 14^d$	49K11	
K		49N5		K		47T3		K		49K11	
				e ⁻	0.2 weak ~ 0.8	s, a s, a	47T3 47T3	γ	1.7	49K11	
				γ	0.217	s	49S34				
				Pb 204 -d-2n			47T3				
				Tl- α -3n			47T3				
d 37^mPo		49K11		d 4^hPo		49K11		d 1.5^hPo		49K11	
p 52^hPb		49N5		p (4%) 68^mPb		47T3					

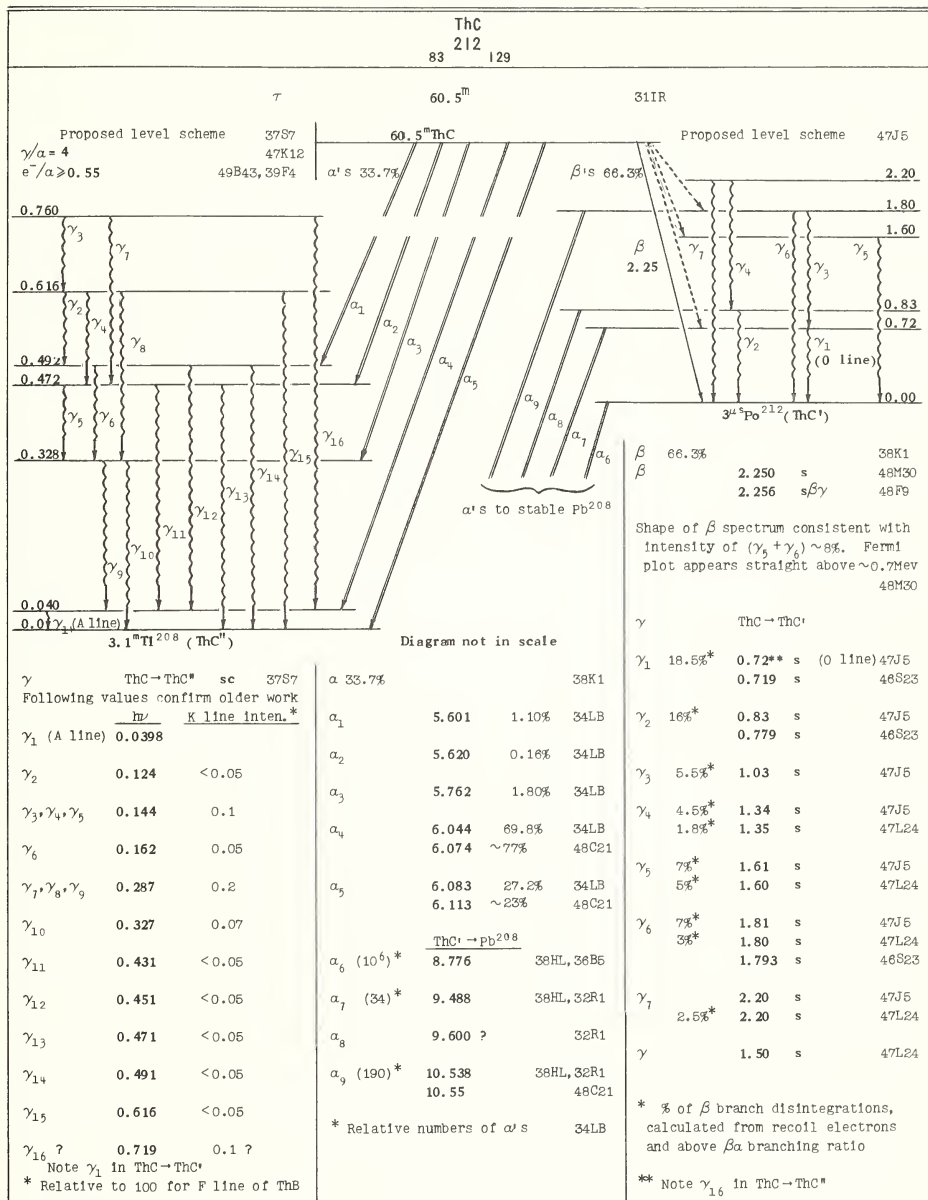
83 BISMUTH Bi

206			207			208		
83	123		83	124		83	125	
τ	6.4 ^d	40K8	No activity found from bombardment of Tl, Pb, Bi with 20Mev d and 40Mev α			τ	<30 ^s or very long >100 ^y	49N3 49N3 47T1
K		47T3						
No β^+		47T3						
γ		sc	49S34					
	0.182	0.470	0.880					
	0.234	0.505	0.889					
	0.260	0.536	1.020					
	0.346	0.590	1.097					
	0.996	0.803	1.720					
γ	0.4	ac	47T3					
	1.1	ac	47T3					
	1.1		41F4					
γ with 1.67 < E < 2.3			49D23					
L X-ray			47T3					
Tl- α -3n	chem		47T3					
Pb-d-2n	?	41F4, 40K8						
Pb ²⁰⁷ -d-3n	chem	40K8						
d ⁹ Po		47T1						

209			RaE 210					
83	126		83	127				
100%		38N3	τ_1	long	49N3	τ_2	4.85 ^d 5.15 5.0	46S22 44H7 31IR
I	9/2	28B1				β^-	1.17 s unallowed shape	39Fe, 40N4 49L6, 40N4, 49L3, 49M18
μ	3.45	S					shape at low energies	49W6
Q	-0.4	S				No γ		47L22, 38G2
σ^+s						Bremsstrahlung studied		47S29
(th n, γ)5 ^d B1	0.015	47S33				No $\beta\epsilon^-$ coincidences		48H42
(1MeV n, γ)5 ^d B1	0.003	49H5				$\alpha \sim 5 \times 10^{-5}\%$		47B6
(α , 2n)7.5 ⁿ At	f	49K10	α	5.02	49N3			
(α , 3n)8.3 ⁿ At	f	49K10						
(9MeV d, p)5 ^d B1	6.6mb	42K7						
(20MeV d, p)5 ^d B1	0.13	47T1						
threshold = 5.3	f	49K10, 47T17						
(20MeV d, n)138 ^d Po	0.036	47T1						
threshold = 8.5	f	49K10, 47T17						
(20MeV d, 3n)3 ^p Po	1.1	47T1						
threshold = 12.5	f	49K10						
(9MeV d, n)138 ^d Po	1.2mb	42K7	Bi-n- γ		49N3			
(γ , n)	f	49M17						
threshold = 7.45, n's detected								
(20MeV γ , n) no activity		48M33						
			p 4 ^m Tl		49N3		d 22 ^y Pb ²¹⁰ (RaD) p 138 ^d Po ²¹⁰ (RaF) p 4 ^m Tl ²⁰⁶	47B6 47B6 47B6

AcC 211 83 128		See next page for Bi ²¹² (ThC)	213 83 130
τ	2.16 ^m	31IR	τ 47 ^m 47H2 46 47E3
β^- not observed 0.32% from ratio of Po ²¹¹ a's to Bi ²¹¹ a's 31IR α_1 16% 6.272 38HL 23% 31R2 36R5 α_2 84% 6.618 38HL 77% 31R2 36R5 γ 0.350 a 37S4, 39S12 0.354 a 25H1 $\gamma/\alpha = 0.14$ 42S9 Other γ 's attributed to AcC 0.460 25H1 0.480 25H1 Proposed cycle scheme for AcC $\rightarrow$ AcC', AcC' $\rightarrow$ AcD 46S23		β^- 98% ~ 1.3 a 47E3 98% ~ 1.2 a 47H2 α 2% 5.86 ic 47E3 4% 6.0 ic 47H2 2.0% 49H35 d 0.018 ^s At ²¹⁷ 47E3, 47H2 p 3.2x10 ⁻⁶ Po ²¹³ 47E3, 47H2	
d 38 ^m Pa ²²⁷ d 2 ^m Ac ²²³ } 48Q6 p 4.8 ^m TL ²⁰⁷ (AcC'') p 5x10 ⁻³ Po ²¹¹ (AcC')			

Rac 214 83 131		19.7 ^m	31IR
β^- 99.98%		γ $\frac{h\nu}{46E1\ SC\ 47L24\ S}$ $\frac{Rel. Intensity}{46S23\ * \ 47L24\ **}$	a's from ground and excited states of daughter Po ²¹⁴ (RaC')
1.650 s $\sim 77\%$	41C4	0.426	<u>Energy</u> <u>Rel. Number</u> 34LB
3.173 s $\sim 23\%$	41C4	0.498	7.683 10 ⁶
3.15 a	33Sar	0.607 0.606 8.9	8.280 0.43
For discussion of β energies and %'s see 48F14		0.766 0.88	8.941 0.45
		0.933 0.90	9.069 22
		1.120 1.120 2.9 1.76	9.315 0.38
		1.238 1.234 0.85 0.41	9.492 1.35
		1.290 0.86 1.32	9.660 0.35
		1.379 1.370 } 0.86 1.32	9.781 1.06
		1.414 1.414 } 0.58	9.908 0.38
		1.520 0.58	10.077 1.87
		1.620 0.38	10.149 0.38
		1.690 1.12	10.329 1.12
		1.761 1.761 2.8 2.51	10.509 0.23
		1.820 3.2	
		2.090 1.0 1.0	
		2.193 2.200 } 1.0 1.0	
		2.420 0.34	
d 28.8 ^m Pb ²¹⁴ (RaB) p 1.47x10 ⁻⁴ Po ²¹⁴ (RaC') p 1.32 ^m TL ²¹⁰ (RaC'')		Proposed cycle scheme for RaC $\rightarrow$ RaC', RaC' $\rightarrow$ RaD 46S23 * Estimated from data of 34E1 on number of conversion e ⁻ 's per dis- integration assuming quadrupole transitions ** Relative intensities of groups indicated from recoil spectrum. Results from conversion e ⁻ 's in good agreement. All transitions appear quadrupole.	



84 POLONIUM Po

202 84 118				203 84 119				204 84 120					
τ	40 ^m		49K11	τ	37 ^m		49K11	τ	4 ^h		49K11		
K	~100%		49K11	K			49K11	K	~100%		49K11		
α	~0.1%	5.56	ic	49K11	α		49K11	α	~0.1%	5.35	ic	49K11	
B1-p			49K11	B1-p-7n			49K11	B1-p-6n			49K11		
p 2 ^h B1			49K11	p 12 ^h B1 p 52 ^h Pb		49K11 49K11		p 18 ^h Pb ²⁰⁰ p 12 ^h B1 ²⁰⁴ p 88 ^m Pb ²⁰⁴	}	49K11			
205 84 121				206 84 122				207 84 123					
τ	1.5 ^h		49K11	τ	9 ^d		47T1	τ	5.7 ^h		47T1		
K			49K11	K	~90%		47T1	K	~100%		47T1		
				γ	0.8 weak ~0.3	a a	47T1 47T1	γ	1.3	a	47T1		
								L X-ray			47T1		
α	5.2	ic	49K11	α	~10%	5.2	ic	47T1	α	~0.01%	5.1	ic	47T1
B1-p-6n Pb- α -3n			49K11 49K11	Pb ²⁰⁴ - α -2n	chem		47T1	Pb ²⁰⁶ - α -3n	chem, σ		47T1		
p ~14 ^d B1			49K11	p 6.4 ^d B1			47T1						

84 POLONIUM Po

208 84 124			209 84 125			RaF 210 84 126		
τ	3.0^{γ} ~ 3	49K10 47T1	τ	$\sim 200^{\gamma}$	49K10	τ	138.3^d 140	49B54 31IR
						γ	0.773 s 0.8 a	47S4 47D1
						$\gamma/a = 10^{-5}$		48Z3
α	5.14 ic	47T1	α	4.95	49K10	α	5.298 s 5.303 s	38HL 46C6
No γ		47T1				No α fine structure		48W17
B1-d-3n	chem, σ f	47T1 49K10				Pb ²⁰⁸ - α -2n	chem, σ	47T1
Pb ²⁰⁶ - α -2n	chem	47T1				B1-d-n	chem, σ	47T1
Pb ²⁰⁷ - α -3n	chem	47T1	B1-d-2n		49K10		chem, σ , f	40C2, 42K7
B1-p-2n		46L1					f	49K10
No daughter activity		47T1					d 5^d B1 ²¹⁰ (RaE)	
d 7.0^h At ²⁰⁸		49B12					d 8.3^h At ²¹⁰	49K10
d 1.7^h At ²⁰⁸	chem	49H13						
d 2.3^h Em ²¹²	chem	49H13						
AcC' 211 84 127			ThC' 212 84 128			213 84 129		
τ	$5 \times 10^{-3}^S$	31IR	τ	$3.04 \times 10^{-7}^S$ 3.0×10^{-7} 3.4×10^{-7} 2.2×10^{-7}	49B9 48H21 48J5 49V1	τ	$3.2 \times 10^{-6}^S$ 4.2×10^{-6}	47E3 48J5
			Levels		B1 ²¹² (ThC)			
α	7.434 s	34LB	α (10^6)*	8.776 s	38HL, 36B5	α	8.336 ic 8.30 ic	47E3, 48C12 47H2
Long range α ? $\sim 0.01\%$ ~ 9.2		33C3	Long range α 's (34)* 9.488 38HL, 32R1 9.600 ? 32R1 (190)* 10.538 38HL, 32R1 10.55 48C21					
			* Relative numbers of α 's		34LB			
d 2.1^h B1 ²¹¹ (AcC)			d 60.5^h B1 ²¹² (ThC)			d 10^{-3}^S Em ²¹⁷		49M16
d 7.5^h At ²¹¹		40C10	d 9.3^h U ²²⁸		49M16	d 47^h B1 ²¹³		47H2, 47E3
						d 3.3^h Pb ²⁰⁹		47H2, 47E3

84 POLONIUM Po

RaC' 214 84 130	ACA 215 84 131	ThA 216 84 132
τ $1.47 \times 10^{-4}^S$ 48B14 1.40×10^{-4} 48R8 1.48×10^{-4} 42W4 1.45×10^{-4} 41R6 1.55×10^{-4} 43J1	τ $1.83 \times 10^{-3}^S$ 42W4 β^- 5x10 ⁻⁴ % 44K2	τ 0.158^S 42W4 β^- 0.014% 43K2
Levels Bi ²¹⁴ (RaC)		
α (10^6)* 7.680 s 38HL Long range α 's 34LB (0.43)* 8.280 (1.06) 9.782 (0.45) 8.941 (0.36) 9.908 (22) 9.069 (1.67) 10.077 (0.36) 9.315 (0.36) 10.149 (1.35) 9.492 (1.12) 10.329 (0.35) 9.660 (0.23) 10.509 9.080 48C22 * Relative numbers of α 's 34LB d 19.7 ^m Bi ²¹⁴ (RaC) d 0.019 ^s Pb ²¹⁸ 46S14 p 22 ^p Pb ²¹⁰ (RaD)	α 7.365 s 34LB Levels Em ²¹⁹ (An) 0.198 0.265 0.389 0.590 d 3.9 ^s Em ²¹⁹ (An) p 36.1 ^m Pb ²¹¹ (AcB) p 10 ⁻⁴ s At ²¹⁵	α 6.774 s 38HL d 54 ^s Em ²²⁰ (Tm) p 10.6 ^h Pb ²¹² (ThB) p 3x10 ⁻⁴ s At ²¹⁶
217 84 133	RaA 218 84 134	
	τ 3.05 ^m 31IR β^- 0.04% 43K4 α 5.998 s 38HL d 3.6 ^d Em ²²² (Rn) p 26.8 ^m Pb ²¹⁴ (RaB) p short At ²¹⁸ p 0.019 ^s Em ²¹⁸ 49W5	

85 ASTATINE At

<205 85			<206 85			207 ? 85 122 ?		
τ	10^m	49B40	τ	25^m	49B40	τ	1.7^h 1.8	48T6 49B12
K ?		49B40	K ?		49B40	K ?		48T6
α	6.10 ic	49B40	α	5.90 ic	49B40	α	5.76 ic	48T6
Bi- α	chem	49B40	Bi- α	chem	49B40	Bi- α	chem	48T6
208 85 123			209 85 124					
τ_1	1.7^h	49H13	τ_2	7.0^h 4.5^h	49B12 48T6	τ	5.7^h	49B12
K 99.5%		49H13	K		49B12, 48T6	K ?		49B12
γ	1.1 a	49H13						
K, L X-rays		49H13						
α ~0.5%	5.65 ic	49H13	α not observed			α	5.65 ic	49B12
			Bi- α	chem	48T6	Bi- α	chem	49B12
d 19.3^a Fr ²¹² chem		49H13						
p 3^y Po ²⁰⁸		49H13	p 3^y Po ²⁰⁸		49B12			

85 ASTATINE At

210 85 125			211 85 126			212 85 127		
τ	8.3 ^h	49K10	τ	7.5 ^h	40C10	τ	0.25 ^S	48We
K		49K10	K	60%	40C10			
γ, e^-	1 a	49K10						
Po K X-ray								
α/K	$<10^{-4}$	49K10	α	5.89 ic 40% 5.94 a	48T6 40C10	α		48We
B1- α -2n	chem	49K10	B1- α -2n	chem	40C10	B1- α -n		48We
threshold ~ 29		49K10						
p 138 ^d Po ²¹⁰		49K10	d 8 ^m Fr ²¹¹ p 5x10 ⁻³ Po ²¹¹		49H13 40C10			
213 85 128			214 85 129			215 85 130		
			τ	short	49M16	τ	$\sim 10^{-4}$ ^S short	49M16 44K1
			α	8.78 ic	49M16	α	8.00 ic 8.43 ic	49M16 44K1
			d 1.7 ^m Pa ²²⁶ ?		49M16	d 1.8x10 ⁻³ Po ²¹⁵ (AcA) d 3.9 ^S Em ²¹⁹ (An) d 2 ^m Ac ²²³		44K1 48GS

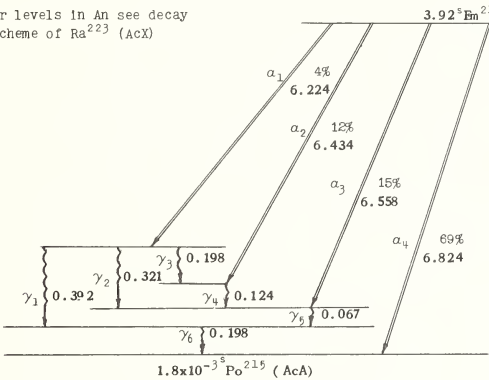
85 ASTATINE At

216 85 131			217 85 132			218 85 133		
τ	$\sim 3 \times 10^{-4} \text{ s}$ short	49M16 44K1	τ	0.018 ^s 0.021	47H2 47E3	τ	1.5 - 2.0 ^s	49W5
						β^- 0.1%		49W5
α	7.79 ic 7.66 ic	49M16 44K1	α	7.00 7.02	47H2 47E3	α	6.76 ic 99.9% 6.7 ic	44K1 49W5
d 54 ^g Em ²²⁰ (Tn) d 2.9 ^h Ac ²²⁴		44K1 49G5	d 4.8 ^m Fr ²²¹ p 47 ^m B1 ²¹³		47H2, 47E3 47H2, 47E3	Not found from Fr separated from Rn d 3.05 ^m Po ²¹⁸ (RaA) d 3.8 ^g Em ²²² (Rn)		48K6 49W5 44K1

86 EMANATION Em
(Radon)

210 ? 86 125			211 86 125			212 86 126		
τ	2.3 ^h	49G16				τ	23 ^m	49H13, 49G16
α		49G16				α	6.17	49H13
Th-p		49G16				Th-p		49G16
							d 19.3 ^m Fr ²¹² p 3 ^h Po ²⁰⁸	49H13 49H13
216 86 130			217 86 131			218 86 132		
τ	short	49M16	τ	$\sim 10^{-3}$ ^s	49M16	τ	0.019 ^s 1.3	46S14 49W5
α	8.07 ic	49M16	α	7.74 ic	49M16	α	7.12	46S14
d 9.3 ^m U ²²⁸		49M16	d 59 ^m U ²²⁹		49M16	gaseous d 3.05 ^m Po ²¹⁸ (RAA) d 38 ^s Ra ²²²		49W5 46S14

86 EMANATION Em
(Radon)

An 219 86 133			Rn 222 86 136		
τ 3.92^s 31IR For levels in An see decay scheme of Ra²²³ (AcX)  0.198 γ very intense, suggesting another α obscured by AcC α 37S7			τ 3.825^d 31IR α 5.486 s 38HL $\beta/\alpha < 10^{-6}$ 46K6 d 11.2^dRa²²³ (AcX) p 1.8x10⁻³Po²¹⁵ (AcA) d 1622^yRa²²⁶ p 3.05^pPo²¹⁸ (RAA)		
τ 54.5^s 31IR α 6.282 s 38HL d 3.6^dRa²²⁴ (ThX) p 0.16^pPo²¹⁶ (ThA)					

87 FRANCIUM Fr

211 87 124			212 87 125			
τ	8 ^m	49H13	τ	19.3 ^m	49H13	
K		49H13	K 56%		49H13	
			α 44%	6.25 ic	49H13	
Th-p	chem	49H13	Th-p	chem	49H13	
p 7.6 ^h At ²¹¹		49H13	p 23 ^m Dn ²¹² p 1.7 ^h At ²⁰⁸		49H13 49H13	

87 FRANC IUM Fr

218 87 131			219 87 132			220 87 133		
τ	short	49M16	τ	$\sim 0.02^S$	49M16	τ	27.5^S	49M16
α	7.85 ic	49M16	α	7.30 ic	49M16	α	6.69 ic	49M16
d	1.7^mPa^{226} ?	49M16	d	2^mAc^{223}	48Q5	d	2.9^hAc^{224}	48Q5
221 87 134			222 87 135			ACK 223 87 136		
τ	4.8^m 5	47H2 47E3	τ	14^m	49H13	τ	21^m	46P5
			β^-		49H13	β^-	1.20 cc	46P5
						γ	0.095 a 0.090 a	46P5 44L9
α	6.30 6.31	47H2 47E3	Th-p	chem	49H13			
d	10^dAc^{225}	47H2, 47E3	p	38^sRa^{222}	49H13	d	21.7^yAc^{227}	39P1
p	0.018^sAt^{217}	47H2, 47E3				p	$11.2^s \text{Ra}^{223} (\text{AcX})$	47G17

88 RADIUM Ra

220 88 132			221 88 133			222 88 134		
τ	short	49M16	τ	31 ^s	49M16	τ	38.0 ^s	46S14
α	7.49 ic	49M16	α	6.71 ic	49M16	α	6.51 ic	46S14
d 9.3 ^m U ²²⁸			d 58 ^m U ²²⁹			d 31 ^m Th ²²⁶ p 0.019 ^s Em ²¹⁸		
		49M16			49M16			46S14

ACX 223 88 135		
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τ			11.2 ^d	31IR
For levels in ACX see decay scheme of Th²²⁷ (RdAc) γ values in kev			α_1 6.9% 5.439 α_2 17.2% 5.533 α_3 34.5% 5.607 α_4 41.4% 5.719	α_1 6.9% 5.439 36R5 α_2 17.2% 5.533 36R5 9.1% 5.533 34LB α_3 34.5% 5.607 36R5 36.4% 5.607 34LB α_4 41.4% 5.719 36R5 54.5% 5.719 34LB
			γ 's (in kev in scheme) sc 3737 γ 's found with cryst spect 144, 155, 180, 270, 340kev. 40F2	
			d 21 ^m Fr ²²³ 47G17 d 2.2 ^m Ac ²²³ 49M16 d 18.6 ^d Th ²²⁷ (RdAc) p 3.9 ^s Em ²¹⁹ (An)	

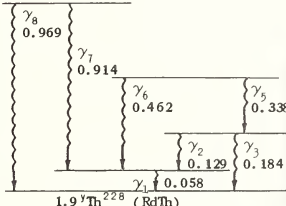
88 RADIUM Ra

ThX 224 88 136			225 88 137			226 88 138		
τ	3.64 ^d	36L7	τ	14.8 ^d 14	47H2 47E3	τ	1620 ^y 1600 1690 1600 1590	47K7 39G6 35G2 (47K7) 34G3 (47K7) 31IR
			β^-	~ 0.2 <0.05	47H2 47E3			
Levels	0.0833 0.0868	Th ²²⁶ (RdTh)	Levels	0.10 ? 0.20 ?	Th ²²⁹	Levels	0.068 ~ 0.190	Th ²³⁰ (Io)
α	5.681 s 5.66 ic	36B5 45C3				α	83.5% 4.795 s 4.791 s	49R8 34LB
	4.0% 5.448 s 0.4% 5.194 s	49R9 49R9					6.9% 4.611 s 4.610 s	49R8 34LB
γ	~ 0.250	15V1				γ	0.188	24H1
No low energy e ⁻		28M2				Probably no additional α fine structure		48W17
	d 1.9 ^y Th ²²⁸ (RdTh) d 2.9 ^h Ac ²²⁴ p 54.5 ^h Em ²²⁰ (Tn)	48G5		d 7x10 ^{3y} Th ²²⁹ p 10 ^d Ac ²²⁵	47H2, 47E3 47H2, 47E3		d 8.0x10 ^{4y} Th ²³⁰ (Io) p 3.62 ^d Em ²²² (Rn)	
227 88 139			MsTh ₁ 228 88 140					
			τ	6.7 ^y	31IR			
β^-		47P9	β^-	~ 0.0015 cc 0.053	49L2 39L14			
			β^- or e ⁻	15% 0.0015-0.018	49L2			
Ra-n- γ		47P9						
	p 21 ^y Ac ²²⁷	47P9		d 1.39x10 ^{10y} Th ²³² d 6.13 ^h Ac ²²⁸ (MsTh ₂)				

89 ACTINIUM Ac

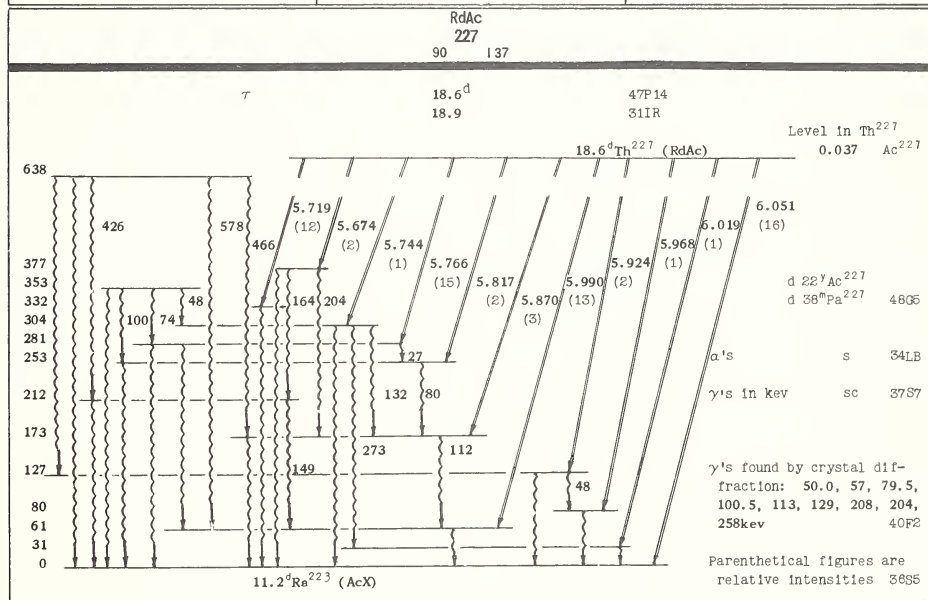
222 89 133			223 89 134			224 89 135		
τ	short	49M16	τ	2.2^m	49M16	τ	2.9^h	49M16
			K	0.1%	49M16	K	$\sim 90\%$	49M16
α	6.96 ic	49M16	α	99.9% 6.64 ic	49M16	α	$\sim 10\%$ 6.17	48G5
d	1.7^mPa^{226} ?	49M16	d	38^mPa^{227} 2.2^mBi^{211} (AcC) 11^dRa^{223} (AcX)	48G5 48G5 49M16	d	22^hPa^{229} 3.6^dRa^{224} (ThX) 27.5^sFr^{220}	48G5 48G5 48G5
225 89 136			226 89 137			227 89 138		
τ	10.0^d 10	47H2 47E3	τ	22^h	48S9	τ	21.7^y 13.5	44C2 31IR
			β^-		48S9	β^-	99% ~ 0.02 cc	46P5
						γ	0.037 a α large	46P5 43L3
						L X-ray	40%	43L3
α	5.80 ic	47H2, 47E3				α	1.2% 4.94 ic 4.92 photographic plate	46P5, 47P15 48G15 48V3
			U- α		48S9		Fine structure reported by 47G9, 46P5, but expected accompanying γ -of 0.35 not found.	
							For possible levels in Ac ²²⁷ see Pa ²³¹	
d	1.5^dAc^{229} 7.8^mTh^{225} 14.6^dRa^{225} 4.8^mFr^{221}	49M16 47H2, 47E3 47H2, 47E3	p	31^mTh^{226}	48S9	d	$3.4 \times 10^{-4} \text{Pa}^{231}$ 18.6^dTh^{227} (RdAc) 21^mFr^{223} (AcK)	

89 ACTINIUM Ac

Ms Th ₂ 228							
89				139			
τ	6.13 ^h			311R			
β ⁻	1.55	s	38L1	α ?	4.54	a	33G1
	~1.7	cc	38L7	Two β groups observed in cloud chamber with ~equal intensity with upper limits 0.060 and 1.5			
	2.0	a	38F3				
γ	sc		24B1	Evidence for delay 49L2			
				γ's at 0.333, 0.461, 0.913, 0.967 found from photo electrons s 26T1 γ of 0.318 also found 24B1 Soft γ's most strongly converted 24B1			
d 6.7 ^y Ra ²²⁸ (MsTh ₁) p 1.9 ^y Th ²²⁸ (RdTh)							

90 THORIUM Th

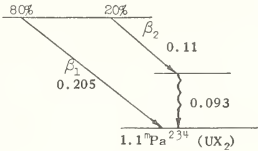
224 90 134			225 90 135			226 90 136		
τ	short	49M16	τ	7.8 ^m	49M16	τ	30.9 ^m	46S14
			K $\sim 10\%$		49M16			
α	7.20 ic	49M16	α	$\sim 90\%$ 6.57 ic	49M16	α	6.30 ic	46S14
d 9.3 ^m U ²²⁸		49M16	d 58 ^m U ²²⁹ p 10 ^d Ac ²²⁹		49M16 49M16	d 21 ^d U ²³⁰ chem p 38 ^s Ra ²²²		46S14 46S14



90 THORIUM Th

	RdTh 228 90 138			229 90 139					
	τ	1.90 ^y	31IR	τ	7,000 ^y ~10,000	47H2 47E3			
				Levels	0.040 ? 0.080 ? 0.31 ?	U ²³³			
	α	72% 5.423 s possibly double 28% 5.338 s	} 49R2	α	5.02 4.94 4.85	} 48J18			
		83% 5.418 s 17% 5.333 s Corroborating results			~10% 5.05 ~20% 4.95 ~70% 4.85		46H20		
	γ	0.0833 0.0868 not K _a lines of Ra d 6.1 ^h Ac ²²⁸ (MsTh ₂) d 22 ^h Pa ²²⁸ p 3.6 ^d Ra ²²⁴ (ThX)	} 41S10 48G5		d 1.62x10 ^{5y} U ²³³ p 14.8 ^d Ra ²²⁵	47H2, 47E3 47H2, 47E3			
	10 230 90 140			UY 231 90 141			232 90 142		
τ	8.0x10 ^{4y} 8.3x10 ⁴	48H21 31IR	τ	25.65 ^h 25.5 24.6	48J17 49K9 31IR	τ	1.39x10 ^{10y}	38K1	
			β^-	0.21 a ~0.2 a	49K9 37E1, 48J15				
Level	0.94 ?	Pa ²³⁰	γ	>80% 0.035 a $\alpha = 4.5$ $\tau < 1\mu^s$	} 49K9 48J15 48J15				
α	~75% 4.682 s ~25% 4.612 s 4.509 ? s 4.66	} 48R5 44C9		0.035 a 0.065 a					
γ	0.068 a 0.190 a 0.068 a $\alpha = 14$ 0.15-0.20 a $\alpha = 5$		39W6 39W6 48C20 48T12, 48C20 48C20 48T12, 48C20	Level	0.16	U ²³⁵	α	3.98 ic 4.20 ic	45C3 37S5
e ⁻ /α = 0.1 L X-rays/α = 0.1			48T12, 49A9 49R10, 48C20			σ ^{1s} (9Mev d, p) ²³³ Th 6.3mb 42K7			
d 17.7 ^d Pa ²³⁰ d 2.67x10 ^{5y} U ²³⁴ p 1.62x10 ^{3y} Ra ²²⁶			d 8.8x10 ^{8y} U ²³⁵ p 3.43x10 ^{4y} Pa ²³¹			p 6.7 ^y Ra ²²⁸ (MsTh ₁)			

90 THORIUM Th

233 90 143			UX ₁ 234 90 144			
τ	23.5 ^m 23.0	47S5 41G3	τ	24.10 ^d 24.1	48K23 39G11	
β^-	1.2 a	42S6				
No γ		42S6				
			β_1^- 80%	0.205 s	46B12	
				0.190 s	46J1	
				0.2 a	38F2	
			β_2^- 20%	0.11 s	46B12	
				0.1 a	38F2	
			γ	0.093 sc	46B12	
			$\alpha_L = 0.34$		46B12	
Th-n- γ	36M4, 41S9, 41G3			0.092 sc	46J1	
Th-d-p	42Q4					
	chem, σ , f	42K7	γ 4.5%	0.180 a	46B12	
			not assigned			
	p 27.4 ^d Pa ²³³			d 4.5x10 ⁹ yU ²³⁸		

91 PROTACTINIUM Pa

226 91 135			227 91 136			228 91 137		
τ	1.7 ^m	49M16	τ	38 ^m	49M16	τ	22 ^h	49M16
			K	16%	49M16	K	98%	48G5
α	6.81 ic	49M16	α	84% 6.46 ic	49M16	α	2% 6.09 ic	49M16
Th-d-8n	chem	49M16	Th-a-7n	chem	48G5	Th-d-6n	chem	48G5
			d 53 ^m Np ²³¹		48G12			
			p 18.6 ^d Th ²²⁷ (RdAc)		48G5			
			p 2.2 ^m Bi ²¹¹ (AcC)		48G5			
			p 4.6 ^m Tl ²⁰⁷ (AcC ^m)		48G5			
						p 61 ^m Bi ²¹² (ThC)		48G5
						p 1.9 ^h Th ²²⁸ (RdTh)		48G5
229 91 138			230 91 139			231 91 140		
τ	1.5 ^d	48H9	τ	17.7 ^d	46O2	τ	34,300 ^y	48V2
	1.4	46H11		17.0	46S14		32,000	30G1
K	99%	48M24	K	90%	48S10	I	3/2 S	34S4
			β^-	~1.1 a	46O2	Levels	0.035	Th ²³¹
			γ	0.94 a	46O2		0.065	
α	1% 5.69 ic	48M24				α	11% 5.042 s	} 49C25
	5.66 ic	48H9					47% 5.002 s	
							25% 4.938 s	
							3% 4.838 s	
							11% 4.720 s	
							1-3% 4.660 s	} 46T2
							~85% 5.00 ic	
							~15% { 4.69 ic	
							{ 4.72 ic	
Th ²³⁰ -d-3n	chem	46H11	Th ²³⁰ -d-2n	chem	46H11	γ	0.095 s	} 28M1, 42H1
			Th-d-4n		46S14		0.294 s	
			Pa-d-p-2n		46O2		0.323 s	
			Pa-a-a-n		46O2	e ⁻	24, 36, 46, 75kev	49T15
			U ²³³ -d-a-n		46H9	e ⁻	27	49S35
p 10 ^d Ac ²²⁹		46H11	p 21 ^d U ²³⁰		46S14	L X-ray	d 25 ^h Th ²³¹ (UY)	49S35
							p 21.7 ^y Ac ²²⁷	

91 PROTACTINIUM Pa

232				233			
91		141		91		142	
τ	1.32 ^d 1.4	46J10 4602		τ	27.4 ^d		41G3
β^-	0.28	a	46J16	β^-	0.23 ~0.2	s s	42H1, 41H6 47L6
γ	~0.23 1.05	a a	46J16 46J16	γ	0.084 0.298 0.309 0.337	sc sc sc sc	47L6
Th-d-2n	chem	42G4, 46S14		Th-d-n	chem	42G4, 46S14	
Th- α -p β n	chem	46S14		Th- α -p β n	chem	46S14	
Pa-d-p		4602		d 23.5 ^m Th ²³³		38M4, 41S9, 41G3	
p 70 ^y U ²³²		42G4		d 2.2x10 ⁶ ^y Np ²³⁷		47H2	
				p 1.62x10 ⁵ ^y U ²³³		47S5	
				Proposed decay scheme 0.471 0.415 0.396 0.339 0.310 0.298 1.62x10⁵^yU²³³ Possibly γ's of 0.396 and 0.471 coincidences shown by two spectrometers			
				50E1			

UX ₂		91 143		UZ	
τ_1	1.14 ^m 1.22	311R 48H6	τ_2	6.7 ^h	311R
Proposed decay scheme		45B5, 47B17	1.14^mUX_2 β_1^- 98% 2.32 s 45B5 $\beta_4^-, \beta_5^- \sim 2\%$ ~ 1.50 47B17 β_6^- 0.2% ~ 0.82 47B17		
1.14 ^m UX ₂	γ_1 0.12% 0.394 β_1 90% 0.45 β_2 10% ~ 1.2 β_3 98% 2.32 β_4 ~ 1.50 β_5 ~ 1.50 β_6 0.2% ~ 0.82	γ_1 0.12% 0.394 γ_2 ~ 0.8 γ_3 ~ 0.8 γ_4 0.782 γ_5 0.822 γ_6 ~ 1.5	γ_1 0.12% 0.394 γ_4, γ_5 0.782, 0.822 s $a_K = 0.36, a_1 = 0.10$ γ_6 ~ 1.5	γ_1 0.12% 0.394 γ_4, γ_5 0.782, 0.822 s γ_6 ~ 1.5	45B5 47B17 47B17 45B5 38F2 43B4 43B4 47B17
$2.67 \times 10^{15} \text{U}^{234}$ $2.67 \times 10^{15} \text{U}^{234}$		6.7^hUZ β_1^- 90% 0.45 s β_7 coincidences β_2^- 10% ~ 1.2 s γ_2, γ_3 ~ 0.8 a a small $\gamma/\beta = 1.8$ No $\gamma\gamma$ angular correlation			
Level in UX ₂	0.093	Th ²³⁴ (UX ₁)	UX ₂ daughter of 24.1 ^d Th ²³⁴ (UX ₁) See decay scheme of Th ²³⁴		

92 URANIUM U

228				229				230			
92		136		92		137		92		138	
τ	9.3 ^m		49M16	τ	58 ^m		49M16	τ	20.8 ^d		46S14
K $\sim 20\%$			49M16	K $\sim 84\%$			49M16				
$\alpha \sim 80\%$	6.72	ic	49M16	$\alpha \sim 16\%$	6.42	ic	49M16	α	5.86	ic	46S14
									5.85	ic	46J4
Th- α - β n			49M16	Th- α - γ n			49M16	Th- α - β n			46S14
p Po ²¹² (ThC')			49M16	p Po ²¹³			49M16	p Po ²¹⁴ (RaC')			46S14
p 22 ^b Pa ²²⁸			49M16	p 1.5 ^d Pa ²²⁹			49M16	d 18 ^d Pa ²³⁰ chem			46S14
231				232				233			
92		139		92		140		92		141	
τ	4.2 ^d		4602	τ	70 ^y		46J8	τ	1.62x10 ^{5y}		46H10
				~ 30			42G4		1.63x10 ⁵		46L7
K			4602					Levels	0.084	} ?	Pa ²³³
K, L X-rays			49C6						0.298		
No γ			49C6						0.309		
									0.337		
α 0.05%			49C6	Levels	~ 0.23 ?		Pa ²³²	α	4.823	ic	46C12
					1.05 ?				4.825	ic	47E3
				α	5.31	a	46J19		4.80	a	43C5
					5.27		44K6	Complexity in α 's not detected			47S19
Pa-d-2n			4602	Th- α -4n			46N4	γ	0.040	a	} 47S19
Pa- α -p3n			4602	Pa-d-n			4602		0.8%	0.080	a, $\alpha \sim 8$
				Pa- α -p2n			4602		0.1%	0.31	a, $\alpha \sim 3$
								L X-ray			47S19
p 18.6 ^d Th ²²⁷ (RdAc)			49C6	d 1.3 ^d Pa ²³²		42G4, 4602		(44Mev α , n) Pu ²³⁶	0.5mb	} 46P10	
p 3.43x10 ^{4y} Pa ²³¹			49C6	d 2.7 ^y Pu ²³⁶		46J8		(44Mev α , 3n) Pu ²³⁴	1mb		
				p 1.9 ^y Th ²²⁸ (RdTh)		42G4		(44Mev α , p2n) Np ²³⁴	0.2mb		
								d 27.4 ^d Pa ²³³			47S5, 47S19
								p 7000 ^y Th ²²⁹			47H2, 47E3

92 URANIUM U

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93 NEPTUNIUM Np

231 93 138			232 93 139			233 93 140		
τ	53 ^m	48G12				τ	35 ^m	48M39
K		48G12				K		48M39
α	6.2 ic	48G12						
$U^{235}-d-6n$ $U^{233}-d-4n$ $U-d-9n$	$\left. \begin{array}{l} \\ \\ \end{array} \right\}$ 48G12							
p 38 ^m Pa ²²⁷		48G12						
234 93 141			235 93 142			236 93 143		
τ	4.40 ^d 4.5	48H9 48J8	τ	435 ^d 400	48J12 48J8	τ	22 ⁿ	48J8
K		48H9, 48J8	K		48J8	β^-	0.5 a	48M25
γ	1.9 a 1.8	48H9 48J8	No γ ?		48J8	γ		48J8
X-ray		48J8						
			$\alpha \sim 0.1\%$	5.06 ic	48J12			
$U^{233}-d-n$ $U^{235}-d-3n$ $U^{235}-\alpha-p4n$ $U^{233}-\alpha-p2n$ $U^{235}-p-2n$	$\left. \begin{array}{l} \\ \\ \\ \\ \end{array} \right\}$ 48H9 48J8 48J8 48H9 48G13		$U^{235}-d-2n$ $U^{235}-\alpha-p3n$ $U^{233}-\alpha-pn$	$\left. \begin{array}{l} \\ \\ \\ \end{array} \right\}$ 48J8 48J8 48H9		$U^{235}-d-n$ $U^{238}-d-4n$ $U^{235}-\alpha-p2n$ $U^{233}-\alpha-p$ $Np-d-t$ $Np-\alpha-\alpha n$	$\left. \begin{array}{l} \\ \\ \\ \\ \end{array} \right\}$ 48J8 48H9 48J9 48J9	
						p 2.7 ^y Pu ²³⁶		48J8

93 NEPTUNIUM Np

237 93 144			238 93 145		
τ	$2.2 \times 10^{6.5} \text{ y}$ 3×10^6	48M23, 48M16 48W4	τ	2.10^d 2.0	47J3 42S7
I	5/2 S	48T8	Proposed decay scheme		47J3
α	4.77 ic 4.72 a	48G13 47L9	γ_1	1.2 $\alpha = 0.018$	47J3
			γ_2	0.075 almost complete L conversion	47J3
			Coincidence measurements		47J3
			Np-d-p		48J9
			U^{235} - α -p		48J8
			U^{235} - α -p3n		48J8
			U-d-2n		46S8, 42K6
			Np-n- γ		45J2
d $6.6^d U^{237}$		48W4	d $400^d Am^{242}$		48S6
p $27^d Pa^{233}$		48SP	p $92^d Pu^{238}$		46S4

239

93 146

τ

2.33^d
2.31
2.3

42W6
46P11
40M2

Proposed decay scheme
 β and γ values s

49K25
44F11

2.3^dNp²³⁹

2.4x10⁴ Pu²³⁹

Proposed decay scheme, β and γ values
s 48S14

2.3^dNp²³⁹

2.4x10⁴ Pu²³⁹

γ_1	0.057	$\alpha = 0.33$	48S14
γ_2	0.061	$\alpha = 0.33$	48S14
γ_3	0.067	$\alpha = 0.33$	48S14
γ_6	0.206	$\alpha = 0.22$	48S14
	0.208		46P11
	0.209		44F11
γ_7	0.227	$\alpha = 0.41$	48S14
	0.226		46P11
	0.228		44F11
γ_8	0.275	$\alpha = 0.19$	48S14
	0.276		46P11
	0.277		44F11
γ	0.5	α	48S14

γ_4 and γ_5 hypothetical			48S14
Other β values			46F6, 40M2, 45H12

94 PLUTONIUM Pu

232 94 138				233 94 139				234 94 140			
τ	22 ^m		48J14					τ	$\sim 8.5^h$ 8		48P10 46H9
								K $\sim 99\%$			48P10
α	6.6	ic	48J14					α < 1%	6.2 ic 6.0 ic		48P10 46H9
$U^{235}-\alpha-n$			48J14					$U^{233}-\alpha-n$			46H9, 48P10
p 9.3 ^m U ²²⁸			48J14					p 21 ^d U ²³⁰			48P10
235 94 141				236 94 142				237 94 143			
				τ	2.7 ^y		48J8	τ	40 ^d		48J9
								K			48J9
								No γ			48J9
				α	5.75 ic 5.7 ic		48G13 48J8				
				$U^{235}-\alpha-n$			48J8	$U^{235}-\alpha-n$			48J8
				$U^{233}-\alpha-n$			46H9, 48P10	$U^{238}-\alpha-n$			48J8
				Np-d-n			48J9	Np-d-n			48J8, 48J9
				d 22 ^h Np ²³⁶			48J8	Np-p-n			46S26
				d 27 ^d Cm ²⁴⁰			48S4				

94 PLUTONIUM Pu

238 94 144			239 94 145			240 94 146		
τ	92 ^y 89 77	48S4 47J2 47J3	τ	2.41x10 ^{4y} 2.44x10 ⁴	47S6 46W4	τ	~6000 ^y	48J8
γ	<2%	42F1	γ weak	0.2 a 0.42 a	45S16 45S16			
			weak	0.05 a 0.3 a	44G3 44G3			
α	5.493 i c 5.51 a 5.4 a	49J2 47C3 42F1	α	5.159 i c 5.140 i c 5.15 a	48C12 48J2 47C3	α	5.1 i c	48J8
U ²³⁵ - α -n		48J8				U- α -2n		48J8
U ²³⁸ - α -4n		48J8						
Np-d-n		48J9						
U ²³⁸ -d-2n		42F1						
d 150 ^d Om ²⁴²		48S4	d 2.3 ^d Np ²³⁹		46K2			
d 2 ^d Np ²³⁸		46S4, 42K6						
241 94 147								
τ	~10 ^y	48S5						
β^-	0.01-0.02 a	48S5						
α	0.002%	45K2, 48S5 47S18						
ms		46B17						
U- α -n		48S5, 48J8						
p 490 ^y Am ²⁴¹		48S5						
p 8.8 ^y U ²³⁷		45K2, 48S5						

95 AMERICIUM Am

238 95 143				239 95 144				240 95 145			
τ	1.5 ^h	48J11		τ	12 ^h	48S5		τ	50 ^h 53	48S5 48J11	
K ?		48J11		K ~100%		48S5		K		48S5	
				γ ~60%	0.285 a α ~0.5	48S5 48S5		γ ~100%	~1.3 a α ~0.06	48S5 48S5	
				Pu K, L X-rays		48S5		Pu K, L X-rays		48S5	
				α ~0.1%	5.77	48J11					
Pu-d-2n		48J11		Pu-d-2n	chem	48S5		Pu-d-n	chem	48S5	
				Np- α -2n	chem	48S5		Np- α -n	chem	48S5	
				Pu-p-n		48J11					
241 95 146				242 95 147							
τ	490 ^y 470 510	48C17 49Y3 48C15		τ_1	~16 ^h 17	48A6 48S5		τ_2	~400 ^y ~600	48T5 48S5	
				β^-	1.0 0.8	48A6 48S5		β^-	~0.5	48S5	
α 100%	5.45 ic 5.48 ic	48S5 48C13						α ~0.2%		48S5	
γ ~80%	0.062 a	48S5									
Np L X-ray		48S5									
X/a = 1		48S5		Am-n- γ		48A6, 48S5		Am-n- γ		48S5	
d 10 ³ Pu ²⁴¹		48S5		p 150 ^d Cm ²⁴²		48S4, 48A6		p 150 ^d Cm ²⁴² p 2 ^d Np ²³⁸		48S5 48S5	

96 CURIUM Cm

238 96 142			239 96 143			240 96 144		
τ	$\sim 2.5^h$	48S11				τ	26.8^d	48S4
α	6.50 ic	48S11				α	6.26 ic 6.3 ic	48G13 48S4
Pu- α -5n		48S11				Pu- α -3n	chem	48S4
						p Pu ²³⁶		48S4
241 96 145			242 96 146					
τ	55^d	48S4	τ	150^d	48S4			
K		48S4						
			α	6.08 ic 6.1	48G13 48S4			
Pu- α -2n	chem	48S4	Pu- α -n	chem	48S4			
				d 16^h and 400^7 Am ²⁴² , 48S4, 48A6				
				p Pu ²³⁸	48S4			

97 BERKELIUM Bk

	$^{243}?$ 97 146 ?	
	τ 4.6 ^h 50T1 K ~ 100% 50T1 α ~ 0.1% 6.72 30% 6.55 53% } 50T1 6.20 17% $\text{Am}^{241} \rightarrow \alpha \rightarrow 2\pi$ 50T1	

98 CALIFORNIUM Cf

	$^{244}?$ 98 146 ?	
	τ $\sim 45^m$ 50T2 K 50T2 α 7.1 50T2 $\text{Cm}^{242} - \alpha - 2n$ 50T2	

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The abbreviations used for names of journals are in most cases self explanatory. For journals containing a good deal of nuclear data the abbreviations are the same as those listed in *Nucleonics* 2, #5, Part 2. These abbreviations do not differ very much from those used in *Physics Abstracts* or *Chemical Abstracts*. For journals not on this list, the abbreviations of *Physics Abstracts* have been used.

In a number of cases unclassified or declassified data have been reported from work done on Atomic Energy Commission projects. Often it has been possible to give a reference for such results to papers which are generally available. But in a number of instances the experimenters have not published the details of their work in the open literature. Their results, therefore, cannot have the authority of work which has been laid open to general study and criticism. But since the measurements do carry some weight, they have been listed in the table wherever they are not completely superseded by open literature results. Project report numbers are given in the references for the benefit of those who have access to project libraries.

The following abbreviations have been used:

AECD Atomic Energy Commission Declassified.
AECU Atomic Energy Commission Unclassified.
MDDC Manhattan District Declassified.
ANL Argonne National Laboratory.
BNL Brookhaven National Laboratory.
CUD Columbia University.
LA Los Alamos.
ISC Iowa State College.
UCRL University of California Radiation Laboratory.
Y Y-12 Plant, Carbide and Carbon Chemicals Corporation.
AERE Atomic Energy Research Establishment (British).
CR Chalk River (Canadian).

Designations such as CC (Chicago Chemistry) or Mon P (Monsanto Physics) are no longer in current use.

NSA Nuclear Science Abstracts. Issued by United States Atomic Commission, Technical Information Division, Oak Ridge, Tennessee.

NNES National Nuclear Energy Series, Manhattan Project Technical Section, Division IV, Plutonium Project Record. The three volumes to which references are given are 9, 14B, and 17B. Volume 9, on the fission products, will be issued during 1950. Volume 14B, *The Transuranium Elements*, appeared in 1949. Volume 17B which will be classified will appear early in 1951.

After July 1, 1950 declassified and unclassified documents of the Atomic Energy Commission which are for sale can be obtained from the Office of Technical Services of the U. S. Department of Commerce, Washington 25, D. C. A list of such documents will be supplied on request by the Technical Information Division of the Atomic Energy Commission, P. O. Box E, Oak Ridge, Tennessee, or by the Office of Technical Services. Some documents which are not for sale can be secured by government agencies on application to the Technical Information Division at the above address.

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