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

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with assistance from
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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 , make grateful acknowledgment of the invaluable assistance which it has received.

Both the Oak Ridge National Laboratory and the Brookhaven National Laboratory ıpported the nuclear data work from the beginning. A. M. Weinberg at Oak Ridge reorganed the Nuclear Data Committee there and made possible an integration of its current data ollection 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 ıformation Division of the Brookhaven National Laboratory. Dr. Goldsmith immediately ılisted the interest of Gerhart Friedlander of the Brookhaven Chemistry Division and the ʀo 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 ıtimely 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.

Contents

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_s 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 A ($E_n \sim 0.08$ 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_o, E_o, 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_o 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

$_{Z}A_{N}$	
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 $_{Z}A_{N}$ 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 quadruple 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 $_{Z}A_{N}$ 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^{m}Ag	**44**	47S33

means that the cross section of Ag^{107} for the production of 2.3^{m}Ag 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$1Mev n, γ)2.3^{m}Ag **0.13** 49H5

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

The following entry

(16Mev e^-, e^-n)24.3^{m}Ag $\mathbf{5.4\times10^{-4}}$ 48S3

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

Finally, under Graphs Available,

σ(n,γ)2.3^{m}Ag 0.003–6Mev 46L7, 47GIF, 50Ad

is intended to convey the information that the activation cross section for production of 2.3^{m}Ag 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

	$_{Z}A_{N}$		
τ	Half-life		Reference
K capture if observed			Reference
β^+ or β^- percentages of β groups	Maximum energy	Method	Reference
γ	Energy Conversion coefficients	Method	Reference
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 100^{s} or 100^{m} 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 ^{123}-n-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 U^{235}. 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 "σ", "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} cm^2) 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
B	band spectra method
β^-	negative beta particles
β^+	positive beta particles
cc	measurement by cloud chamber
ce	crystal effects
chem	chemical separation of product made
d	(1) deuteron; (2) descendant of; (3) days, when used as superscript
D	deuterium
e or e^-	electron
E_0	neutron resonance energy, usually in ev
E_β, E_γ, etc.	energy of β-ray, energy of γ-ray, etc.
$\overline{E}$	average energy
ev	electron volts
f	excitation function determined
γ	gamma rays
Γ	resonance half-width (the whole width at half-maximum), usually in ev. Breit-Wigner formula: $\sigma=[\sigma_0\Gamma^2(E_0/E)^{1/2}]/[4(E_0-E)^2+\Gamma^2]$
γn	measurement by means of photo neutron detection
h	hours, when used as superscript
I	(1) spin in units of $\hbar$; (2) nuclear induction method
ic	measurement by ionization chamber
IT	isomeric transition
K	electron capture from the K shell
K/L	α_K/α_L
kev	thousand electron volts
KU	β-ray end point found using Konopinski-Uhlenbeck theory
L/(M+N)	$\alpha_L/(\alpha_M+\alpha_N)$
L capture	electron capture from the L shell
L/M	α_L/α_M
m	minutes, when used as superscript
M	molecular or atomic beam resonance method
mb	millibarns
Mev	million electron volts
Mic	microwave method
ms	mass spectroscopic identification of mass number
μ	magnetic moment in units of nuclear magnetons
μs	microseconds
n	neutron
N	measurement by means of nuclear scattering experiments
p	(1) proton; (2) predecessor of
P	polarization of resonance radiation method
pc	measurement by means of proportional counter
q	electric quadrupole moment in units of barns
Q	reaction energy in Mev
rel	relative
s	(1) spectrometer measurement by means of secondary electrons; (2) seconds, when used as superscript
S	measurement by means of atomic spectra
s$\beta\gamma$	spectrometer measurement of β's in coincidence with γ's
sc	spectrometer measurement by means of conversion electrons
scin	measurement by means of scintillation counter
σ	cross section in barns
σ_0	cross section at resonance energy, E_0. See Γ.
σ_a	absorption cross section in barns
σ_{ac}	activation cross section in barns
σ_{eff}	effective cross section in barns
σ_s	scattering cross section in barns
σ_s bound	bound scattering cross section or $4\pi(p_1f_1^2+p_2f_2^2+ - - -)$ where the f's are the bound scattering lengths and the p's are the relative isotopic abundances. See 49S12.
σ_s coh	coherent scattering cross section or $4\pi(p_1f_1+p_2f_2+ - - -)^2$
σ_t	total cross section in barns
t	triton
th	thermal
τ	half-life in units indicated
wt	weight
y	years, when used as superscript
Z	method of zero moments

1. Alphabetical Index to Elements

2. Atomic Number Index to Elements

3. Index for Classical Radioactive Families

Thorium Family

Uranium Family

Actinium Family

	1 0 1	
	τ 10-30^{m} 50S6 9-18 50R2 I 1/2 N 37S9 μ -1.9135 49Po I 48B29, 47A10, 49R15 β^{-} 50S6 p 50R2, 50S6 D-γ-p 50HLM	

Neutron Cross Sections for Natural Element

σ_s	coh	2.0	(-)	49S12
σ_s	bound	80		49S12
		$E_n = 0.025$ev		
σ_a		0.32		(48WH)
		0.33		48R13
		0.25		49H2
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
		$E_n = 1$Mev		
σ_t		4.2		49B48
				See graphs

Graphs Available

σ_t (H_2, H_2O, methane, ethane, propane, n-butane, cetane, ethylene, 1,3-butadiene)	0.003-100 ev	49M40
σ_t	0.03-23Mev	47GIF
	0.03-290Mev	50Ad
	0.8-1.6Mev	49L20

Other fast n references on graphs and in 48WH

1 (Z = 1, N = 0)

	99.9844%		36H3
I	1/2	B	30H2, 29M1, 30C1
		SH*	27D1
μ	2.7926**		49H49
	1.4100** dyne cm/gauss		49T18
	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 (Z = 1, N = 1)

0.0156%		36H3
0.015		39S19

σ_s	coh	5.0	(+)	49S12
σ_s	bound	7.4		49S12
		$E_n = 0.025$ev		
σ_a	(D_2O)	0.92mb*		47S38
σ_s	(D_2O)	15.3*		46R9
σ_t	(D_2O)	14.6*		See graphs

* per molecule

	$E_n = 1$Mev	
σ_t	3.1	See graphs

Graphs Available

σ_t	0.005-40 ev	48R6, 47GIF
	0.35-14Mev	47GIF
	0.35-290Mev	50Ad

Other references on graphs and in 48WH

I	1	B	34M3
		OP*	34F2
μ	0.85761		49P0
		I	49S37, 49Z2, 47B29, 47R8, 47B30
		M	39K12
q	0.00273	M	40K10

* ortho-para conversion

3 (Z = 1, N = 2)

τ	12.5^y		49J4
	12.1		47N1
	10.7		47G8
I	1/2	B	49D31
		I	47B31
μ	2.9795		49P0
		I	47A9, 47B32
β^-	0.0189	pc	49H1
	0.0180-0.0186	pc	49C8
	0.0180	a	49G7
	0.0170	cc	49B22
$\overline{E_\beta}$	5.69kev		49J4
	5.64		48H51
	calorimetric measurements		
No γ			46G14
D-n-γ			50HLM
He^3-n-p			50HLM
D-d-p			50HLM
Li-n-α			48HL, 48Lau
Be-d-t			48HL, 48Lau

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Neutron Cross Sections for Natural Element	3 2 1	4 2 2
$E_n = 0.025$ev σ_s 1.55 50H5 Graphs Available σ_s 0.6-1.6Mev 47K13,47GIF σ_t 0.04-6.4Mev 49B48 Only one peak observed 49B48 σ(elastic back scattering) 0.5-1.8Mev 40S11 0.5-4.3Mev 39S18	Atmospheric Value: 1.3×10^{-4}% 49C9,47F1 1.2×10^{-4} 48A7 Wide variations in well and mineral values 49C9,48A7 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 Graphs Available σ(np) 0.001-0.03ev 49K17	~100% 47F1 I 0 B 29M1 N 31B1

5 2 3	6 2 4	
τ $\sim2.4\times10^{-21}$s Calculated weighted mean from several experiments 50HLM He-d-p Li-d-α } 50HLM	τ 0.82s 48K13,49H24 0.85 46S5 0.87 47C15 0.89 46H17 β^- 3.23 s 50P1 3.7 a 48K13 3.5 a 49A2,46S5 No γ 48K13 Li-γ-p Li-n-p Be-n-α } 50HLM	

Neutron Cross Sections for Natural Element

σ_s coh	0.4	(-)		49S12
	$E_n = 0.025$ev			
σ_a	67			49P3
	65			44F13
σ_t	70			44F13
	71			46H26
	$E_n \sim 2.5$Mev			
σ_t	2.0			39A5
Other fast n values				48WH

Graphs Available

σ_t	0.015-5ev	50Ad, 46H26, 47GIF
$\sigma(n,\alpha)$	0.04-1.8Mev	50Ad, 47GIF

5 (Z = 3, N = 2)

H^2-He^3-α	50HLM
He-p-p	50HLM

6 (Z = 3, N = 3)

	7.30%		48W9
	7.40		48I6
	7.40-7.46		47H27
I	1	M	40K9
		Z	37M6
μ	0.8221	M	49S37 (49K31)
$\frac{q(Li^6)}{q(Li^7)}$	$\leqslant$0.044	M	49K30
Levels ?	$\sim$1.0		50HLM
	$\sim$3.0		

σ's

σ_s coh	(+)	$\sim$6	49S12

By calculation from Li and Li^7

Large absorption cross section of element attributed to n,α reaction in this isotope 37LB

7 (Z = 3, N = 4)

	92.70%		48W9
	92.60		48I6
	92.54-92.60		47H27
I	3/2	B	30H1
		S	32G3
		M	40K9
		Z	35F3
μ	3.2567		49Po
		I	49B7, 49Z2, 49S37
		M	41M8
q	$\sim$+0.02		49K29
Levels	0.477		48Lau, 48HL, 50HLM
	7.38		

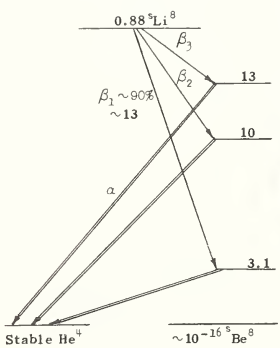
σ's

(th n,γ) 0.88 s Li		33mb	47H6
		1mb	46P12
σ_s coh	(-)	0.8	49S12
σ_s bound		$\sim$2	49S12

8 (Z = 3, N = 5)

τ	0.88^s	49B24, 4702, 45H5, 37L1
	0.89	47H6

Proposed decay scheme 50H1



Maximum β energy $\sim$13 50H1

β spectrum consistent with proposed decay scheme 50H1

β_1^-	$\sim$90%	$\sim$13	s	50H1
		12	a	4702
		12	cc	37B1
β_2^-, β_3^-	$\sim$10%			50H1

<5% of transitions to 4.8Mev γ emitting state of Be^8 50H1

No γ 37R3, 37B1

Li-d-p	48HL, 48Lau
Li-n-γ	
Be-γ-p	
B-n-α	

Neutron Cross Sections for Natural Element

σ_s	coh	7.7	49S12
σ_s	bound	7.5	49S12
		$E_n = 0.025$ev	
σ_a		0.009	47N5
		0.0085	47A8
		0.01	47H3
		$\leqslant$0.01	46M20
σ_s		6.9	37G1
σ_t		ce	See graphs

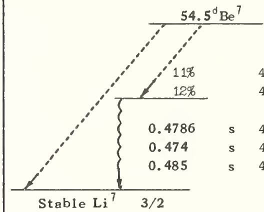
Values at other n energies 48WH, 49H16

Graphs Available

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

$^{7}_{4}$ 3

τ	54.5^d	49B14
	52.9	49S20
	54.3	47B21
	53	40H14



Maximum energy of Li^7 recoils = 57ev 49S38

$\frac{\lambda(BeO)-\lambda(Be)}{\lambda(Be)} \sim -3\times10^{-4}$ 49S20

Level 0.43 50HLM

Li-p-γ, Li-d-n, Li-p-n, B-p-α — 48HL, 48Lau

$^{8}_{4}$ 4

τ 10^{-16}-10^{-17} ^{S} calculated value 37B5

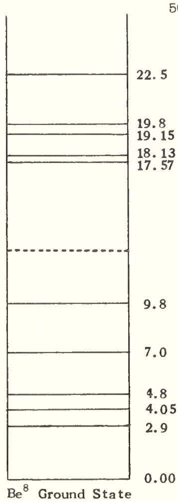
Mass difference in Mev

Be^8-2 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 — 48HL, 48Lau

d $0.88^s Li^8$

Levels 50HLM

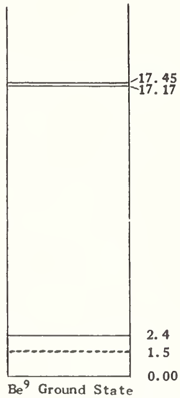


$^{9}_{4}Be_{5}$

100% 37N2

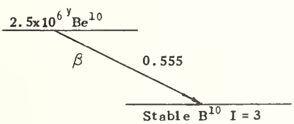
I	3/2 ?	S	41P4
μ	-1.1776		49Po
		I	49C2, 49D25
		M	39K9

Levels 50HLM



$^{10}_{4}Be_{6}$

τ	2.5×10^6 y	47M14
	2.9×10^6	47H3



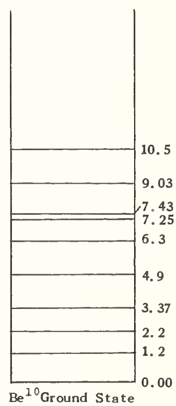
β^-	0.555	s	50F1, 49W18
	0.553	pc	49F12
	0.560	s	50A2
	0.560	a	47M14
	0.530	scin	49B15
	0.570	a	49H19

Straight line found from β spectrum when D_2 correction made 50A2, 49W18, 49F12

$\beta\gamma$ coincidences 49H20

Probably no γ 47L3, 47M14, 49H19

Levels 50HLM



Be-d-p	ms	46P3
Be-n-γ		48HL, 48Lau
Be-d-p		48HL, 48Lau
B-n-p		48HL, 48Lau
Li-α-p		48HL, 48Lau

Neutron Cross Sections for Natural Element

	E_n = 0.025ev	
σ_a	718	49P3
σ_t	702	47F13
	708	46B31
	737	47S36
	745	46R8
	Epi-Cd	
σ_s	3.7	44A3
	3.9	46D16
	E_n = 1Mev	
σ_t	~1.7	See graphs

Graphs Available

σ_t	0.01-1000ev	47S36, 47GIF
	0.01-100ev	46R8
See also		49H16
	0.023-14Mev	50Ad, 47GIF
	0.2-3Mev	46B32

References on graphs and in 48WH

$\sigma(n, \alpha)$ 0.3-3.0Mev 47GIF, 50Ad

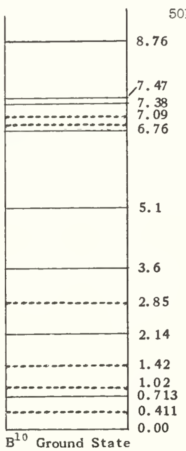
$^{9}_{5}$ 4

$^{10}_{5}$ 5

18.83% 4611

I	3	Mic	48G20
μ	1.801		49Po
		I	49B7
		M	39M5
q	0.06	Mic	49G23

Levels 50HLM



σ's

(th n,p)	<0.2	46B34
(~1Mev n,p)	3mb	47E4
σ_s (Epi-Cd)	2.6	46D16

Graph Available

σ_t 0.2-3Mev 46B32

σ's

Large absorption cross section of natural element attributed to n,α reaction in this isotope 37LB

5 BORON B

11 (5, 6)

81.17% — 46I1

I	3/2	Mic	48G20
μ	2.6886		49Po
		I	49Z2, 49B7, 49A12
		M	39M5
q	0.03	Mic	49G23

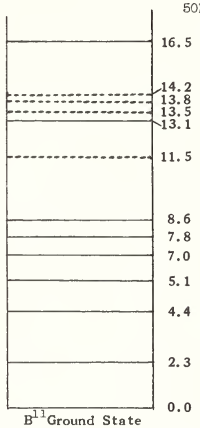
σ's

(th n,γ) $0.027^{s} B^{12}$	< 0.05	46B33
(~1Mev n,α)	0.085mb	46G31
σ_s (Epi-Cd)	4.0	46D16

Graph Available

σ_t	0.2-3Mev	46B32

Levels — 50HLM



12 (5, 7)

τ	0.027^{s}		48J3
	0.022		39B6
β^-	13.43	s	50H1
	13.3	a	48H54
	12	cc	37B1

$\beta\gamma$ coincidences ? — 49H41

β spectrum does not have simple allowed shape — 50H1

Level ~1.5 — 50HLM

B-d-p, N-n-α, C-n-p — 48HL, 48Lau

Neutron Cross Sections for Natural Element

σ_s	coh	5.2		49S12
σ_s	bound	5.2		49S12
σ_a	$E_n = 0.025$ev			
		$\sim$4.5mb		(48WH)
		4.9mb		47A8
σ_t	$E_n > 1$ev			
		4.70		49H18
		4.8		(48WH)
	Graphs Available			
σ_t	0.002-4ev		ce	50Ad, 47GIF
	0.02-300Mev			50Ad
	0.1-6Mev			47GIF
	0.6-1.6Mev			49L20

Fast n graphs in 50Ad and 47GIF based on many others. References on graphs and in 48WH

10 (6 4)

τ	19.1^s		49S25
β^+	2.2	a	49S25
γ	$\sim$1		49S25
B^{10}-p-n	chem		49S25
C-γ-2n ?			48P3

11 (6 5)

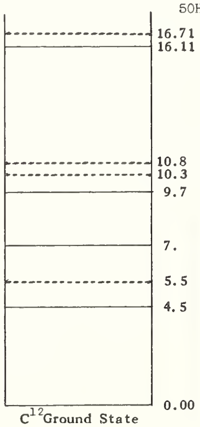
τ	20.35^m		41S11
	20.5		48P3, 41S1
	20.0		44S3
β^+	0.970	s	44S3
	0.981	s	41T1
	0.95	cc	40D6
No $\beta\gamma$ coincidences			46S12
Level	2.0		50HLM
	4.5 ?		
	6.7 ?		
	10.1		
B-p-γ			48HL, 48Lau
B-d-n			48HL, 48Lau
B-p-n			48HL, 48Lau
C-n-2n			48HL, 48Lau
N-p-α			48HL, 48Lau

12 (6 6)

98.892%	limestone	50N1
variations		41M7

I	0	B	48J21

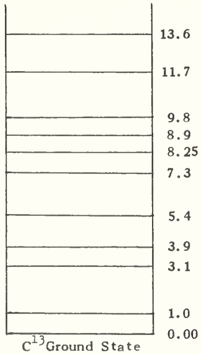
Levels 50HLM



$^{13}_{6}C_{7}$

1.108%	limestone		50N1
variations			41M7
I	1/2	B	48J21
μ	0.7023		49Po
		I	49P8
		M	41H14
σ's			
(th n,γ) 5,720^{y}C		~0.1	45L8
C-n-γ			
E_γ(max) = 4.9			49K32

Levels 50HLM



Also 22 levels found between 12.6 and 16.6 39F5, 48HL

$^{14}_{6}C_{8}$

τ	5,720^y		49E5
	5,589		49J7
	6,400		48H26
	7,200		48Y2
	5,100		48N2
I	0	B	48J21
β^-	0.155	s	49F2, 48B21
	0.154	s	47L8
	0.156	s	48C10
	0.154	a	47S26
	0.158	pc	49A3
No γ			41R5
Level	5.6		50HLM
	6.1		
σ's			
(th n,γ)		< 200	46E8
B-α-p, C-d-p, N-n-p, O-n-α			48HL, 48Lau

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Neutron Cross Sections for Natural Element

σ_s coh	4.6	49S12
σ_s bound	6-10	49S12
	E_n = 0.025ev	
σ_a	1.86	49P3
	1.45	49H2
σ_t	12.7	See graph
	E_n = 10-200ev	
σ_t	9.96	49M40

Graphs Available

σ_t	0.003-2000 ev	49M40
	0.3-3.4Mev	50Ad, 49B50
	0.03-90Mev	50Ad
	0.05-4Mev	47GIF

References on graphs and in 48WH

$^{12}_{7}N_{5}$

τ	12.5×10^{-3} s		49A5
β^+	16.6	a	49A5
C-p-n			49A5

$^{13}_{7}N_{6}$

τ	10.1 m		45S3
	10.2		48C11
	9.93		39W4
β^+	1.24	s	45S3
	1.25	s	48C11
	1.22	s	41T1

No γ of 0.28Mev — 46S12

No γ between 0.135 and 0.700Mev — 47L4

Level	2.4	50HLM
	3.5	

C-p-n, B-d-n, C-d-n, C-p-γ, N-d-t — 48HL, 48Lau

N-γ-n	relσ	48W13
threshold = 10.7		49M17
11.1		45B12

$^{14}_{7}N_{7}$

99.635%	50N1
99.637	31U1
99.620	35W1, 34V1

I	1	B	28O1
		Mic	46D15, 46C10
μ	0.403	M	39K10 (49Po)
q	0.02	Mic	48T11, 49T17

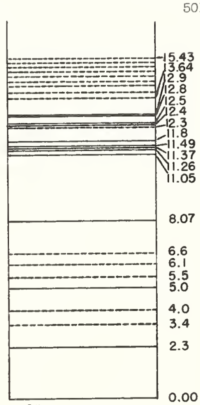
σ's

(th n,p)	1.75	49C10
	1.60	49B32

Graphs Available

σ(n,p)	0.2-1.7Mev	50Ad, 46B35
σ(n,α)	1.3-1.7Mev	47GIF
n,p and n,α resonances		48S34

Levels — 50HLM



N^{14} Ground State

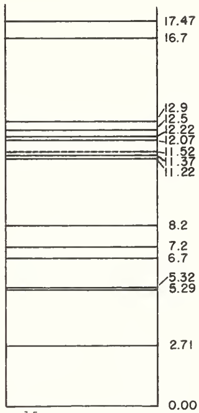
15 (Z = 7, N = 8)

	0.365%		50N1
	0.363		31U1
	0.380		35W1, 34V1
I	1/2	B	39K11, 40W10
μ	±0.280	M	40Z2(49Po)

σ's

(th n,γ) 7.35ˢN	<0.013mb	45H14

Levels 50HLM



N^{15} Ground State

Also 19 levels reported between 14.6 and 17.5 48HL, 48Lau, 50HLM

16 (Z = 7, N = 9)

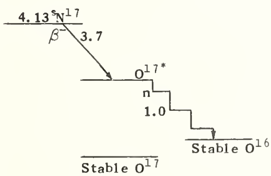
τ		7.35^s		47B3
		7.3		46S5
		7.5		46H17
β^-	~40%	3.8	a$\beta\gamma$	47B3
	~40%	4.3	a$\beta\gamma$	47B3
	~2%	4.6	cc	47B3
	~18%	10.5	a	47B3
		10	cc	46H17
γ		6.2	ac	46B10
		6.2		49M49
		photographic plate		
		6.7	ac	46B10
		7.0		49M49
		photographic plate		

Best estimate of disintegration energy = 10.3 ±0.7 47B3

N-d-p
O-n-p
F-n-α
} 50HLM

17 (Z = 9, N = 10)

τ	4.13^s	48K2
	4.5	49C27



* excited level

Half width of n energy distribution <0.5 49A4

Neutron energy distribution has high energy tail suggesting 0.6Mev wide level or two distinct levels 49H43

C-α-p
O-n-p
F-γ-2p
} 50HLM

β^-	3.7	a	49A4

Most probable neutron energy

0.9	pc	49A4
from O^{16} recoil		
1.0	cc	49H43
from knock-on protons		

βn coincidences 49A4

Neutron Cross Sections for Natural Element

σ_s	coh	4.2	49S12
σ_s	bound	4.15	49S12
	$E_n = 0.025$ev		
σ_a		<0.9mb	See D_2O
σ_s		4.2	37G1
σ_t		4.2	See graph
	$E_n = 15-1000$ev		
σ_t		3.73	49M40
	Resonances		
E_0		0.440Mev	49A8, 50Ad
		1.0	
		1.3	
		4.0	
	Graphs Available		
σ_t	0.003-2000ev		50Ad, 49M40
	0.02-6Mev		47GIF
	0.1-1.4Mev		50Ad
	1.5-300Mev		50Ad
	0.01-0.6Mev		49A8

References on graphs and in 48WH

$^{14}_{8}O_{6}$

τ		76.5^s		49S25
β^+	simple	1.8	a	49S25
γ		2.3	a	49S25
N-p-n		chem		49S25

$^{15}_{8}O_{7}$

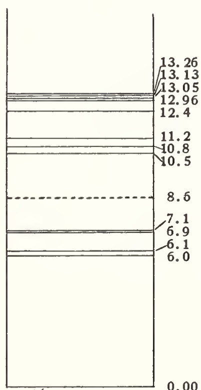
τ	1.97^m		49P12
	2.1		35M1, 39B5, 48P3, 49S25
	2.2		48W13
β^+	1.683	s	49P12
	1.68	a	49S25
	1.7	cc	36F1
Levels ?	4.0		50HLM
	7.9		
C-α-n			50HLM
N-d-n			
N-p-γ			
O-γ-n			
O-n-2n			
F-n-p4n			
O-γ-n	relσ		48P3, 48W13

$^{16}_{8}O_{8}$

99.759%	atmospheric		50N1
99.757			44T1
99.7			49H3

I	0	B	29M1
	σ's		
(~1Mev n,p)		0.014mb	46G31

Levels 50HLM



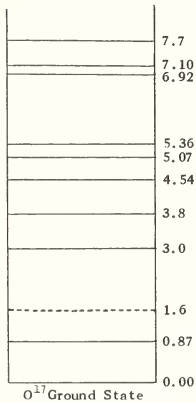
O^{16} Ground State

$^{17}_{8}O_{9}$

0.0374%	atmospheric	50N1
0.039		44T1
0.035		49H3

I	1/2 ?	Mic	49L21

Levels 50HLM



σ's

(th n,α)	0.48	46H27
	<0.4	46E9

$^{18}_{8}O_{10}$

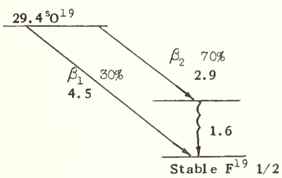
0.2039%	atmospheric	50N1
0.204		44T1
0.195		49H3

σ's

(th n,γ) $29.4^{s}O$	0.22mb	46S24
	0.20mb	45H14

$^{19}_{8}O_{11}$

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 F-n-p			} 50HLM

Neutron Cross Sections for Natural Element

σ_s	coh	~4	49S12
σ_s	bound	~3.5	49S12
		E_n = 0.025ev	
σ_a		⩽0.01	46M20
σ_t		4.0	48R6
		E_n = 0.25–40ev	
σ_t		3.3	48R6
		E_n = 1Mev	
σ_t		3.7	See graphs

Graphs Available

σ_t	0.02-40ev	50Ad, 48R6, 47GIF
See also		49H16
	0.02-3Mev	50Ad, 47GIF

References on graphs and in 48WH

$^{17}_{9}F_{8}$

τ	72.0^s		48P3
	74		38D1
	66		49B27
β^+	2.1	cc	36K2
No γ			48K13
Level ?	3.9		50HLM

N-α-n
O-d-n
O-p-γ
F-γ-2n
F-n-3n
} 50HLM

$^{18}_{9}F_{9}$

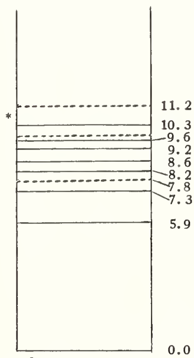
τ	1.87^h	37S1, 48P3, 49B26
	1.92	44H8
	1.78	38D1

β^+	simple	0.64	s	49B26
		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
O-p-n
O-d-n
O-t-n
F-n-2n
F-d-t
F-γ-n
Ne-d-α
Na-γ-αn ?
} 50HLM

F-γ-n relσ 48P3, 48W13

Levels 50HLM



F^{18} Ground State

* 7 levels reported between 10.3 and 11.2 50HLM

19
9 10

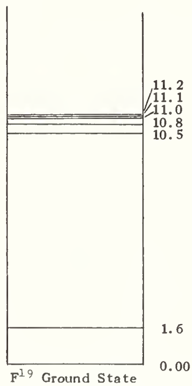
100% 42A2

I	1/2	B	29G1
		S	33C4
μ	2.6283		49P0
		I	49Z2, 49P8, 49S37
		M	41M8

σ's

(th n,γ) 12^sF	0.009	47S33
	0.01	41M6
(~1Mev n,p) 29^sO	0.5mb	46G31
(~1Mev n,α) 7.3^sN	4.5mb	46G31

Levels 50HLM



20
9 11

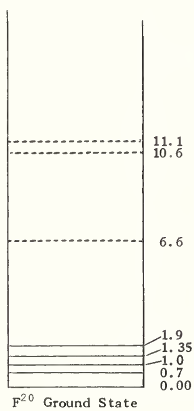
τ 12^s 35C1

β^-	5.1	a	40C11(46B27)
	5.1	cc	39B10
γ	2.2	cc	39B10

5.1Mev β in coincidence with γ, $\gamma\gamma$ coincidences also observed 40C11

F-d-p
F-n-γ
Na-n-α } 50HLM

Levels 50HLM



Neutron Cross Sections for Natural Element

	$E_n = 0.025$ev		
σ_t	2.8		41C5
σ_s	2.3		50H5

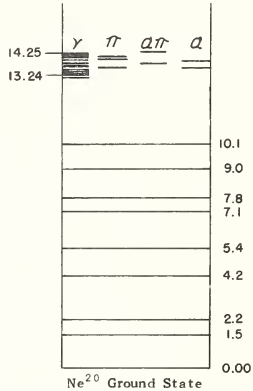
19 (Z = 10, N = 9)

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

20 (Z = 10, N = 10)

89.99%	49H3
90.51	47D9

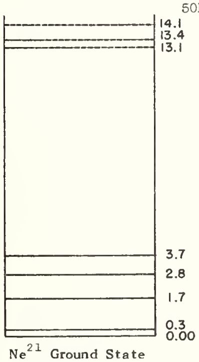
Levels 50HLM



21 (Z = 10, N = 11)

	0.30%		49H3
	0.28		47D9
I	≥3/2	S	49K21
μ	negative	S	49K21

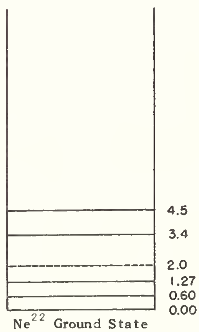
Levels 50HLM



22 (Z = 10, N = 12)

9.72%	49H3
9.21	47D9

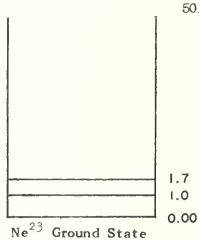
Levels 50HLM



23 (Z = 10, N = 13)

τ	40.7^s		44H4
	40		35A1, 49B27
	43		40P4
β^-	4.3	a	40P4 (46B27)

Levels 50HLM



Ne-d-p
Na-n-p
Mg-n-α } 50HLM

Neutron Cross Sections for Natural Element

σ_s coh	1.5	49S12
σ_s bound	3.5	49S12
	E_n = 0.025ev	
σ_a	0.46	49P3
	0.51	49H2
	0.41	48W19
σ_s	4.0	37G1

Resonances

E_o	
~1700ev	47L18
>1000	48H45

Graphs Available

σ_t	0.02-14Mev	47GIF
	0.02-1Mev	49A8,50Ad
	many resonances	

Other references on graphs and in 48WH

21 / 11 10

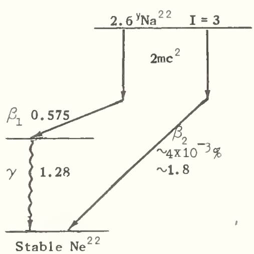
τ	$\sim 20^s$	48B22
	23	40C3

Ne-p-n		40C3
Ne-d-n		40P4
Mg^{24}-p-α		48B22
Ne^{20}-p-γ	f	47B18

22 / 11 11

τ	2.6^y	49L12
	2.8	41S13
	3.0	37L2

I	3	M	49D1
μ	1.7454	M	49D1(49Po)
Levels	?		F-α-n



$\beta\gamma$ coincidences	46G1,44M3,49A7
No K capture	44B8,46G1

β_1^+	0.575	s	46G1
	0.55	s	39O1
	0.53	a	37L2(46B27)
β_2^+ $\sim 4x10^{-3}$%	~1.8	cc	49M34
γ	1.277	s	49A7
	1.30	s	46G1
	1.3	s	39O1

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

889592 O - 50 - 4

23
11 12

100% 36S3

I	3/2	B	33J4
		S	33G3
		M	40M8
		Z	34R1
		P	34L4,34E2,47R7
μ	2.2166		49Po
		I	49B7,49Z2
		M	41M8

σ's

(th n,γ)14.9^{h}Na	0.6	47S33
see also natural element		
(~1Mev n,γ)14.9^{h}Na	0.29mb	49H5
Other fast n values		48WH
(~1Mev n,p)41^{s}Ne	0.7mb	46G31
(~1Mev n,α)12^{s}F	0.4mb	46G31
(~1Mev n,2n)2.6^{y}Na	0.006mb	47H27

Levels 49AH
3 levels between 10.8Mev and (10.8+4.3) Mev from resonances in
F-α-n 34B2
F-α-p 34C5,32C1

Ne-α-p Q = −2.54 37P4(37LB)

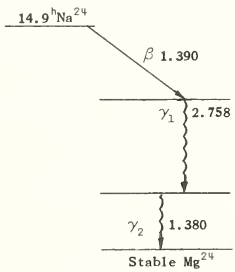
24
11 13

τ	14.90^h	49W19
	14.8	36V1

Levels in Na^{24} 49AH

0.38	Na-d-p
1.26	Na-d-p
3.38	Na-d-p

9 levels between 6.95Mev and (6.95+0.88) Mev from resonances in
Na-n-γ 47L18,49A8



β^-	1.390	s	46S9
	1.4	s	39L6
γ_1	2.758	s	46S9
	2.765	s	49R4
	2.76	s	49R13,43E1
γ_2	1.380	s	46S9,49R4
	1.38	s	43E1

γ's in cascade 46C4,47W2,47B23

No $\beta\gamma$ angular correlation 49G21

$\gamma\gamma$ angular correlation consistent with I = 4,2,0 48B18

Na-d-p	chem	35L1
	Q = 4.76,4.38,3.50,1.38	39M9
Na-n-γ	chem	35A1
	σ	47S33
Al-n-α	chem	35A1
	σ	46G31
Al-d-pα	f	48H56,47C14
	σ	49H47

Mg-γ-p	relσ	47H4
	threshold = 11.5	49M17
Mg-n-p	chem	35A1
	relσ	44R1
Mg-d-α	f,σ	44B8,46C5
	yield	46C9

$^{25}_{11}Na_{14}$			
τ	62.5^s		46B7
	62.0		48P3
	60		44R1
	58		47B4
β^- ~45%	2.7	a	47B4
~55%	3.7	a	47B4
	3.3	a	44R1
	2.8	a	46B7
γ	>0.5	a	47B4
Mg-γ-p	relσ		47H4,49B51
threshold =	14		49M17
Mg-n-p	chem		47B4
Al-γ-2p	relσ		48P3

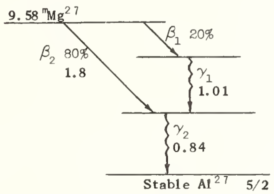
Neutron Cross Sections for Natural Element		23 (12 11)
σ_s coh 2.4 49S12		τ 11.9^s 43H2
σ_s bound 4.2 49S12		11.6 39W2
$E_n = 0.025$ev		β^+ 2.82 cc 39W2
σ_a 0.06 49P3		No γ 39W2
0.07 49H2		
σ_s 3 (48WH)		
σ_t 3 See graphs		
$E_n = 1$Mev		
σ_t $\sim$3 See graphs		
Graphs Available		
σ_t 0.02-400ev 48R6, 47GIF, 50Ad		
0.023-14Mev 47GIF		Na-p-n 39W2, 44D9
0.5-2Mev 49W21		threshold $\sim$4.7 39W2
2-90Mev 50Ad		Mg-γ-n 43H2, 46B7
		threshold = 16.2 49M17
Other references on graphs and in 48WH		relσ 48W13

24 (12 12)	25 (12 13)	26 (12 14)
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-α-p
4.14 Mg-p-p, Na^{24}	0.8 Al-d-α	1.91 Na-α-p, Mg-d-p
5.51 Mg-p-p	1.0 Mg-d-p, Na^{25}	2.85 Na-α-p, Mg-d-p
	1.58 Al-d-α	4.0 Na-α-p
Mg-p-p 49R12, 43D3, 41W12, 48F13	2.54 Al-d-α	5.0 Na-α-p
Mg-n-n 46L8		
25 levels between 11.72Mev and (11.72 +1.85) Mev from resonances in Na-p-γ 41B3, 47T19, 39C8, 36G2		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-α Q = 1.32 48E7	Mg-d-p	Na-α-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-α	Q = -0.4, -2.1, -3.1 36M2(37LB)
	Q = 6.52, 5.71, 4.94, 3.98 49P21	Mg-d-p 41P5

$^{27}_{12}Mg_{15}$

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
$\gamma_3/\gamma_2 < 5\%$				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

Neutron Cross Sections for Natural Element

σ_s	coh	1.5	49S12
σ_s	bound	1.5	49S12
	$E_n = 0.025$ev		
σ_a		0.22	49P3
		0.23	49H2
σ_s		1.35	(48WH)
σ_t		1.6	See graphs
	Resonances		
E_o		2300 ev	49H18
		> 10000	49H18
		9100	47L18
		60	48C24
	$E_n = 1$Mev		
σ_t		~2.5	See graphs

Graphs Available

σ_t	0.025-1000 ev	47GIF, 50Ad
	0.01-1.0Mev	47S35, 50Ad
	0.001-10Mev	47GIF
	0.5-4Mev	47A7

Other references on graphs and in 48WH

25 (Z = 13, N = 12)

τ	7.3^s	48B22
Mg^{25}-p-n		48B22

26 (Z = 13, N = 13)

τ	6.3^s		48B22
	7.2		48W13
	7.0		48P3, 48A8, 39W2, 34F1
β^+	2.8	a	48A8
	2.6	a	38B6 (46B27)
	3.4	a	34F1 (46B27)

Levels 49AH

10 levels between 5.18Mev and (5.18 + 0.8) Mev from resonances in Mg-p-γ 39C8, 47T19

Mg^{26}-p-n		48B22
Al-γ-n		46B7
	threshold = 14.4	47B25
	14.0	49M17
	relσ	48P3, 48W13
Na-α-n		37M1, 34F1
Mg-p-γ		47T19, 39C8

27 (Z = 13, N = 14)

100% 42A2

I	5/2	S	38H6
		M	49L15
μ	3.639		49P0
		I	49Z2, 49B7
		M	39M8
q	0.156	M	49L15

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	46G31
(14Mev n,p) 9.6^{m}Mg	~30 mb	50G2
(~1Mev n,α) 14.9^{h}Na	0.6mb	46G31

See also natural element

Other fast n,γ; n,p; n,α values 49B4, 48WH

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

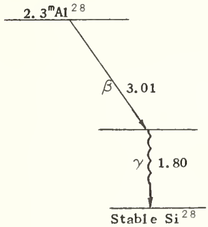
Al-p-p 48H59, 49B30, 48F13, 43D3, 49R12

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)

$^{28}_{13}$ Al $_{15}$

τ	2.30^m	49S40, 43E7, 35A1
	2.4	36E1
	2.6	35M2, 36C1, 37R1



β^-	3.01	s	48B3
	2.75	aβγ	47B4
	3.10	a	47D2
γ	1.80	s	48B3, 41I1
	1.80	ac	47B4

Levels in Al^{28} — 49AH, 49P21

1.03, 1.48, 1.57, 2.16, 2.61, 2.97, 3.41, 3.90, 4.47, 4.72, 4.88, 5.16, 5.44, 5.76 — Al-d-p

Al-n-γ	σ	47S33
Si-n-p		35A1, 47B4
Si-γ-p		46B7
	relσ	47H4, 48P3
Mg-α-p	f, relσ	48S35
Q = -1.05		34D1
P-n-α	chem	35A1
threshold ~3		45T7

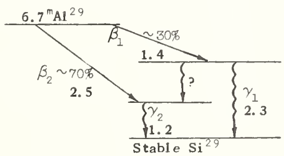
13 levels between 7.63Mev and (7.63 + 2.8) Mev from resonances in Al-n-γ 47A7, 47S35, 47L18

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, 0.64 35M2

$^{29}_{13}$ Al $_{16}$

τ	6.56^m	49S40
	6.7	39B9
	6.8	48P3

Decay scheme proposed by 49S40



β_1^- ~30%	1.4	aβγ	49S40
β_2^- ~70%	2.5	aβγ	49S40
γ_1	2.3	ac	49S40
γ_2	1.2	ac	49S40
βγ coincidences			49S40

See also Si^{29}

Si-γ-p		46B7
	relσ	48P3, 47H4
Si-n-p	σ	46G31
P-γ-2p		46B7
	relσ	48P3, 47H4
Mg-α-p		39B9, 49S40

Neutron Cross Sections for Natural Element

	$E_n = 0.025$ev	
σ_a	0.10	49P3
	0.17	49H2
σ_s	1.7	37G1
σ_t	2.2	48R6
Fast n values		49W21, 48WH

Graphs Available

σ_t 0.01-100ev		48R6, 47GIF, 50Ad
0.5-2Mev		49W21
many resonances		49W21

27 (Z = 14, N = 13)

τ	4.9^s		40C3, 41E3
	4.5		48W13
β^+	3.5	cc	40B1
	3.7	cc	40M1
Mg-α-n			41E3
Al-p-n			40B1
threshold = 6.1			39K2
Si-γ-n		relσ	48W13
threshold = 16.8			49M17
16.9			47B25

28 (Z = 14, N = 14)

	92.19%	49H3
	92.16	48W9
	92.28	46I1
Levels		49AH
	1.8	Al-d-n, Al^{28}
	4.47	Al-d-n, Si-p-p
	4.91, 6.11, 6.65, 7.10, 7.55, 8.18, 9.16	Al-d-n
Si-p-p		48F13

53 levels between 11.69Mev and (11.69 + 2.451) Mev from resonances in Al-p-γ 47B27, 47T19, 40P6

3 levels between 10.40Mev and (10.40 + 5.3) Mev from resonances in Mg-α-p 36E2, 35F1, 34D1

σ's

(~1Mev n,p) 2.3^mAl	3.0mb	46G31

Al-d-n
Q = 9.08, 7.30, 4.61, 4.17, 2.97, 2.43, 1.98, 1.53, 0.90, -0.08 49P13

29 (Z = 14, N = 15)

	4.70%	49H3
	4.71	48W9
	4.67	46I1
Levels		49AH
	1.29, 2.06, 2.43, 3.08, 3.60, 4.09, 4.87	Si-d-p

See also Al^{29}

σ's

(~1Mev n,p) 6.7^mAl	2.7mb	46G31

Si-d-p
Q = 6.21, 4.92, 4.15, 3.78, 3.13, 2.61, 2.12, 1.34 49M54
Q = 6.16, 4.87, 3.75 49A14

S-n-α
Q = 1.16 48S34

30 (Z = 14, N = 16)

	3.12%	49H3
	3.13	48W9
	3.05	46I1
Levels		49AH, 49B30
	2.3, 3.6, 4.8, ~5.5	Si-d-p, Al-α-p
	7.18, 8.20, 9.26, 9.87, 10.86	Al-α-p

σ's

(th n,γ) 2.7^hSi	0.12	47S33
(~1Mev n,γ) 2.7^hSi	1.1mb	46H34

Al-α-p
Q = -1.27, -3.22, -4.96, -5.98, -7.04, -7.65, -8.64 49B30
Q = 2.22, -0.06, -1.44, -2.63 48B25
Q = 2.26, -0.02, -1.32, -2.49 34D1
Q = 2.3, 0.0, -1.1, -2.6 34H1
Q = 2.25, 0.01, -1.15 40M8

Si-d-p
Q = 8.38, 5.98, 4.59, 3.56, 2.72 49M54

31 (Z = 14, N = 17)

τ	2.62^h		38C2
	2.7		49P15
	2.8		40A2, 37N1
β^-	1.5	a	37N1
	1.8	cc	36K2
No γ			37N1
Levels			49AH
	0.59		Si-d-p, P-n-p
	1.29, 1.79, 2.29, 2.89		Si-d-p

Si-d-p chem 37N1
Q = 4.95, 4.36, 3.66, 3.16, 2.66, 2.06 49M54
Q = 4.16 49A14

P-n-p σ 48M37, 45T7
threshold = 1.40 45T7
Q = -0.97, ~-1.7 48M37

Si-n-γ σ 47S33

S-n-α 36S1, 38C2

15 PHOSPHORUS P

Neutron Cross Sections for Natural Element

	$E_n = 0.025$ev	
σ_a	0.15	49P3
σ_s	10.4	37G1
σ_t	4.3	See graphs
	13.6	37G1
	$E_n = 1$Mev	
σ_t	~3	See graphs
Other fast n values		48WH

Graphs Available

σ_t	0.02-300ev	47GIF, 50Ad
	0.03-3Mev	47GIF, 50Ad
$\sigma(n,p)$	1.4-5Mev	45T7, 47GIF

29 (15, 14)

τ	4.6^s		41W2
β^+	3.6	cc	41W2
Si-p-n			41W2
P-γ-2n			46B7
	relσ		48P3
Si-d-n	$Q = -0.80$		48P15

30 (15, 15)

τ	2.18^m		38C2
	2.55		37R1
	2.5		48P3
β^+	3.5	s	41M4
	3.4	a	34F1 (46B27)
	3.0	cc	40B1
Levels			49AH
	1.02		Al-α-n, Si-d-n
	5.64+0.315		Si-p-γ
	5.64+0.400		Si-p-γ
Si-p-γ			47T19
	E_γ(mean) = 5.2		47T19
Al-α-n	yield, σ		49H46
	chem		41M4
	$Q = -2.93, -3.91$		48P15
Si-p-n			40B1
Si-d-n	$Q = +3.38, +2.11$		48P15
P-n-2n			37P2
	threshold = 5-7		38S14
P-γ-n	relσ		48P3
	threshold = 12.3		49M17
	Not produced by		
P-d-t	$\sigma(7.5\text{Mev d,t}) < 5\times10^{-6}$		49K36

31 (15, 16)

	100%	42A2

I	1/2	B	33A1
		S	49C31
μ	1.1309		49Po
		I	49C2, 49B7, 48P9
		S	49C31

σ's

(th n,γ) 14.3^d P	0.2	47S33
(th n,γ)	0.15	49P3
(~3Mev n,p) 2.6^h Si	0.074	48M37

Graphs Available

$\sigma(n,p)$	1.4-5Mev	45T7, 47GIF

Levels		49AH
	0.44	Si-d-n
	1.02	Si-α-p, Si-d-n
	1.74	Si-α-p, Si-d-n
	8.02+0.355	Si-p-γ
	8.02+0.483	Si-p-γ
Si-p-γ		47T19

7 levels between 10.26Mev and (10.26+6.8) Mev from resonances in

Al-α-n	36W1, 35F5, 37S8
Al-α-p	32C1, 34D1

Si-d-p	$Q = 4.56, 4.12, 3.57, 2.78$	48P15
Si-α-p	$Q = -2.23, -3.28, -3.92$	34H1 (37LB)

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$^{32}_{15}P_{17}$

			Ref.	Notes	Ref.
τ	14.30^{d}				38C1
	14.35				48K28
	14.07				40M7
β^-	**1.712**	s	46S9	Average disintegration energy found to be 0.685 calorimetrically	47C16
	1.715	s	47P17		
	1.69	s	49L6		
	1.72	s	39L6		
	1.75	s	41W7		
No γ			36K2	$<5\times10^{-5}$ 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
P-n-γ	σ		47S33		
P-d-p	chem		37N1		
	yield		40C9		
	Q = +5.9		40P5		
S-n-p	chem		35A1		
	f		48K28,47B26		
	Q = −0.93		41H10		
Cl-n-α			35A1		
	Q = +0.44,σ		47M31		
Si-α-p			39K1		

$^{33}_{15}P_{18}$

$^{34}_{15}P_{19}$

				Ref.
τ		12.4^{s}		46B1
		12.7		40C12
β^-	25%	**3.2**	a	46B1
	75%	**5.1**	a	46B1
S-n-p		chem		46B1,40C12
Cl-n-α		chem		46B1,45H2

16 SULPHUR S

Neutron Cross Sections for Natural Element

σ_s coh	1.2		49S12
σ_s bound	1		49S12
	$E_n = 0.025$ev		
σ_a	0.47		49P3
	0.52		49H2
σ_s	1.1		37G1
σ_t	1.6		See graphs
Values at other energies			49H16

Resonances

E_o	σ_o	Γ	
108kev	21.5	18	49A13
205			49A13

Many resonances between 0.5 and 2Mev — 49W21

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

31 (Z 16, N 15)

τ	3.18^s		41E3
	3.2		41W2
	2.9		41H15, 48W13
β^+	3.87	cc	41E3
	3.85	cc	41W2

P-p-n		41W2
Si-α-n		41E3
S-γ-n		41H15
	relσ	48W13
	threshold = 14.8	49M17
	15.0	47B25

32 (Z 16, N 16)

	95.06%		38N2
I	0	B	36O1

Levels — 49AH

2.25	S-p-p
4.34	S-p-p

S-p-p — 43D3

5 levels between 10.0Mev and (10.0 + 0.92) Mev from resonances in P-p-γ — 47T19, 39C8

σ's

(2.9Mev n, α)	2.9	41H10
(~1Mev n,p) 14.3^dP	~0.012	46G31
Other fast n values		48WH

Graphs Available

σ(n,p)	2-3.7Mev	47B26, 50Ad
	1.6-5.8Mev	48K28

33 (Z 16, N 17)

	0.74%		38N2
I	3/2	Mic	48T13
μ	0.6-0.9	Mic	49J9
q	-0.08	Mic	49T17

Levels — 49AH

0.79	4.15
1.90	4.42
2.17	4.70
2.85	5.11
3.15	5.63
3.88	6.30

all from S-d-p

2 levels from S-n-α — 48S34

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 = 6.62, 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

34 (Z 16, N 18)

	4.18%		38N2
I	0 ?		47T18

Levels — 49AH

0.82	S-d-p
1.9	P^{34}
3.4	Cl^{34}
?	P-α-p

σ's

(th n,γ) 87^dS	0.26	47S33

S-d-p	Q = 8.67, 7.85	49D28
P-α-p	Q = 0.31, -1.0, -2.5, -4.5	36M2 (37LB), 36P1 (37LB)

35 (Z 16, N 19)

τ	87.1^d		43H6
	88		40L8, 41K3
I	3/2	Mic	49C12
q	+0.06	Mic	49C12 (49T17)
β^-	0.166	s	48A3
	0.167	s	49P20
	0.169	s	48B1
	0.167	a	47S26

Fermi plot straight above 16kev — 48A3

Discussions of spectral shape — 48C10, 48B1, 48A3, 49C32

Cl^{35}-n-p	chem	42K9
Cl-n-p	chem, yield	41K3
	σ	49M27, 47S33
	Q = +0.52	44G4
Cl-d-α	chem, yield	41K3
S-n-γ	σ	47S33
S-d-p	chem	39C7

36 (16, 20)				37 (16, 21)				
	0.0136%		49L21	τ		5.04^{m}		46B1
	0.016		38N2			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
	σ's							
(th n,γ)5.0^{m}S		0.14	46H35					
				Cl-n-p		chem		46B1
				S-n-γ				46H25
				A-n-α		Q = −1.8 ?,σ		46G32

17 CHLORINE Cl

Neutron Cross Sections for Natural Element

σ_s coh	12.2		49S12
σ_s bound	15		49S12
	$E_n = 0.025$ev		
σ_a	32.7		49P3
	32.1		49H2
σ_t	55		See graph
	Resonance		
E_o	1800 ev		47L18
Assigned to Cl^{37}			47L18
	$E_n \sim 3$Mev		
σ_t	3.4		39Z1
Other fast n values			48WH
	Graphs Available		
σ_t	0.023-70 ev		47GIF
See also			49H16

33 (Z = 17, N = 16)

τ	2.8^s		48S20, 40H7
	2.4		41W2
β^+	4.1	cc	41W2
S-d-n			48S20, 40H7
S-p-n			41W2

34 (Z = 17, N = 17)

τ	33.2^m		48W13
	33.0		48P3
	33		38B6, 36S1
β^+ 20%	2.4	cc	46H1
80%	5.1	cc	46H1
	3.0	a	38B6(46B27)
	3.4	a	34F1(46B27)
γ	3.4	cc	46H1
P-α-n	chem		38B6, 34F1
	yield		37R1
S-d-n	chem		46H1, 36S1
Cl-γ-n	relσ		48P3, 48W13
Cl-n-2n	chem		37P2
S-α	chem		40S7
S-t-n			50K14

35 (Z = 17, N = 18)

	75.4%		36N4
I	3/2	Mic	47T16
μ	0.8210		49P0
		I	49C2, 49B7
		M	40S12
q	-0.0795	M	49D14
		Mic	49T17, 48G22
Levels			49AH
0.6			S-α-p
1.5			S-α-p
	σ's		
(th n,p)87.1^dS	0.34		49M27
	0.17		47S33
(th n,p)	0.34		44G4
(th n,γ)	$\sim$32		See element
($\sim$3Mev n,α) 14.3^dP	17mb		47M31
Other fast n values			48WH
S-α-p	Q = -2.1, -2.7, -3.6		35H7(37LB)
			36B7(37LB)

36 (Z = 17, N = 18)

τ	4.4×10^{5y}	From specific disintegration rate	49W15
	3.6×10^5	From specific disintegration rate	49R11
	2.0×10^5	From n,γ yield	49R11
	10^6	From n,γ yield	4703

I	2	Mic	49T10
q	-0.0172	Mic	49T10
Levels			49AH
	0.96		Cl^{35}-d-p
	4.81		Cl^{35}-d-p
Cl^{35}-d-p	Q = 6.31, 5.35, 1.50		41S14
	chem		41G2

β^-	0.713	s	49W16
	0.73	a	49R11, 49W15
	0.66	a	4703
	0.64	a	41G2
γ weak	0.10	a	49J8
	0.57	a	49J8
bremsstrahlung or annihilation?			49J8
No γ unless of energy < 20kev or of low intensity			49W15
$\beta^+/\beta^- < 10^{-4}$			49W15
$0.57\gamma/\beta^- < 3\times10^{-4}$			49J8
β spectrum has forbidden shape consistent with $\Delta I = 3$, no			49W16
Cl-n-γ	chem		41G2
	σ		47S33, 49M27
E_γ(max) = 9.8			49K15

37 (17, 20)

	24.6%		36N4
I	3/2	Mic	47T16
μ	0.683		49P0
		M	39K7
q	-0.0621	M	49D14
		Mic	49T17, 48G22
Level	2.6		S^{37}

σ's

(th n,γ) 38.5^mCl	0.6	47S33
	0.4	4104
(~1Mev n,γ) 38.5^mCl	0.8mb	49H5

38 (17, 21)

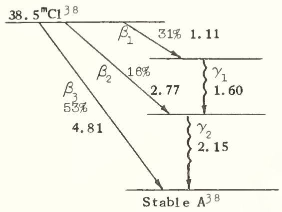
See below

39 (17, 22)

τ	55.5^m		49H30
	1^h		48M3, 48H27
β^-	2.5	a	49H30
A-γ-p	chem		49H30

38 (17, 21)

τ	38.5^m	46H2
	37.5	37H1, 40C4
	37.0	45S2, 36V1



β_1^-	31%	1.11	s	50L2
	36%	1.19	s	46H2
		1.1	s	39W5
β_2^-	16%	2.77	s	50L2
	11%	2.70	s	46H2
		2.6	a$\beta\gamma$	41W3
β_3^-	53%	4.81	s	50L2
		forbidden shape		50L2
	53%	~5.2	s	46H2
		5.0	s	39W5
		4.99	a$\beta\gamma$	41W3
γ_1	43%*	1.60	s	46H2, 40C4
		1.6	s	41I1
γ_2	57%*	2.15	s	46H2
	57%*	2.5	s	40C4
γ		1.19	s	41I1

* % of γ's

Levels 49AH

1.00	Cl^{37}-d-p
1.92	Cl^{37}-d-p
6.21 ± 0.0018	Cl-n-γ

Cl^{37}-n-γ	chem	40K3
Cl^{37}-d-p	Q = 4.02, 3.02, 2.10	41S14
Cl-d-p	chem	46H2
	yield	46C9
Cl-n-γ		47L18
	σ	47S33, 4104
K-n-α	chem	37H1

Cross-over γ, if any, in $< 3\times10^{-4}$ disintegrations 49M8

$\beta\gamma$ and $\gamma\gamma$ coincidences 41I1

Summary of early work 46H2

Neutron Cross Sections for Natural Element

	$E_n = 0.025$ ev	
σ_a	0.6	43W6
σ_s	0.75	50H5
σ_t	1.4	See graph

Resonances

E_o	> 1000 ev	50H5, 49M40

Graphs Available

σ_t	0.01-200 ev	48M34, 50Ad
	15-10,000 ev	49M40, 50Ad

35 (Z = 18, N = 17)

τ	1.84^s		48S20
	1.88		41E3
	2.2		41W2
β^+	4.4	cc	41E1, 41W2

S-α-n	chem	41E3, 48S20
Cl-p-n		41W2

36 (Z = 18, N = 18)

0.337%	50N1
0.35	47D9

37 (Z = 18, N = 19)

τ	34.1^d	44W2

K capture	44W2
L capture	49P22
L capture / K capture ~0.08	49P22
No γ	44W2
Cl K_α X-ray	44W2

Levels 49D29

Levels	
1.53	A^{36}-d-p
1.67	A^{36}-d-p
2.27	A^{36}-d-p
2.56	A^{36}-d-p
3.46	A^{36}-d-p
5.01	A^{36}-d-p

Cl-p-n	chem, yield	44W2
Cl-d-2n	chem, yield	44W2
K-d-α	chem, yield	44W2
S-α-n	chem, yield	44W2
Ca-n-α	chem, yield	44W2

Not produced by

K-n	44W2
Cl-α	44W2

A^{36}-d-p
Q = 6.59, 5.06, 4.92, 4.32, 4.03, 3.13, 1.58 — 49D29
Possibly others — 49D29

Cl-p-n
Q = −1.596 — 48R10

38 (Z = 18, N = 20)

0.063%	50N1
0.08	47D9

Levels 49AH

2.15	Cl-α-p, Cl^{38}, K^{38}
3.75	Cl-α-p, Cl^{38}

7 levels between 10.44 Mev and (10.44 + 0.97) Mev from resonances in Cl-p-γ — 47T19, 39C8

Cl-α-p	Q = 0.1, −2.5, −4.2	36P1

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

39 (18 21)	40 (18 22)	
τ long 49H30	99.600% 50N1	
	99.57 47D9	
	Relative abundance of A^{40} higher in potassium minerals than in the atmosphere due to decay of K^{40} 48A5	
4^m activity sometimes assigned here not found from		
A-γ-n 49H30		
K-n-p 37H1	Levels 49AH	
	1.5 K^{40}, A-p-p	
	2.4 A-p-p	
	A-p-p 47H30	
	σ's	
	(th n,γ) 0.6 43W3	
	(pile n,γ) 1.78^hA 1.2 43K6	
	(~1Mev n,γ) 1.78^hA 0.93mb 49H28	
d 55^mCl ? 49H30		

41 (18 23)		
τ	1.78^h 49B57	
	1.82 46B11,36S2	
	β⁻ simple 1.25 s 49B57	
	1.18 a 46B11	
	1.1 a 36S2	
	0.7% 2.55 a 46B11	
Levels 49D29		
0.66, 1.21, 1.34, 1.94, 2.27, 2.80, 3.29, 3.69, 4.01 } A-d-p	γ 1.3 ac 46B11	
	1.3 cc 36S2	
	1.4 cc 36R1	
	α~0 49B57	
	γ in coincidence with 1.18β 46B11	
	A-d-p chem, f 36S2	
A-d-p	A-n-γ 36S2	
Q = 3.84, 3.18, 2.63, 2.50, 1.90,	σ 43K6	
1.57, 1.04, 0.55, 0.15, −0.17	K-n-p 46B11,37H1	
49D29		

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

Neutron Cross Sections for Natural Element		
σ_s coh 1.5 49S12 σ_s bound ~2 49S12 E_n = 0.025ev 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)	39 (19 20)
τ 1.3^s 48L7 K-γ-2n ? 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(46B27) γ ~2.1 a coin 47R3 Cl-α-n chem 37H1, 47R3 chem, yield 37R1 Ca-d-α chem 37H1 K-n-2n 37P2 K-γ-n relσ 48W13, 48P3 threshold = 13.2 49M17	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} ~3 49H48

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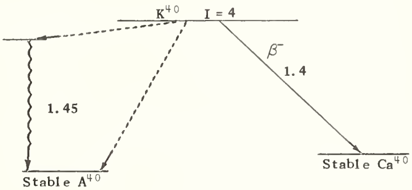
$^{40}_{19}$K$_{21}$

	0.0119%	50N1
	0.010	49H32
Summary of early work on K abundances		48W9
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
μ	-1.29	M	49D1
Levels in K^{40}			49AH
	0.81	K^{39}-d-p	
	2.01		
	2.56		
	3.3		
	3.7		
	4.2		
	4.8		

K^{40} produced by

K^{39}-d-p Q = 5.48, 4.67, 3.47, 2.92, 2.2, 1.8, 1.3, 0.7		50S3
A-p-n	f	48R11
K-n-γ	chem, σ	49H48
E_γ(max) = 7.2		49K15

β^-	1.40	s	49A15
	1.36	scin	50B8
	1.35	s	46D1
	1.41	a	48H58, 46H7
	1.45	a	49F19
	1.3	a	47H8
	1.7	cc	48F1
β spectrum has third forbidden shape			50B8
No $\beta\gamma$ coincidences			47M7
γ	1.45	scin	50B9
	1.47	scin	50P4
	1.54	a coin	46H7, 48H58
	1.55	a	47G7
	1.5	s	49C33
	1.5	a	47M7
γ's/sec(gram of K) = 3.6			47G7, 49S31
E_γ /sec(gram of K) = 4.9Mev			48A4
γ/β^- = 0.05			49F19
0.087			48H58
0.127			48G8
β^+/γ < 0.025			50B9
Argon K X-ray			47B7
X-ray			43T1

K capture/β^-	1.9	†	47B7, 48G8
	~3	††	48A4
	~3.5	†	43T1
	<0.1	†††	48S15
	~0.02	†††	48A5

† From measurement of ratio of X-rays to β's

†† From measurement of ratio (radiogenic Ca^{40})/K^{40} = 11 for lepidolite 2.1×10^9 years old. This ratio determines τ (K-capture) if τ_β is known. Assuming τ_β = 16.0×10^{8} y
τ (K-capture) = 5.1×10^8
(total) = 3.9×10^8

††† From measurement of Argon content in minerals

* Enriched material used

** Natural K used. τ_β calculated assuming relative abundance of K^{40} = 0.0119%

*** Assumed abundance not stated

$^{41}_{19}$K$_{22}$

	6.91%		50N1
	6.75		49H32
K^{39}/K^{41}	abundance = 13.6		48W9
I	3/2	Z	36M3
		M	40K9
μ	0.2148		49P0
		M	40K9
Levels	1.3		A^{41}

5 levels between 7.80Mev and (7.80 + 1.2) Mev from resonances in A^{40}-p-γ 48B26

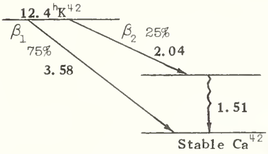
σ's

(th n,γ) 12.4^{h}K	1.0	47S33
(~1Mev n,γ) 12.4^{h}K	2.9mb	49H5

$^{42}_{19}$K$_{23}$

τ	12.44^h	47S8
	12.5	37H1

Decay scheme 47S8



Levels in K^{42} 0.62, 1.18, 1.97, 2.29 } K^{41}-d-p

K^{41}-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 ΔI = 2, yes 47S8 (49S41)

β_2^-	18-25%	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 K^{42} 47S8

No $\gamma\gamma$ coincidences 47S37

$^{43}_{19}$K$_{23}$

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

Neutron Cross Sections for Natural Element	?	39 20 19
σ_s coh 2.9 49S12 $E_n = 0.025$ev σ_a 0.41 49P3 0.43 49H2 σ_t 4.4 40R9 σ_t ($CaCO_3$) 5.5 ce per molecule See graph $E_n \sim 2.5$Mev σ_t 3.9 39A5 Graphs Available σ_t($CaCO_3$) 0.06-10,000 ev 48H46 σ_t 0.02-0.6Mev 49A8, 50Ad several resonances	τ 4.5^m 37P2, 40W2 Ca-fast n 37P2, 40W2	τ 1.06^s 43H2 Ca-γ-n relσ 48W13 threshold = 15.9 49M17 16 47B25

40 20 20	41 20 21	42 20 22
96.92% 48W9 96.96 38N2	τ ? 8.5^d activity formerly assigned here not found 47M12, 4705 Levels 49AH 1.95, 2.41, 2.96, 3.23, 3.49, 3.67, 3.86 } Ca-d-p 6 levels between 8.28Mev and (8.28 + 0.5) Mev from resonances in Ca-n-γ 49A8 K-p-n Q = −1.22 48R10 Ca-d-p Q = 6.09, 4.14, 3.68, 3.13, 2.86, 2.60, 2.42, 2.23 49S44, 49S43	0.64% 48W9, 38N2 Levels 49AH 1.5 K^{42}, K-α-p 2.6 K-α-p K-α-p Q = −0.89, −2.3, −3.5 36P1 (37LB)

43 (Z = 20, N = 23)

	0.13%	48W9
	0.14	38N2
Levels	~0.4	K^{43}
	1.0	Sc^{43}
A-α-n	f	38P7
	Q = -4.0, -5.6 ?	

44 (Z = 20, N = 24)

	2.13%		48W9
	2.06		38N2
Levels	1.33		Sc^{44}
		σ's	
(th n,γ) 152^dCa		0.6	47S33

45 (Z = 20, N = 25)

τ	152^d		47M12
	180		40W2
β^-	0.254	s	50M3
	0.248	s	47P10
	0.260	a	48S2
	0.[illegible]2	a	49M32
No harder β			48S2
No γ			49M32, 48S2, 47P10
Sc-n-p			48S2
	chem		40W2
Ca-d-p	chem		40W2
Ca-n-γ			40W2
	σ		47S33
Ti-n-α	chem		48H47

46 (Z = 20, N = 26)

	0.0032%	48W9
	0.0033	38N2

47 ?

τ	5.8^d	47M12
β^-	1.1	47M12
γ	1.3	47M12
Production methods not stated		47M12

48 (Z = 20, N = 28)

	0.179%	48W9
	0.19	38N2

$^{49}_{20}$ 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	

Neutron Cross Sections for Natural Element		
$E_n = 0.025$ ev σ_a 12 49P3 31 49H2 See activation σ of Sc^{45}		

41 21 20	42 21 21	43 21 22
τ 0.87^s 41E3 β^+ 4.94 cc 41E3 Ca-d-n 41E3		τ 3.92^h 45H3 4.0 40W1 β^+ 0.4 a 40W1 1.1 s, a 45H3 1.4 a 40W1 γ 1.05 s 46P1 1.0 a 40W1 1.65 a 45H3 $\beta^+/\gamma \sim 4$ 45H3 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

44 (21 23)

τ_1	2.44^d		45H3
	2.2		48W13, 40W1, 42S1
IT			42S1, 40W1
γ	0.269	sc	42S1
	$\alpha = 0.07$, K/L = 8		42S1
	$\alpha = 0.5$		41H1
	0.28	ac	45H3
Sc-n-2n	chem		45H3
Sc-γ-n	relσ		48W13
K-α-n	chem		45H3, 40W1
Ca-d-n	chem		45H3
	threshold = 4		42S1
	p 3.9^hSc		42S1, 40W1

τ_2	3.96^h		48W13
	3.92		45H3
	4.1		42S1
K			45H3
β^+	1.45	s	42S1
	Fermi plot not straight. Spectrum complex?		
	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-γ-n	relσ		48W13
K-α-n	chem		45H3, 40W1
Ca-d-n	chem		45H3
Ca-p-n	chem		45H3
	d 2.4^dSc		42S1, 40W1

45 (21 24)

	100%		42A2
I	7/2	S	34S1, 34K1
μ	4.8	S	37K2

σ's

(pile n, γ) 20^sSc	10	48G16
(th n, γ) 85^dSc	>13	46B25
	22	47S33

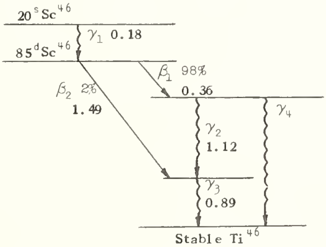
See also natural element

Activation σ falls off faster than 1/v for both 20^s and 85^dSc 48G16

46 (21 25)

τ_1	20^s	48G16
τ_2	85^d	49F3, 37W4

Additional level of Sc^{46} at 2.30Mev. See Sc-d-p below.



$\gamma\gamma$ angular correlation consistent with I = 4, 2, 0 48B18

$20^s Sc^{46}$ produced by

Sc-n-γ		48G16

$85^d Sc^{46}$ produced by

Sc-n-γ	σ	46B25, 47S33
Ti-n-p	σ_{eff}	48H47
Ca-α-p	chem	40W1
Sc-d-p	chem	37W4
	Q = 4.48, 6.78	39D7
Ti-d-α		37W3

β_1^-	98%	0.36	s	48P2
		0.358	s	47F2
		0.36	s	47M9
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
		1.116	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
γ_4		$1.63 < E_\gamma < 2.3$ in 1.2×10^{-5}% of disintegrations		49F5

$\gamma\gamma$ coincidences 48M9, 48J7

No K capture 47M9

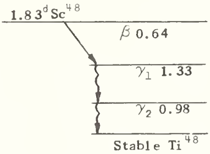
$\beta\gamma$ coincidences only for 0.36 β^- 48M9, 48J7

47 (21, 26)

τ	3.43^d		49K12
	3.4		45H4
β^-	0.61	a	49K12
γ			49K12
Level	1.3		Ca^{47}
Ti^{49}-d-α	chem		49K12
Ca-α-p	chem		45H4
Ti-d-α	chem		44H3
Ti-n-p	σ_{eff}		48H47

48 (21, 27)

τ	1.83^d	49K12, 45H4



β^-	0.64	s	42S1
	0.57	a	49K12, 45H4
γ_1	1.33	s	46P1
	1.35	s	43M3
	1.34	a	45H4
γ_2	0.98	s	46P1

Probably softer γ's — 46P1
K X-ray — 45H4
γ/e^- ~14 — 45H4
See also Ti^{48}

V-n-α	chem	45H4
Ca-p-n	chem	45H4
Ti-n-p	chem	45H4
Ca-d-2n	chem	45H4
Ti-d-α		44H3

49 (21, 28)

τ	57^m		47S33, 40W1
	1^h		49D18
β^-	2.4	a	49D18
	1.8	a	37W6
No γ			40W1
Ca-d-n	chem		37W6, 40W1
Ti-n-p	chem		37P2, 40W1
Ti-γ-p	relσ		49H4
	d 8.5^mCa		49D11

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22 TITANIUM Ti

Neutron Cross Sections for Natural Element

σ_s coh	1.8	(-)	49S12
σ_s bound	~6		49S12
	$E_n = 0.025$ev		
σ_a	5.8		49P3
	5.9		49H2
$\sigma_s(TiO_2)$	14		37G1
$\sigma_t(TiO_2)$	28		46D13

Values at other energies 46D13, 49H16

	$E_n = 2.5$Mev	
σ_t	1.7	39A5

Graphs Available

σ_t	0.1-1.4Mev	50Ad

43
22 21

τ	0.58^s	48S20
Ca-α-n		48S20

44
22 22

τ	$<1^m$ or $>100^y$ from Sc-d	49B55

45
22 23

τ		3.08^h		41A2
		3.1		48W13
β^+		1.2	cc	41A2
	(19)*	1.00	s	49K36
γ	(4)*	0.48	s	49K36
	(1)*	0.80	s	49K36

3.1^d activity reported from Sc-p-n (given as 21^d due to typographical error) probably attributable to 80^hZr from Y impurity. 49D3

* relative intensities

Ca-α-n	chem	41A2
Sc-p-n	chem	41A2
Sc-d-2n	chem	41A2
Ti-n-2n		41A2
Ti-γ-n	relσ	48W13

46
22 24

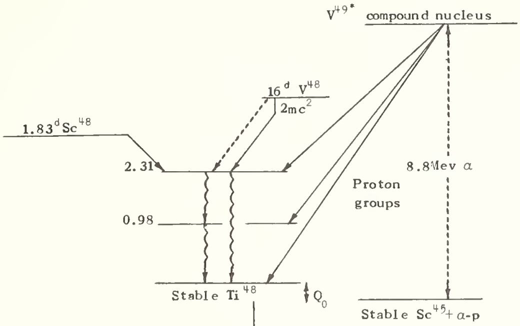
	7.95%	38N2
	8.22	49H38
Levels	0.89	Sc^{46}
	2.01	

47
22 25

7.75%	38N2
7.42	49H38

48 (Z = 22, N = 26)

	73.45%	38N2
	73.38	49H38



Sc-α-p

$Q_0 = -0.3$
$Q_1 = -1.4$
$Q_2 = -2.6$ } 38P6

49 (Z = 22, N = 27)

	5.51%	38N2
	5.56	49H38

50 (Z = 22, N = 28)

	5.34%	38N2
	5.41	49H38

	σ's	
(th n, γ) 6^mTi	0.14	47S33

51 (Z = 22, N = 29)

τ	6^m		47S33, 49S13
β^-	1.6	a	47S33, 49S13
γ			37W3

Ti-n-γ	σ	47S33
Ti-d-p		37W3

72^d activity previously assigned here not found by Ti-n-γ 49D11

Neutron Cross Sections for Natural Element

σ_s coh	<0.1	49S12
σ_s bound	5	49S12
	$E_n = 0.025$ev	
σ_a	4.7	49P3
	5.6	49H2
σ_s	<4	37G1
σ_t (V_2O_5)	40	46D13
	Resonance	
E_o		
3370 ev		47L18

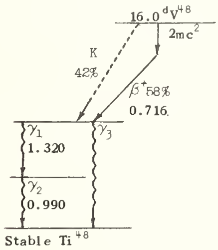
47 (23, 24)

τ	33^m		37W3, 4201
β^+	1.65	a	49K12
	1.8	a	4201
	2.0	a	37W3(46B27)
γ			49K12
Ti^{47}-p-n			49K12
Ti-d-n	chem		37W3
Ti-p-n	chem		4201

Not produced by Ti-α, Sc-α, V-n-2n 49K12

48 (23, 25)

τ	16.0^d		37W3
K	42%		46G1
β^+	58%		46G1
	0.716	s	46P1
	1.0	cc, a	37W3
γ_1	1.320	s	49R4
	1.33	s	46P1
γ_2	0.990	s	49R4
	0.98	s	46P1
	1.0	cc	38R2
γ_3	$1.63<E_\gamma<2.3$ in 1% of disintegrations		49F5



See also Ti^{48}

$\gamma/\beta^+ = 2$		46P1
$\gamma/\beta^+ = 4$		38R2
Sc-α-n	chem	37W3
Ti-d-n	chem	37W3, 44H3
Ti-p-n		44D9
Cr-d-α	chem	37W3, 46P1

49 (23, 26)

τ	500^d	39W1
K		39W1
No β^+		39W1
No γ, no e^-		39W1
Ti-d-n	chem	39W1

50
23 27

0.25%	49H33
0.23	49L13

No vanadium X or γ activity of $\sim 4^h$ found from Ti-d, Ti-α, V-fast n or Ti-p. Activity of this period previously reported by 37W3 and 40A3 possibly due to Sc^{44}. 49K12

51
23 28

	~100%		24A1
I	7/2	S	36K4
μ	5.15	I	49K24
Levels	0.267		Cr^{51}
	0.320		Cr^{51}
	1.1	Ti-α-p	38D7
	4.7	Ti-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) 26^dCr	10mb	48S29

Ti-α-p 38D7
Q = 1.10, 0.00, -3.63 38D7

52
23 29

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 Mn^{52}

$\gamma/\beta = 0.65$ 47B20
$= 0.36$ 47M17

$\beta\gamma/\beta$ 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		39D7, 37W3
	Q = 7.80, 5.33, 3.10	39D7
Cr-n-p		37W3, 37P2
Cr-γ-p	relσ	47H4
Mn-n-α		37W3, 37P2

Neutron Cross Sections for Natural Element

	$E_n = 0.025$ ev	
σ_a	2.8	49P3
	3.1	49H2
σ_s	~3.6	37G1
σ_t	7.3	47GIF
Values at other energies		49H16

Resonances

E_o	
115-300 ev	49H16
4,200	49H18

	$E_n \sim 2.5$ Mev	
σ_t	3.4	39A5
Other fast n values		48WH

Graphs Available

σ_t	0.01-1000 ev	47GIF, 50Ad

49 (Z = 24, N = 25)

τ	41.9^m		4201
	45		48W13
	40		49H29
β^+	1.45	a, cc	4201
γ	0.19	a	4201
	1.55	a	4201
γ's ~ equal intensity			4201
Ti-α-n	chem		4201
Cr-n-2n	chem		4201
Cr-γ-n	rel σ		49P5, 48W13

50 (Z = 24, N = 26)

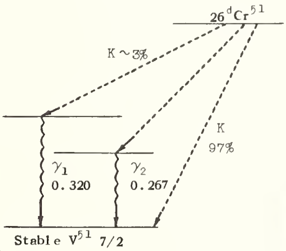
4.41%	49H3
4.31	48W9
4.49	39N2

σ's

(th n,γ) 26.5^d Cr	11	47S33
(th n,γ)	16.3	49P4

51 (Z = 24, N = 27)

τ	26.5^d	40W3
	26	48H4
	25	49H29



K			45B1
No β^+			45B1, 48K10
γ_1	0.320	s	48K10, 46M6
	0.323	sc	49K14
~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

52 (Z = 24, N = 28)

83.46%	49H3
83.76	48W9
83.78	39N2

Levels	1.46	Mn^{52}, V^{52}
	2.40	Mn^{52}
	3.13	Mn^{52}

See Mn^{52} for diagram

σ's

(th n,γ)	0.73	49P4

$^{53}_{24}$ 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
				Level	0.835	Mn^{54}				
	σ's				σ's					
(th n,γ)	17.5	49P4		(th n,γ)	$\leqslant$0.3	49P4				
				(th n,γ) 1.3^hCr	0.006	47S33				
								Cr-n-γ	chem	40D2
									σ	47S33
								Cr-d-p	chem	40A3

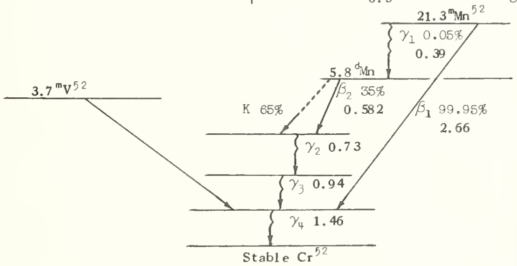
Neutron Cross Sections for Natural Element			
σ_s coh	1.3	(-)	49S12
σ_s bound	2.2		49S12
	$E_n = 0.025$ev		
σ_a	12.8		49P3
	12.5		49H2
σ_s	2.3		(48WH)
σ_t	15.5		(48WH)
Values at other energies			49H16
	Resonances		
E_o	σ_o	Γ	
300 ev	~5,000	~10	49S1
Scattering resonance			49S1
	E_n ~2.5Mev		
σ_t	~3		39A5
Other fast n values			48WH
	Graph Available		
σ_t	0.015-5,000 ev		47R6, 47GIF

51
25 26

τ	46^m		38L1
	45		48M12
β^+	2.4	a	38L1(46B27)
Cr-d-n	chem		38L1
Cr-p-γ	chem		39D1
Cu-d	chem		48M12

52
25 27

τ_1	21.3^m	40H1
	21	38L1
τ_2	5.8^d	48M20
	6.2	49H29
	6.5	38L1



Order of γ_2, γ_3 not established 46P1

21.3^mMn				
β_1^+	99.95%	2.66	s	4701
γ_1	0.05%	0.39	sc	4701

5.8^dMn				
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

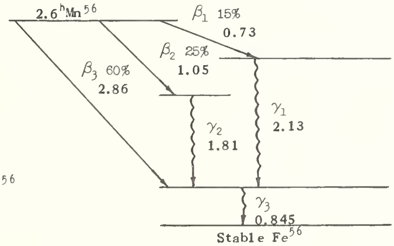
21.3^mMn produced by		
Cr-d-2n	chem	46P1
Cr-p-n	chem, rel σ	40H1
threshold ~6.3		40H1
Fe-d-α	chem	38L1
d 7.8^hFe		48M12

5.8^dMn produced by		
Cr-d-2n	chem	46P1
Cr-p-n	yield	46C9
threshold = 8		46C9
Cr-p-n	chem, rel σ	40H1
threshold ~6.3		40H1
Fe-d-α	chem	38L1

53 (25, 28)	54 (25, 29)				55 (25, 30)			
	τ	310^d		38L1		100%		36S4
	K			38A2	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	44D1				
		0.85	a	38L1				
	Not identical with 0.845γ of Mn^{56}			43E4				
	Cr K_α (?) X-ray			38A2				
	Xγ coincidences			44D1	σ's			
					(th n,γ) 2.6^hMn		13.0	44D10
					(~1Mev n,γ) 2.6^hMn		3.5mb	49H5
					Other fast n values			48WH, 49B4
	V-α-n			38L1				
	Cr-d-n	chem		38L1	(1.2Mev p,n) 4^y Fe		0.5mb	48S29
	Cr-p-n			44D9				
	Fe-d-α	chem		38L1				
	Mn-γ-n			49H17				
	threshold = 10.2			49H17				

56
25 31

τ	2.59^h	38L1
	2.62	48P3



See also Co^{56}

γ~2.7Mev in ~0.23% of disintegrations — 47L23

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

Mn-n-γ	σ	44D10
Mn-d-p	chem	38L1
Fe-d-α	chem	38L1
Fe-γ-p	rel σ	48P3
Fe-n-p	chem	38L1
Co-n-α	chem	38L1
Cr-α-p	chem	37R1
Mn-n-γ		49K15
E_γ(max) = 8.9		49K15

β_1^-	15%	0.73	s	43E4
	20%	0.75	s	46S2
β_2^-	25%	1.05	s	43E4
	30%	1.04	s	46S2
β_3^-	60%	2.86	s	43E4
	50%	2.81	s	46S2
γ_1		2.13	s	43E4
		2.06	s	46S2
	12.5%*	2.11		42K8
γ_2		1.81	s	43E4
		1.77	s	46S2
	18.75%*	1.83		42K8
γ_3		0.845	s	43E4
		0.822	s	46S2
	68.75%*	0.866		42K8
Not identical with 0.835γ of Mn^{54}				43E4

* relative %

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Neutron Cross Sections for Natural Element

σ_s coh	10.3	49S12
σ_s bound	11.4	49S12
	$E_n = 0.025$ev	
σ_a	2.39	49P3
	2.46	49H2
σ_s	11	(48WH)
σ_t	13	(48WH)
	$E_n = 1$Mev	
σ_t	~2.5	See graphs
	Graphs Available	
σ_t	0.013-1,000 ev	48H46
	0.013-2,000 ev	50Ad, 49H18
	0.025-15Mev	47GIF
	0.02-0.5Mev	48B24
	0.02-1.4Mev	50Ad
	1-40Mev	50Ad

51 (26 25)

52 (26 26)

τ	7.8^h	48M12
β^+	~0.55 a	48M12
Cu-d	chem, rel σ	48M12
	p 21^mMn	48M12

53 (26 27)

τ	8.9^m	44H5, 38L6
β^+		49P5
Fe-γ-n	rel σ	49P5, 48W13
threshold	= 13.8	49M17
	14.2	45B12
Cr-α-n	chem	38L6
Fe-n-2n	chem	38L6

54 (26 28)

5.90%	49H3
5.81	48W9

55 (26 29)

τ	2.91^y	49B35
	~4	48V8
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	Co^{55}
	1.41	
Mn-p-n	chem	46B5
	σ, Q = -1.16	48S29
Mn-d-2n		48H35
Fe-d-p	chem	39L8
	d 18.2^hCo	41L1

56 (Z = 26, N = 30)

	91.52%	49H3
	91.64	48W9
Levels	0.845	Mn^{56}, Co^{56}
	2.66	Mn^{56}
	2.98	Mn^{56}
	Others ?	Co^{56}

57 (Z = 26, N = 31)

	2.245%		49H3
	2.21		48W9
μ	$\sim$0	S	49B20, 49G6
Levels	0.014		Co^{57}
	0.131		

Fe-n-γ 49K15

E_γ (max) = 7.8

58 (Z = 26, N = 32)

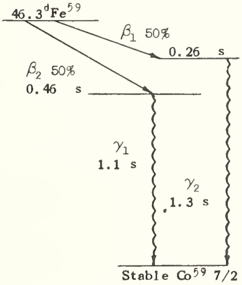
	0.33%	49H3
	0.34	48W9
Level	0.81	Co^{58}

	σ's	
(th n, γ) 47^d Fe	0.36	47S33
	0.83	4804
(th n, α)	$\leqslant$1.5mb	44H6

59 (Z = 26, N = 33)

τ	46.3^d	47S22
	45.5	43G3
	46	49H29

Probable decay scheme 42D1



Fe-n-γ	σ	47S33
Co-n-p	chem	38L6, 46I2
Co-d-2p		48T4
Fe-d-p	chem	38L6, 42D1
Cu-d	chem	48M12

60 (Z = 26, N = 34)

Neutron Cross Sections for Natural Element

σ_s coh	1.76		49S12
σ_s bound	~5		49S12
	$E_n = 0.025$ev		
σ_a	34		49P3
	36		49H2
σ_s	~5		37G1
σ_t	~41	Extrapolation	49B2

Resonances

E_o	σ_o	Γ	
108	12,500	2	49S1
115			47W8
Scattering resonance			47H23, 49S1, 49H16

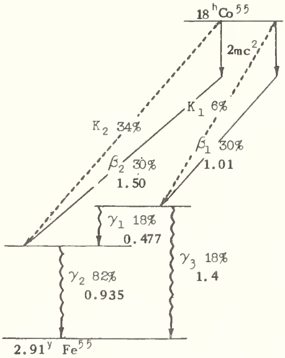
	$E_n = 2.5$Mev	
σ_t	2.6	39A5

Graphs Available

σ_t	0.03-0.7ev	49B2
	0.15-10,000ev	47W8, 47GIF, 50Ad

55 (Z = 27, N = 28)

τ	18.2^h	37D1
	18.0	41L1



K_1	6%			49D2
K_2	34%			49D2
β_1^+	30%	1.01	s	49D2
β_2^+	30%	1.50	s	49D2
		1.50		39L6
γ_1	18%	0.477	s	49D2
		α~0.0025		49D2
γ_2	82%	0.935	s	49D2
		α~0.0004		49D2
	strong	0.8	cc	39C6
γ_3	18%	1.41	s	49D2
		α~0.0001		49D2
	weaker	1.2	cc	39C6
γ_4	weak	0.095	sc	49D2
Probably not in Co^{55}				49H34

$\beta\gamma$ coincidences support decay scheme. 49D2

Fe-d-n	chem	49D2
Fe-p-γ		41L1
	p 2.91^yFe	41L1

56 (Z = 27, N = 29)

τ	80^d		42C1
	72		41L1
β^+	1.50	s	43E2

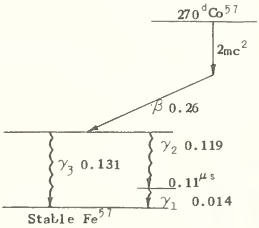
γ			
1.0*	0.845	s	43E2
0.5	1.26	s	43E2
0.2	1.74	s	43E2
0.1	2.01	s	43E2
0.2	2.55	s	43E2
0.2	3.25	s	43E2

* Relative intensities

Fe-d-2n	41L1
threshold > 5.5	41L1
Fe-α-np	41L1
Ni-d-α	42C1

57 (Z = 27, N = 30)

τ	270^d	41L1



β^+	0.26		41L1
γ_1	0.014		49H34
	$0.11^{\mu s}$ delay		49H34
	$\alpha < \infty$		49H34
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}

Fe-d-n	chem	41L1
Fe-p-γ		41L1

58 (Z = 27, N = 31)

τ_1	9.3^h	49S29	τ_2		72^d	41L1
IT		49S29	K	85.5%		46G1
γ	0.023	49S29	β^+	14.5%		46G1
					0.47	44D1
			γ		0.81	44D1
			Mn-α-n			41L1
			Fe-d-n			41L1
			Fe-α-pn			41L1
			Fe-p-γ			41L1
			Ni-n-p		chem	44D1

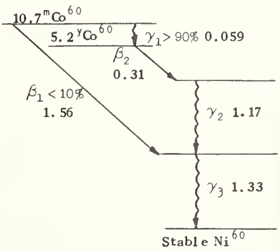
59 (Z = 27, N = 32)

	100%		41M5
I	7/2	S	35K5, 34M2
μ	2.7	S	35M7
Levels	1.1		Fe^{59}
	1.3		

σ's		
(th n,γ) 10.7^mCo	0.66	47S33
(th n,γ) 5.3^yCo	22	47S33
(1Mev n,γ) 10.7^mCo	0.23mb	49H5

60 (Z = 27, N = 33)

τ_1	10.7^m	41L1



Angular correlation of γ's consistent with I = 4, 2, 0 — 48B18

$10.7^m Co^{60}$ produced by

Co-n-γ	σ	47S33
Co-d-p	chem	45D1
Ni-n-p		41L1, 37H3

τ_2		5.2^y		49B35
		5.3		41L1
$10.7^m Co^{60}$				
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
$5.2^y Co^{60}$				
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	$<2\times10^{-6}$	49M8
	$<2\times10^{-7}$	49F5
γ with 1.63<E<2.3 per 10^5 disintegrations		49F5
Lifetime of γ's	$<2\times10^{-9}$ s	49D22
	$<3\times10^{-9}$	49B39
No βγ angular correlation		49G21

$5.2^y Co^{60}$ 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

61 (Z = 27, N = 34)

τ	1.75^h		49P1
	1.74		48P3
	1.83		49H20
β^-	1.3	a	49P1
No γ			49P1
Ni-d-2n	ms		49P1
Ni^{61}-n-p	chem		49P1
Ni^{64}-p-α	chem		49P1
Ni^{64}-d-αn	chem		49P1
Cu-n-nα	chem		49P1
Ni-γ-p	relσ		48P3
Cu-γ-2p	relσ		48P3

62 (Z = 27, N = 35)

τ_1	13.9^m		49P1
β^-	2.3	a	49P1
γ	1.3	a	49P1
$\beta/\gamma \sim 1$			49P1
Ni^{62}-n-p	chem		49P1

τ_2	1.6^m	49P1
β^-		49P1
γ		49P1
Ni^{62}-n-p		49P1
Ni^{64}-d-α		49P1

63 (Z = 27, N = 36)

64 (Z = 27, N = 37)

τ	$4\text{-}5^m$	49P1
Ni^{64}-n-p		49P1

28 NICKEL Ni

Neutron Cross Sections for Natural Element

σ_s coh	13.5		49S12
σ_s bound	17.2		49S12
	$E_n = 0.025$ev		
σ_a	4.5		49P3,49H2
σ_s	17.5		47T14
σ_t	~18.5	ce	48H46
	Resonance		
E_0 3600ev			49H18
	E_n = 1Mev		
σ_t	~3.5		47GIF,50Ad
	Graphs Available		
σ_t	0.01-1000ev		48H46
	0.01-3000ev		50Ad
		See also	49H16
	0.01-10Mev		47GIF
	0.01-0.5Mev		48B24
	0.01-1.5Mev		50Ad

See also Ni^{58} and Ni^{60}

$^{57}_{28}Ni_{29}$

τ	36^h		49M38,38L3
	37		44H5
	34		48H4
β^+	0.73	a	49M38
	0.67	a	38L3
γ	1.97	a coin	49M38
	1.9	a, scin, γn	50F2

$\gamma\gamma$ coincidences indicate 2 γ's in cascade. 49M38

$\beta\gamma$ coincidences indicate only one β. 49M38

Coincidences between hard γ and annihilation γ 50F2

Co K X-ray 50F2

Fe-α-n	chem	50F2,49M38,42N2
Ni-n-2n	chem	42N2
Ni-γ-n	relσ	49P5,48P3,44H5
threshold = 11.7		49O2

$^{58}_{28}Ni_{30}$

67.76%	48W9
67.92	48I6
69.18	48E6

σ's

(th n,γ)	4.2	49P4
σ_t graph 0.025-0.5ev		49B2
Big σ_s due to this isotope		
σ_s coh	26	49S12
σ_s bound	25	49S12

$^{59}_{28}Ni_{31}$

τ	$(2\text{-}3)\times10^5$ y	49F6
	1.5×10^5	49B38

Both results from yield measurements

K		49F6,48B13
No β^-		48B13
Co K X-ray		49F6
Ni^{58}-n-γ	chem	49F6
Co-d-2n	chem	48B13
Ni-n-γ		48B13

$^{60}_{28}Ni_{32}$

26.16%	48W9
26.22	48I6
25.82	48E6

Levels	1.33	Co^{60}
	1.5	Cu^{60}
	2.50	Co^{60}

σ's

(th n,γ)	2.7	49P4
σ_t graph 0.025-0.5ev		49B2
σ_s coh	1.0	49S12
σ_s bound	1.0	49S12

$^{61}_{28}Ni_{33}$

1.25%	48W9
1.16	48I6
0.97	48E6

σ's

(th n,γ)	1.8	49P4
(6.1Mev p,n)3.4^hCu	0.11	38S5

62 (Z 28, N 34)

	3.66%		48W9
	3.71		48I6
	3.28		48E6
Levels	0.6		Cu^{62}
	1.3		Co^{62}
σ's			
(th n,γ)		14.8	49P4
(6.1Mev p,n)10^mCu		0.15	38S5

63 (Z 28, N 35)

τ	85^y From yield		49B38
β^-	0.063	pc	49W10
	~0.05	a	49F6
	0.05	a	48B13
No β^+			49W10
No γ observed (<1%)			49F6,49W10
Ni^{62}-n-γ	chem		49F6,48B13
Ni-n-γ	chem		49W10,48F4

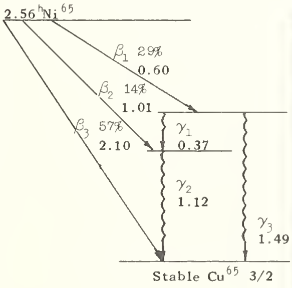
64 (Z 28, N 36)

	1.16%		48W9
	0.98		48I6
	0.75		48E6
Level	1.34		Cu^{64}
σ's			
(th n,γ)2.6^hNi		2.6	46H32
		1.5	47S33
(~1Mev n,γ)2.6^hNi		6.7mb	49H5

65 (Z 28, N 37)

τ	2.564^h		49S2
	2.6		49M38,48H4,38L3

Proposed decay scheme 49S21



β_1	29%	0.60	s	49S21
		0.44	aβγ	49M38
β_2	14%	1.01	s	49S21
β_3	57%	2.10	s	49S21
		1.97	a	49M38
		1.9	a	46S8,38L3
γ_1		0.37	s	49S21
γ_2		1.12	s	49S21
γ_3		1.49	s	49S21
		1.64	a	49M38
γ's		0.280, 0.65, 0.93	s	41G1

βγ, γγ coincidences support decay scheme › 49M38,49S21

Cu^{65}-n-p	chem	46S8
Ni^{64}-n-γ		46C3,46G15
Ni-n-γ	chem	42N2
Zn-n-α		37H3
Ni-d-p		42N2

66 (Z 28, N 38)

τ	56^h	48H4,48G1
β^-		48G1
Bi fission		48G1
As-d		48H4
p 4.34^mCu		49G13,48G1

Neutron Cross Sections for Natural Element

σ_s coh	7.3		49S12
σ_s bound	7.7		49S12
	$E_n = 0.025$ev		
σ_a	3.66		49P3
	3.63		49H2
σ_s	7		(48WH)
σ_t	~11	ce	48H46

Resonance

E_o	
3,000 ev ?	48H46
570	47L18
Scattering resonance 500-1000 ev,	48H57
140 (12^hCu), 100 (5^mCu)	48C24

Graphs Available

σ_t	0.015-10,000 ev	50Ad,
		48H46
	0.015-100 ev	47GIF
	See also	49H16
	0.025-14Mev	47GIF
	0.2-1.5Mev	50Ad

58 ? (Z = 29, N = 29)

τ	3^s	49A1
Ni^{58}-p		49A1

59 ? (Z = 29, N = 30)

τ	10^m	47L7
	7.9	39D1
β^+		39D1
Ni-p-n	chem	39D1
Ni^{58}-p	chem	47L7
Ni-d		42C2

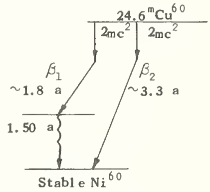
59 ? (Z = 29, N = 30)

τ	81^s	47L7, 39D1
β^+		39D1
Ni-p-n	chem	39D1
Ni^{58}-p		47L7

60 (Z = 29, N = 31)

τ	24.6^m	47L7
	~20	48H4

Possible decay scheme 47L7



Ni^{60}-p-n	ms, chem	47L7
threshold = 5.1		47L7
Ni^{60}-d-2n		47L7
Ni^{58}-α-pn		47L7

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61 (29, 32)

τ	3.33^h		48C8
	3.3		48H4
	3.4		49B16, 37T1, 37R1
K			49B16, 38A2
β^+	1.205	s	48C8
	1.225	s	45B2
K/β^+ = 0.32			49H21
0.55			49B16
No γ			45B2, 38G1
Spectral shape			49O4
β spectrum probably complex			50B4
Ni^{61}-p-n			47L7
Ni-p-n	σ		38S5
threshold > 3			38S5
threshold = 2.7			39D1
Ni-d-n	chem		37T1
Ni-α-p	chem		37R1
Cu-γ-2n	rel σ		48P3
Ni-p-γ	chem		39D1

62 (29, 33)

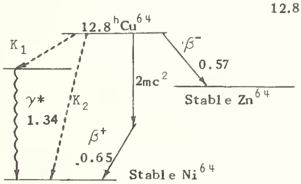
τ	9.9^m		49P15, 48P3
	10.1		47L7
	10.5		37H3
β^+	2.83	s	49B17
	2.92	s	49H42
	2.92	a	50K1
γ	0.56	a	47T8
Ni^{62}-p-n			47L7
Cu-γ-n	rel σ		48P3
threshold = 10.9			45B12, 49M17
Ni-p-n	σ, f		38S5
Ni-p-γ	threshold < 3		38S5
Co-α-n	chem		37R1
Cu-n-2n	chem		37H3
threshold ~ 12			40S10, 38S14
threshold = 11.2, σ			49F14
Cu-e^--e^-n	f		48S3
Cu-d-t	Q = 5.2		46M7
d 9.5^hZn			48M12

63 (29, 34)

	69.09%		48H40
	68.94		48W9
	68.39		44E1(48H40)
	67.66		47D13(48H40)
I	3/2		32R2
μ	2.2215		49Po
		I	49B7, 49Z2, 48P11
q	-0.1	S	36S7
Levels	0.96		Zn^{63}
	1.89		
	2.60		
σ's			
(th n, γ) 12.8^hCu	2.8		47S33
(th n, γ)	4.3		49P4
(1Mev n, γ) 12.8^hCu	0.009		49H5
(14Mev n, 2n) 10^mCu	0.48		49F14
	0.32		49P15
For other fast n values see			48WH, 49B4
(6.1Mev p, n) 38^mZn	0.093		38S5
(14Mev d, 2n) 38^mZn	0.30		46C5

64 (29, 35)

τ	12.88^h		49S2
	12.8		48W13, 36V2



* Coincidence measurements show this line follows K capture 46B3

Ni-p-n	chem, σ		39D1, 38S5
threshold = 2.1-2.3			39D1
	2.5		38S5
Zn-n-p	chem		37H3
Cu-d-p			36V2
Cu-n-2n			37H3
Cu-n-γ	E_γ(max) = 7.7		49K15
Cu-p-pn	threshold ~ 13		46R2
Cu-γ-n			44H5
threshold = 10.2			49M17
	rel σ		48W13, 49P5

K			38A2
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
	$\alpha < 5x10^{-3}$		48M26
	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
Ni K_α, K_β X-rays		49C4

65 (Z = 29, N = 36)

	30.91%		48H40
	31.06		48W9
	32.34		47D13(48H40)
	31.61		44E1(48H40)
I	3/2		32R2
μ	2.3796		49Po
		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
(1Mev n,γ)4.3^{m}Cu	0.006		49H5
For other fast n values see			49B4, 48WH
(14Mev d,2n)250^{d}Zn	0.51		46C5

66 (Z = 29, N = 37)

τ	4.34^m		49S2
	5.05		46M7
β^-	2.58		40G3
	2.9	cc, KU	38S1
γ	1.32	a	46M7
Cu-n-γ	σ		47S33
Cu-d-p			46M7
Zn-n-p			37H3
Ga-n-α			37C1
	d 56^{h}Ni		49G13, 48G1

67 (Z = 29, N = 38)

τ	56^h		49G13
	61		48H4
β^-	0.5	a	49G13
Bi fission			49G13
As-d			48H4

30 ZINC Zn

Neutron Cross Sections for Natural Element

σ_s	coh	4.3	49S12
σ_s	bound	4.2	49S12
		$E_n = 0.025$ev	
σ_a		1.0	49P3
		1.1	49H2
σ_s		3.6	(48WH)
σ_t		4.5	(48WH)

Resonances

E_o	>300ev	49H16
	480 strong	48H45
	800 possible	48H45
	3100	48H45
	14000	48H45

480ev resonance assigned to $Zn^{68}(n,\gamma)52^mZn^{69}$ $\Gamma \sim 4$ 48C24

Scattering resonances observed 48H57

	E_n = 1Mev	
σ_t	~4	See graphs

Graphs Available

σ_t	0.001-2000ev	50Ad, 47GIF
	0.02-11Mev	47GIF
	0.02-1.5Mev	50Ad
	1-80Mev	50Ad

Other references on graphs and in 48WH

62 (Z = 30, N = 32)

τ		9.5^h		48M12
		9.2		49H42
		10		49H14
K	90%			49H42
β^+	10%	0.665	s	49H42
γ		0.0418	s	49H42

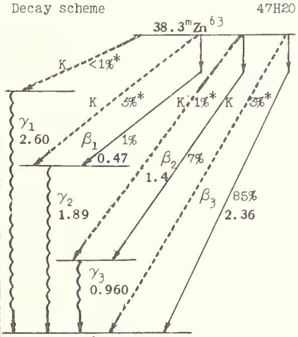
Cu-d-3n or		
Cu-d-5n	chem	48M12
Zn-γ-2n	relσ	49H44

p 9.9^mCu 48M12

63 (Z = 30, N = 33)

τ	38.3^m	48W13, 38S5
	38	39B5, 39D1
	39	49H14

Decay scheme 47H20



* % calculated from Fermi theory for allowed transitions. K capture observed in 5-10% of disintegrations 47H20

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
γ_3		0.960	sc	47H20
		$\alpha \sim 1.8 \times 10^{-4}$		47H20
Cu K X-ray				47H20

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

Zn-n-2n	chem	37H3, 37P2
threshold	9-10	38S14
Cu-p-n	f	39D1, 38S5
threshold	= 4.1	38S5
	3.6	39D1
Ni-α-n		37R1
Zn-γ-n	relσ	49H44, 49P5, 48W13
threshold	= 11.8	49H17
	11.6	45B12
Cu-d-2n	f	46C5
threshold	= 6.5	46C9
	~7	40L4
	rel yield	48M12

64 (Z = 30, N = 34)

48.87%		49H3
48.89		48L5, 48H40

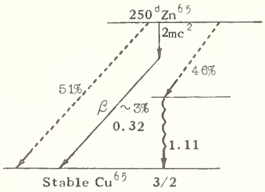
Possible levels or level groups from n groups in Cu-d-n 49G5

σ's

(th n,γ) 250^{d}Zn	0.51	47S33
(th n,p) 12.8^{h}Cu	$< 10^{-5}$	49M27

65 (Z = 30, N = 35)

τ	250^d	39L2
	long	49H14



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, 38P1
	f		46C5
	yield		46C9
	threshold = 4.6		46C9

β^+	2.8%			47Z2
	2.2			46G2
		0.32	s	47P10
γ	46%	1.11	s	49J2
		1.14	s	42D3, 43M4

Cu X-ray 38A2

Xγ coincidences show 46% of K captures go to 1.11 level 46G2

γ's of 0.45, 0.65, and 1.0 cc 40W4

66 (Z = 30, N = 36)

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 Cu^{66}

σ's

(~4Mev n,p) 4.3^{m}Cu	3.7mb	40D8

67 (Z = 30, N = 37)

	4.12%		49H3
	4.07		48L5
	4.14		48H40
I	5/2	S	37L7, 48A6
μ	0.9	S	37L7
Levels	0.093		Ga^{67}
	0.390		
	0.570		

68 (Z = 30, N = 38)

18.71%		49H3
18.61		48L5
18.54		48H40

σ's

(th n,γ) 13.8^{h}Zn	0.89	49H5
(th n,γ) 52^{m}Zn	0.085	49H5
(~1Mev n,γ) 13.8^{h}Zn	0.007	49H5
(~1Mev n,γ) 52^{m}Zn	0.013	49H5

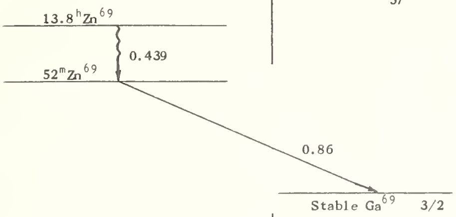
E_0 (n,γ) 52^{m}Zn = 500ev 48C24

Γ = 1.7–5.5ev 48C24

69 (Z = 30, N = 39)

τ_1	13.8^h	39L2
	14	48H4

τ_2	52^m	49H17
	51	48H4
	57	39L2



γ	0.439	sc	41H1, 41G1
	$\alpha \sim 0.01$-0.1		41H1
	0.450		44N7
	$\alpha = 0.06$		44N7

No $\beta\gamma$ coincidences 39K4

β^-	0.86	a	39L2(46B27)
	1.0	a	39K4

Zn-d-p	chem	39K4
Zn-n-γ	chem	39L2
	σ	49H5
Ga-d-α	chem	39L2
Ga-n-p	chem	39L2

Zn-d-p	chem	39K4
Zn-n-γ	chem	39L2
	σ	49H5
Ga-d-α	chem	39L2
Ga-n-p	chem	39L2
Zn^{70}-γ-n		49H17
threshold = 9.2		49H17

70 (Z = 30, N = 40)

0.69%	49H3
0.620	48L5
0.617	48H40

σ's

(th n,γ) 2.2^mZn	0.085	49H5
	0.086	46H25

71 (Z = 30, N = 41)

τ	2.2^m	46H25
β^-	2.1	46H25
γ		46H25
Zn-n-γ	σ	46H25
Ge-n-α		46H25

72 (Z = 30, N = 42)

τ	49^h		50s1
	~ 50		48H4
β^- 95%	0.3	a	50s1
5%	1.6	a	50s1
γ			50s1
Fission	chem		50s1

p 14.25^hGa 50s1

73 (Z = 30, N = 43)

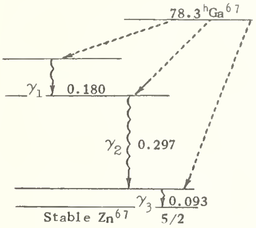
τ	$< 2^m$	50s1

Neutron Cross Sections for Natural Element		63 31 32
$E_n = 0.025$ev σ_a 2.8 49P3 3.1 49H2 σ_t ~19 42L1 Resonances Scattering resonance in both isotopes in range 100-500ev 48H57		

64 31 33	65 31 34	66 31 35
τ 48^m 38B4 β^+ 38B4 Zn-p-n chem, f 38B4 threshold = 4.1 38B4	τ 18.5^m 39V2 γ 0.054 sc 39V2 0.117 sc 39V2 Assignment of 0.117γ to this activity doubtful 39V2 Zn-d-n chem 39V2 Zn-p-γ 39V2	τ 9.4^h 38B4, 37R1 9.2 37M2 10 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-2n 42C2 d 2.5^{h}Ge 49H29

67
31 36

τ	78.3^h		48M32
	83		48H4, 38A2



γ_1 weakest	0.180	s	41H1
	0.187	s	42C2
γ_2	0.297	s	41H1
	α=0.01		41H1
	0.302	s	42C2
	0.292	s	41G1
γ_3 strong	0.093	s	41H1
	α=2, K/L=8		41H1
	0.094	s	42C2

Additional γ of 0.174 found 42C2

Zn X-ray		38A2
Zn-d-n	chem	38G2, 39V2
Zn-α-p	chem	38M1, 48M32
Zn-p-n		39V2
Zn-d-2n		42C2
d 21^mGe		49H29

68
31 37

τ	68^m		37R1, 48P3, 48H4
β^+	1.9	a	37R1
	1.97	a	37M2

Cu-α-n	chem, f	37R1, 37M2
Zn-p-n	chem, f	38B4
threshold = 3.7		38B4
Zn-d-n	chem	38G2, 39V2
Ga-n-2n	chem	37P2
threshold = 6-7		38S14
Ga-γ-n		39B5
	rel yield	48P3
Ge-γ-pn	rel yield	49P5
Ge-d-α	chem	41S2
d 250^dGe		48H4

69
31 38

	60.2%		48I3
	60.0		49H3
I	3/2	S	32J1, 33C2
		M	48B17
		Z	40R6
μ	2.012		48P9, 48B17 (49P0)
	2.11	Z	40R6
q	+0.2318		48B17 (49D14)
	0.20		40R3
Level	1.22		Ge^{69}

σ's

(th n,γ) 20^mGa	1.4	47S33
	1.5	49H5
(~1Mev n,γ) 20^mGa	23mb	49H5

70
31 39

τ	20.3^m		47B13
	20		35A1, 39B5, 49H14
β^-	1.65	s	48H23
	1.62	a	47B13
	1.68	cc	39S9
γ			48H23

Zn-p-n	chem, f	40D1, 39V2
threshold = 1.6		40D1
Zn-α-p	chem, rel yield	38M1
Ga-n-γ	σ	47S33
Ga-n-2n		37P2
Ga-γ-n		39B5
	rel yield	48P3
Ge-n-p	chem	41S2, 45G2

71
31 40

	39.8%		48I3
	40.0		49H3
I	3/2	S	32J1, 33C2
		M	48B17
		Z	40R6
μ	2.556		48P9, 48B17 (49P0)
	2.69	Z	40R6
q	+0.1461		48B17 (49D14)
	0.13		40R3

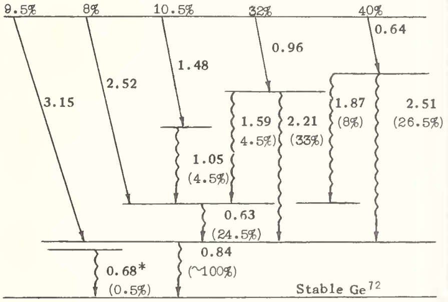
σ's

(th n,γ) 14^hGa	3.4	47S33

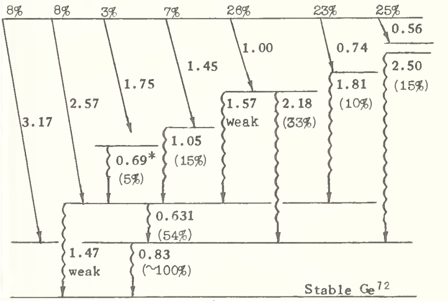
$^{72}_{31}Ga_{41}$

τ	14.25^h	50s1
	14.1	39G2

Decay scheme proposed from spectrometer results 48H23



Decay scheme proposed from spectrometer results 48M17



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	50s1,48SP
d 49^hZn		50s1

Delayed βe^- coincidences for ~0.6 e^- and a β of ~1% intensity	48B10
$\tau = 0.5^{\mu s}$ No delayed γ's	48B10
$\tau = 0.29^{\mu s}$	49M29

βγ coincidences	48J7
βγ and γγ coincidences	47M29
Average γ energy per β = 2.6	47B22
Only 2.51Mev γ produces D-γ-pn	49B25
*Only line converted	48M1,48H23

$^{73}_{31}Ga_{42}$

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^mZn ?		46PP

$^{74}_{31}Ga_{42}$

No long-lived activity produced by Ge^{76}-d-α 48M32

No Ga with τ > 1^d found in fission 50s1

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Neutron Cross Sections for Natural Element

σ_s coh	8.5		49S12
σ_s bound	8.5		49S12
	$E_n = 0.025$ev		
σ_a	2.2		49P3
	3.5		49H2
σ_t	~6	ce	47W8
	Resonance		
E_o	$\sigma_o \Gamma^2$		
95ev	800		47W8
	Graphs Available		
σ_t	0.015-5000ev		47GIF, 47W8

66 (Z 32, N 34)

τ	~2.5^h	49H29
Ge-d-p5n		49H29
p 9.4^h Ga		49H29

67 (Z 32, N 35)

τ	21^m	49H29
β^+		49H29
Ge-d-p4n		49H29
p 78.3^h Ga		49H29

68 (Z 32, N 36)

τ	250^d	49H29
	~195	38M1
K		48H4
Zn-α-2n	chem, yield	38M1
As-d-α5n	chem	48H4
	Not produced by	
Ga-d		48M32
p 68^m Ga		48H4

69 (Z 32, N 37)

τ		39.6^h		48M32
		40		49H29
		36		44H5
K	67%			48M32
β^+	33%	1.0	a	48M32
		1.22	a	38M1 (46B27)
		1.2	a	41S3
γ		1.22	a	48M32
X-ray				48M32

This activity previously confused with 40^h As

Ge-γ-n	rel yield	44H5
Ga-d-2n	chem	48M32
Zn-α-n	chem, yield	38M1
Ga-p-n		48D8
Ge-n-2n	chem	48M32, 41S2
	Not produced by	
Ge-d-p		48M32
Ge-n-γ		49M28
Not d 60^h As		49H14

70 (Z 32, N 38)

	20.55%		47I13
	20.65		48H35
I	0	Mic	49T9
	σ's		
(th n,γ)11^d Ge		~0.5	47S33

71 (Z 32, N 39)

τ	11.4^d		48H4,48M32
	11		49H29
K			44S5,48M32,49M28
No particles			44S5,47S33,48M32
No γ			48M32
Ga K X-ray			47S33,48M32
Ga-d-2n			48M32
Ge-d-p	chem		48M32
Ge-n-γ	σ		47S33
As-d-α2n	chem		48H4
Not found from Ge-γ-n			44H5
	d 50^hAs		48H27

72 (Z 32, N 40)

	27.38%		47I13
	27.43		48H35
I	0	Mic	49T9
Levels	0.68		As^{72},Ga^{72}
	τ=0.29^μs		49M29
	0.83		Ga^{72}
	1.45		Ga^{72}
	others ?		As^{72},Ga^{72}

73 (Z 32, N 41)

	7.61%		47I13
	7.86		48H35
I	9/2	Mic	49T9
q	-0.2	Mic	49T9
Levels	0.052		As^{73}
	0.1		

74 (Z 32, N 42)

	36.74%		47I13
	36.34		48H35
I	0	Mic	49T9
Level	0.582 ?		As^{74}
	σ's		
(th n,γ)82^m Ge		0.4	47S33

75 (Z 32, N 43)

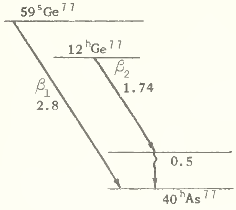
τ	82^m		48M32
	89		41S3
β⁻	1.2	a	41S3
	1.1	cc	41S2
No γ			48M32
X-ray			41S3
Ge-n-γ	chem		41S2
Ge-d-p	chem		41S3,41S2
Ge-n-2n	chem		41S3,41S2
Ge-γ-n	rel yield		49P5,48W13, 44H5
As-n-p	chem		48M32
Se-n-α	chem		41S3,41S2

76 (Z = 32, N = 44)

	7.67%		47I13
	7.72		48H35
I	0	Mic	49T9
	σ's		
(th n,γ)59^sGe		0.10	47A1
(th n,γ)12^hGe		0.09	47S33

77 (Z = 32, N = 45)

τ_1	59^s		47A1



No hard γ			47A1

59^sGe produced by

Ge-n-γ	σ	47A1

p 40^hAs 47A1

τ_2	12^h		41S3
	11		50s2
β_1^-	2.8	a	47A1
β_2^-	1.74	a	49M28
	2.0	a	50s2
	1.9	cc	41S2
γ	0.5	a	49M28
βγ coincidences			49M28

12^hGe produced by

Fission	chem	49G13
	chem	50s2
Ge-n-γ	chem	47A1
Ge-d-p	chem	41S2, 41S3
Se-n-α	chem	41S3

Not produced by

As-fast n	41S3
Ge-fast n	41S3

p 40^hAs 49M28, 47A1

78 (Z = 32, N = 46)

τ	2.1^h		50s2
β^-	~0.9	a	50s2
γ			50s2
Fission	chem		50s2

p 90^mAs 50s2

No Ge with τ >3^d found in fission 50W1

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

68 (33 35)

69 (33 36)

70 (33 37)

τ	52^m	48H4
β^+		48H4
As-d	chem	48H4
	d 44^mSe	48H4
	Not p active Ge	49H14

71 (33 38)

τ	50^h		48M31, 39S10
	60		48H27
K ~67%			48M31
β^+~33%	0.6	a	41S2
Ge-d-n	chem		48M31
	p 11^dGe		48M31

72 (33 39)

τ	26^h		48H4, 48M31
K ~67%			48M31
β^+~33%	2.8	a	48M31
	2.8	a	47M11
	complex		47M11
γ	0.6	a	48M31
	delay found		49G17
	1.4	a	48M31
	2.4	a coin	47M11
See decay scheme of Ga^{72}			
Ga-α-n	chem		47M11
Ge-p-n			48V8
Se^{74}-d-α	chem		48M31
	d 9.7^dSe		48H4

73
33 40

τ	76^d	48M31
	90	39S10
	100	43E3
K		48M31, 43E3
No β^+		48M31
γ	0.052 sc	43E3
	α large, K/L = 5	43E3
	0.1 a	48M31
	$\alpha = 0$	48M31
Ge K X-ray		48M31
Ge^{70}-α-p		48M31
Ge-d-n	chem	43E3, 48M31

74
33 41

τ		17.5^d		48M31
		19.0		48H4
		16.8		48M33
K	35%			42E4
β^+	35%	0.95	s	42E4
		0.9	cc	39S10
β^-	15%	0.72	s	42E4
		1.40	s	42E4
		1.3	cc	39S10
γ		0.588	s	42E4
		$\alpha \sim 0$		
		0.582	s	41D1
	Follows K and β^+			42E4
Fission	chem			49G13
As-γ-n				48M33, 4902
	threshold = 10.3			4902
As-n-2n	chem			38C3
Ga-α-n	chem			48M31
Ge-d-n	chem			48M31, 42I1
Ge-p-n				44D9
Se-d-α	chem			40F3

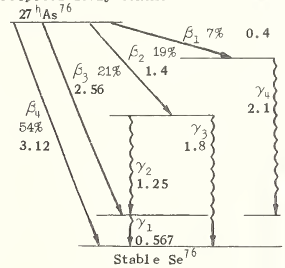
75
33 42

	100%		37N2
I	3/2 S		33C1, 32T1, 33R1
	Mic		48D8
μ	1.5 S		36S5
q	+0.3 S		36S5
Levels	several low		Se^{75}
	σ's		
(th n,γ) 27^h As		4.2	47S33
(th n,γ)		4.1	49P3
		5.5	49H2
($\sim$1Mev n,γ) 27^h As		0.023	49H5
For other fast n values see			49B4, 48WH

76
33 43

τ	26.8^h	42W1
	26.3	40M4
	26.1	48P8

Proposed decay scheme 49M3



As-n-γ	chem	48P8
	σ	47S33
As-d-p		38C3
Ge-p-n		48V8
Se-n-p	chem	39S10
Se-d-α	chem	40F3
Se-γ-p	relσ	47H4
Br-n-α		38C3

β_1^-	7%	0.4	s	49M3
β_2^-	19%	1.4	s	49M3
	15%	1.29	s	47S9
β_3^-	21%	2.56	s	49M3
	25%	2.49	s	47S9
β_4^-	54%	3.12	s	49M3
	60%	3.04	s	47S9
γ_1		0.567	s	49M3
		0.557	s	48W2
		0.55	s	47S9
		0.57	s	46M6
γ_2		1.25	s	49M3, 46M6
		1.22	s	48W2
		1.20	s	47S9

γ_3	weak	1.78	s	48W2
		1.70	s	47S9
	weak	1.84	s	46M6
γ_4	weak	2.15	s	46M6
Cross-over γ		$2.3 < E_\gamma < 2.76$		48M36
β^+/β^-	$<0.1\%$			48W2
	$<0.03\%$			47B8
	$<0.5\%$			49M3
High $\gamma\gamma$ coincidence rate				40M4
Summary of early work				48P8

77 (33 44)				78 (33 45)					79 (33 46)
τ	40^h		50s2	τ		90^m		50s2	
						80		38C3	
						65		39S10	
β^-	0.7	a	50s2	β^-	70%	1.4	a	50s2	
					30%	4.1	a	50s2	
No γ			49M28						
				γ		0.27	a	39S10	
Level	0.5		Ge^{77}						
Fission	chem		50s2, 48SP	Fission		chem		50s2	
				Br-n-α		chem		39S10	
				Se-n-p		chem		39S10	
	d 59^sGe		47A1						
	d 12^hGe		49M28, 48M32, 50s2			d 2.1^hGe		50s2	
	Not p 17.5^sSe		49F10						

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

$E_n = 0.025$ ev

σ_a	12.1	49P3
	12.5	49H2
σ_s	13	37G1
σ_t	21	37G1
Values at other energies		49H16

$E_n \sim 3$ Mev

σ_t	4.0	39Z1
Other fast n values		48WH

69
34 35

70
34 36

τ	44^m	48H4
β^+		48H4
As-d	chem	48H4

p 52^m As which has no active Ge daughter 49H14

71
34 37

72
34 38

τ	9.7^d	49H14
K		48H4
As-d-5n	chem	48H4

p 26^hAs 48H4

73
34 39

τ	6.7^h		48H4
	7.1		48C7
K ~50%			48C7
β^+ ~50%	1.29	a	48C7
γ ?			48C7
Ge-α-n	chem		48C7
As-d-4n	chem		48H4

Not produced by As-d-2n 48C7

74 (Z = 34, N = 40)

	0.96%		49H3
	0.87		48W9
I	0 ?	Mic	49S7
Level	0.582 ?		As^{74}
		σ's	
(th n,γ) 127^{d}Se		22	47F8, 47S33
		26	50g20

75 (Z = 34, N = 41)

τ	127^{d}	48C7
	120	48H4
	125	50g20
	115	47F8

K		47F8, 50g20
No β^{+}		47F8

γ	49T2	48J13, 48J6
		0.067
	0.076	0.077
	0.099 ?	0.099
	0.123	0.124
	0.137	0.139
		0.203
	0.267	0.269
	0.283	0.281
		0.308
	0.405	0.405

Note: 0.123 and 0.283 = 0.406
0.137 and 0.267 = 0.404

No delayed βγ coincidences 49M26

As K´X-ray		47F8, 50g20
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 (Z = 34, N = 42)

	9.12%		49H3
	9.02		48W9
I	0 ?	Mic	49S7
Levels	0.567		As^{76}
	1.8		As^{76}, Br^{76}?
	2.7		As^{76}
	others ?		Br^{76}
	σ's		
(th n,γ) 17.5^{s}Se		~7	47A1

77 (Z = 34, N = 43)

τ	17.5^{s}		49G4, 47A1
IT			48G17
γ	~0.15	a	47A1
	0.15	ac	49G4
Se K X-ray			48G17
Se-n-γ	σ		47A1
Se^{76}-n-γ			48G2, 47D10
Se-γ			49G4

Not d 40^{h}As 49F10

	7.50%		49H3
	7.58		48W9
I	1/2 ?	Mic	49S7
	>1/2	S	49M11
Levels	0.7		Br^{77}
	1.45		49G4

from γ excitation curve

889592 O - 50 - 11

78 (Z 34, N 44)

	23.61%		49H3
	23.52		48W9
I	0 ?	Mic	49S7
Levels	0.046 } ?		Br^{78}
	0.108 }		
	0.27 ?		As^{78}

79 (Z 34, N 45)

τ	6.5×10^{4} y	49P14
	$>7\times10^{6}$	
	if β energy >30kev	50g1

80 (Z 34, N 46)

	49.96%		49H3
	49.82		48W9
I	0	B	3401
Levels	?		Br^{80}

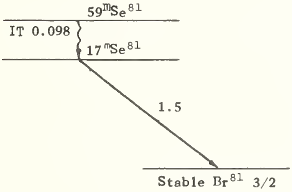
σ's

(th n,γ) 17^{m}Se	0.46	47S33
	0.50	47A1
(th n,γ) 59^{m}Se	0.034	47S33

81 (Z 34, N 47)

τ_1	59^{m}	50g1
	57	37S2, 40L3
	56.5	48W13

τ_2	17^{m}	50g1
	19	40L3
	13.6	48W13



$59^{m}Se^{81}$

IT	0.098	sc,a	40L3
	0.099	sc	41H1
	K/L = 4		41H1

$17^{m}Se^{81}$

β^-	1.5	a	40L3, 46PP
No γ			46PP

Fission	chem	50g1
Se-d-p	chem	37S2, 40L3
Se-n-γ	σ	47A1, 47S33
Se^{80}-n-γ		47L14
Se-γ-n	relσ	48W13
Br-n-p	chem	37S2, 40L3

p $17^{m}Se^{81}$ chem 40L3, 50g1

Fission	chem	50g1
Se-d-p	chem	37S2, 40L3
Se-n-γ	σ	47A1, 47S33
Se-γ-n	relσ	48W13
threshold = 9.8		45B12
Br-n-p	chem	40L3

d 59^{m}Se chem 40L3, 50g1

82 (Z 34, N 48)

	8.84%		49H3
	9.19		48W9
I	0 ?	Mic	49S7
Levels	?		Br^{82}

σ's

(th n,γ) 67^{s}Se	0.047	47A1
(th n,γ) 25^{m}Se	0.004	47A1

34 SELENIUM Se

$^{83}_{34}Se_{49}$

τ_1	67^s		47A1
β^-	3.4	a	47A1
γ			47A1
Fission			50g2
Se-n-γ	chem,σ		47A1
	p 2.4^hBr		47A1

τ_2	25^m		50k1
	30		40L3
β^-	1.5	a	46PP
γ	0.17	a	46PP
	0.37	a	46PP
	1.1	a	46PP
Fission			48SP
	chem		46PP
Se-d-p	chem		40L3
Se-n-γ	chem,σ		47A1
	chem		40L3
	p 2.4^hBr		50k1

$^{84}_{34}Se_{50}$

τ	$\sim 2^m$	50e1,50k2
Fission	chem	50e1,50k2
	p 30^mBr	50e1,50k2

No long lived Se other than Se^{79} produced in fission 50w3, 50g1

Neutron Cross Sections of Natural Element

σ_s coh	5.7	49S12
	$E_n = 0.025$ev	
σ_a	6.4	49P3
	9.1	49H2
σ_s	7	37G1
	Resonance	
E_o	<115ev	49H16
	$E_n = 2.5$Mev	
σ_t	2.7	39A5

75 (35 40)

τ	1.7^h		48W8
K ~81%			48W8
β^+ ~19%	1.6	a	48W8
No γ			48W8
Se^{74}-d-n			48W8
Se^{74}-p-γ			48W8

p 127^dSe ?
125^d activity found after Se^{74}-p 48W8

76 (35 41)

τ	15.7^h		48H27
β^+	3.15	s	48H27
γ	2	a	48H27
e^-	0.18	s	48H27
As-α-3n	chem		48H27

77 (35 42)

τ	57.2^h		48H27
	58		48W8
K 95%			48W8
β^+ 5%	0.36	a,s	48W8
	0.36	s	48H27
γ	0.7		48H27
Se^{74}-α-p			48W8
Se^{76}-d-n			48W8
As-α-2n	chem		48H27

78 (35 43)

τ	6.4^m		37S2
	6.3		48W13
β^+	2.3	a	37S2
γ	0.046	sc	39V2
	0.108	sc	39V2
As-α-n	chem		37S2
Se-d-n	chem		37S2
Se-p-n	chem		38B4
Br-γ-n	relσ		39B5, 48W13
threshold = 10.7			49M17
Br-n-2n			37S2
threshold = 9-13			38S14

79 (35 44)

	50.57%		49H3
	50.51		48W9
	50.5		46W3
I	3/2	S	32T2, 40T2
		Mic	47T16
μ	2.0999		49Po
		I	49Z2, 47P16
		M	47B24
q	+0.28		47T15
Level	0.2		Kr^{79}

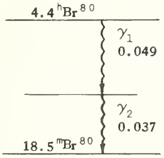
σ's

(th n,γ) 4.4^hBr	8.9	49H5
	8.1	47S33
(th n,γ) 18^mBr	3.0	49H5
	2.8	47S33
(~1Mev n,γ) 4.4^hBr	0.014	49H5
(~1Mev n,γ) 18^mBr	0.030	49H5
Other fast n values		48WH

80 (Z = 35, N = 45)

τ_1	4.4^h	38B4
	4.5	37S2

τ_2	18.5^m	37S2



Se^{80}-p-n	chem	48W8
threshold	~3.1	38B4
Se-d-2n		48W8
Se-α-p		48W8
Br-d-p	chem	37S2
Br-γ-n	relσ	48W13, 39B5
Br-n-2n		37P2
Br-n-γ	chem	37S2
	σ	49H5, 47S33

γ_1	0.049	sc	39V2
	α=∞		40G6
	chemical effects		
	α=∞		49H15
	chemical effects		
	α=57		40D3
	assuming α=∞, K/L=7.3		44B7
	0.047	cc	41S4
	α=1	K/L=10	41S4
	(assuming no conversion of other γ)		
γ_2	0.037	sc	39V2
	α=0.64	K/L=6.8	44B7
	0.037	a	40G6
	α=1		40G6
	0.037	cc	41S4
	α~2		40D3

Relative amounts of isomers produced by different reactions 39B5

β^-		2.0	a	48C25
	complex	2.3	a	37S2(46B27)
		2.0	s	36A1
β^+	3%	~0.7	a	47B8
		~0.8	s	48W8
	1.0%	1.0	s	49D19
β^- and β^+ ft values ~ equal				49D19
γ		>0.6	a	40D3
		<0.5	a	37S2

Se-p-n	chem	36B4
threshold	~ 2.9	38B4
Br-d-p	chem	37S2
Br-γ-n	relσ	48W13, 39B5
threshold	= 10.2	49M17
Br-n-2n		38S13, 37P2
Br-n-γ	relσ, chem	49F15
	chem	37S2
	σ	49H5, 47S33

d 4.4^hBr 39S3, 40D3, 41S4

81 (Z = 35, N = 46)

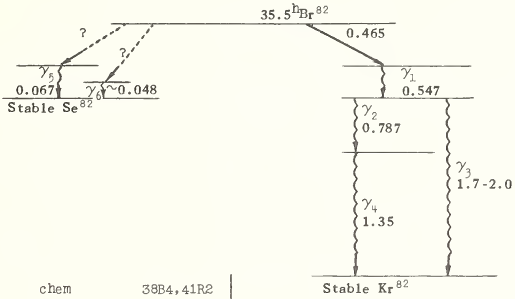
	49.43%		49H3
	49.49		48W9
	49.5		46W3
I	3/2	S	32T2, 40T2
		Mic	47T16
μ	2.2633		49Po
		I	49Z2, 49B7, 47P16
		M	47B24
q	+0.23		47T15

σ's

(th n,γ) 36^hBr	2.3	47S33
(~1Mev n,γ) 36^hBr	0.017	49H5
Other fast n values		48WH

$^{82}_{35}Br_{47}$

τ	35.5^h	49T5
	33.9	37S2
	36	35K1



Se-p-n	chem	38B4, 41R2
Se-d-2n	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

γ_1, γ_2, γ_4 in cascade	41R1
High energy e^-'s probably secondaries	42D4
No β^+	49D19
β^+/β^- ⩽0.004 through 30 mg/cm² Al	47B5

K	<5%	No X-ray found		41R1
β^-		0.465	s	41R1
γ_1		0.547	s	41R1
γ_2		0.787	s	41R1
γ_3	0.14%	1.7-2.0	γn	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.	49S30
	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 βe^- coincidences observed 44B7

$^{83}_{35}Br_{48}$

τ	2.4^h		50k1
	2.3		40L3
β^- complex	1.45	a	37S2(46B27)
	0.9	a	46PP
	1.1	a	40L3
	1.0		50k1
No γ			37S2, 46PP
Levels			Se^{83}
	0.17 } ?		
	0.37 } ?		
	1.1 } ?		
Se-d-n	chem		37S2
Fission	chem		40S3, 48SP, 49G13, 50k1
	d 25^mSe		50e1, 40L3
	p 1.88^hKr		50e1, 40L3

$^{84}_{35}Br_{49}$

τ	33^m		50k2
	30		40S3
β^-	5.3	a	50k2
	4.5	a	43B2
γ			50k2
Rb-n-α			43B1
Fission	chem		39D2, 48SP
	d ~2^mSe		39D2, 50e1

$^{85}_{35}Br_{50}$

τ	3.00^m		49S14
	3.0		40S3, 43B1
β^-	2.5	a	49S14
No γ			48S16
Fission	chem		48S16, 43B1, 48SP
	p 4.5^hKr		40S3, 43B1

86 (Z = 35, N = 51)

(no data)

87 (Z = 35, N = 52)

τ	55.6^s		48H33
	55.0		47R2
	56.1		49S14
β^-			40S3
55%	~2	a	49S15
45%	~8	a	49S15
Delayed neutron emitter			47S7
$\overline{E_n}$	0.25		48H33
	0.3		46B22
γ	>3	a	49S15
Delayed n's in ~2% of disintegrations			50l2
Fission	chem		40H12,48SP
	p 78^mKr		43B1,43S1

88 (Z = 35, N = 53)

τ	15.5^s	49S14
β^-		49S14
Fission	chem	49S14
	p 3^hKr	49S14

89 (Z = 35, N = 54)

τ	4.51^s		47S10,46PP
	4.3		46S28
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

No Br with τ >3^d found in fission 50k1

36 KRYPTON* Kr

Neutron Cross Sections for Natural Element			$^{77}_{36}$ 41				$^{78}_{36}$ 42		
	$E_n = 0.025$ev		τ	1.1^h	48W7		0.342%	47L2
σ_a	0.045	44W11					0.36%	47D9
σ_t	24	42R3						
			K ~70%		48W7			
σ_s	6.7	50H5	β^+ ~30%	1.7 a	48W7			
			γ		48W7			
							σ's	
						(th n, γ) 34^hKr	0.26	50h2
			Se^{74}-α-n	chem	48W7			

$^{79 \text{ or } 81}_{36}$			$^{79}_{36}$ 43				$^{80}_{36}$ 44		
τ	13^s	40C6	τ	34.5^h		40C6		2.228%	47L2
				34		48W7		2.25	47D9
γ	0.187 sc	40C6	K 98%			48W7			
			β^+ 2%	1.0 a		48W7			
				~0.6 a	70%	50h2			
				~0.9 a	30%	50h2			
			γ	0.2 a		50h2			
							Level	~0.5	Br^{80}
			Kr-d-p	chem		41C2			
			Se^{76}-α-n	chem		48W7			
Br-p-n		40C6	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.

81 or 79 (Z=36)			81 (Z=36, N=45)			82 (Z=36, N=46)		
τ	55^s	40C6					11.50%	47L2
							11.57%	47D9
γ	0.127 sc	40C6						
			Level	0.8	Rb^{81}	Levels	?	Br^{82}, Rb^{82}
Br-p-n		40C6						
Se-α-n ?		39K1						

83 (Z=36, N=47)						84 (Z=36, N=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	41H1						
	K/L = 1	41H1	μ	-0.968 M	46K5			
			q	+0.15 S	49K21, 38S10			
						σ's		
						(th n,γ) 4.4^hKr	0.096	50h2
						(th n,γ) 10^yKr	0.063	50h2
						(~1Mev n,γ) 4.4^hKr	1.9mb	49H28
						(~1Mev n,γ) 10^yKr	<8mb	49H28
Se-α-n	chem	41C2						
Kr-d	chem	41C2						
Kr-γ-γ		45W3						
Kr-n-γ		45W3						
Kr-n-n		46R7						
Fission	chem	46PP						
	d 2.4^hBr	40L3						

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

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$^{85}_{36}Kr_{49}$

τ	4.36^h		49K13
	4.5		50h2, 37S2
	4.4		48W7
	4.6		46R7
β^-	1.0	a	50h2
	0.75	a	49K13
	0.85	a	43B2
γ	0.17	a	50h2
	0.37	a	50h2
Fission	ms		49K13
	chem		50h2
Se-α-n	chem		48W7
Kr-d-p	chem		41C2
Kr-n-γ	σ		50h2
Rb-n-p	chem		43B1
Sr-n-α	chem		43B1
d 3^mBr			43B1, 43S1

τ	$\sim 10^y$		47T6, 50h1
β^-	0.74	a	50h1
No γ			50h1
Fission	ms		47T6
	chem		50h1
Kr-n-γ	σ		50h2

$^{86}_{36}Kr_{50}$

	17.43%	47L2
	17.24	47D9
σ's		
(th n,γ) 78^mKr	0.061	50h2
($\sim$1Mev n,γ) 78^mKr	2.4mb	49H28

$^{87}_{36}Kr_{51}$

τ	78^m		49K13
	74		37S2
	75		43S1
β^-	3.2	a	49K13
	$\sim$4	a	43B2

Neutrons emitted following 56^sBr disintegration — Br^{87}

σ's			
(th n,γ)		<470	50h2, 45S17
Fission	ms		49K13
	chem		43B1, 43S1
Kr-d-p	chem		37S2
Rb-n-p	chem		43B1
Kr-n-γ	σ		50h2
d 56^sBr			43B1, 43S1

$^{88}_{36}Kr_{52}$

τ	2.77^h		49K13
	3		40H4, 39L11
	2.8		40G5
β^-	$\sim$0.5	a	49K13
	2.4 ?	a	49K13
	2.4	a	48J20
	2.5	cc KU	42W1
γ			49K13

Distribution of nuclear recoils indicates β's and neutrinos emitted in same direction — 46J3

Fission	ms	49K13
	chem	40S5, 40H10
p 17.8^mRb		40G5, 40H10

$^{89}_{36}Kr_{53}$

τ	2.6^m	50d1
	2.5	43H9

Neutrons emitted following 4.5^sBr disintegration — Br^{89}

Fission	chem	50d1, 40S5, 40H10
p 15.4^mRb		40G5, 40H10
p 53^dSr		40G5, 50d1

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

90 (36, 54)			91 (36, 55)			92 (36, 56)		
τ	25^{s}	50d1	τ	9.8^{s}	50d1	τ	2.4^{s}	50d1
	33	46PP		5.7	50o1			
						Mass assignment from range of fission fragments		48K9
Fission	chem	50d2	Fission	chem	48SP, 50d1	Fission	chem	43H9, 50b2, 50d1
				p 9.7^{h}Sr	50d1			
	p 25^{y}Sr	50d2, 46PP		p 57^{d}Y	50b2, 50d2, 50o1		p 3.5^{h}Y	50b2, 50d1, 40H10

93 (36, 57)			94 (36, 58)			97 (36, 61)		
τ	2.3^{s}	50d1	τ	1.4^{s}	50d1	τ	$\sim 1\text{-}2^{s}$	50d1
Fission	chem	43H9, 50d1, 50d2, 50b2	Fission	chem	43H9, 50d1	Fission	chem	50d1
	p 10^{h}Y	50d1, 50d2, 50b2, 46S18		p 16.5^{m}Y	43H9, 50d1		p 17^{h}Zr contested by	50d1 50g2

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

Neutron Cross Sections for Natural Element

σ_s coh	3.8		49S12
σ_s bound	5.5		49S12
σ_a	$E_n = 0.025$ev 0.70		49P3
σ_t	12		42L1

80 (37 43)

81 (37 44)

τ	5.0^h		49R1
K ~70%			49R1
β^+ ~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)

τ_1	6.3^h		49R1
	6.5		40H11
K ~85%			49R1
β^+ ~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-3n	chem	49R1
Kr-d-2n	chem	40H11

82 ? (37 45 ?)

τ_2	20^m	40H11
Br-α-n	chem	40H11
Not produced by Kr-d		40H11

83 (37 46)

84
37 47

τ	$\sim 40^d$	47B8
β^+		47B8
K		49G13
K X-ray		49G13
Br-n-2n		47B8
Sr-d-α		47B8

85
37 48

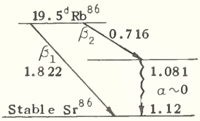
	72.8%		36N5
I	5/2	S	33J1, 33K1
		Z	36M1
		M	40M11
μ	1.349		49Po
		I	49B7, 49C2
		M	39K7
Levels ?	0.17		Sr^{85}, Kr^{85}
	0.37		Kr^{85}
	0.510		Sr^{85}

σ's

(th n,γ) 19.5^dRb	0.7	47S33
($\sim$1Mev n,γ) 19.5^dRb	0.023	49H28

86
37 49

τ	19.5^d		48W13, 41H2
	18		37S2



1.081		s	48Z2
1.12		a	48J7
β_1^- 80%	1.822	s	48Z2
67%	1.8	a	48J7
	1.8	a	50f2
	1.60	s	42H1
β_2^- 20%	0.716	s	48Z2
33%	0.56	a	48J7

$\beta\gamma$ angular correlation indicates I (Rb^{86}) = 2 — 49F16

Rb-n-γ	chem	37S2, 38S6
	σ	47S33
Rb-γ-n		44H5
	relσ	48W13
Sr-d-α	chem	41H2
Fission	chem	50f2

87
37 50

	27.2%		36N5
I	3/2	S	33J1, 33K1
		Z	36M1
		M	40M11
μ	2.742		49Po
		I	49B7, 49Z2
		M	39K7

σ's

(th n,γ) 17.8^mRb	0.12	47S33
($\sim$1Mev n,γ) 17.8^mRb	1.8mb	49H28

τ	$6.0 \times 10^{10\,y}$		49K28, 48H41
	6.3×10^{10}		38S8
	5.8×10^{10}		46E2
β^- or e^-	0.13	s	41O3, 39L1
	0.25		35K4
	0.144	s	46S1
	0.56	cc	48F10
	<0.01	a	48H41
γ	0.034	sc	} ? 41O3
	0.053	sc	
	0.082	sc	
	0.102	sc	
	0.129	sc	
βe^- coincidences			48H41

88
37 51

τ	17.8^m		40G5
	17.5		42W1
	18		39H4
β^-	5.0	a	40G5 (46B27)
	5.1	cc	42W1
	2.5	cc	42W1
γ			49K13

σ's

(th n,γ)	< 200	45S17

Rb-n-γ	chem	37P2, 37S2
	σ	47S33
Fission	chem	39H3, 40G5, 42W1, 40H10
	d 3^hKr	39L11, 40H10

89
37 52

τ	15.4^{m}		40G5
	15.5		40H10
β^{-}	4.5	a	40G5(46B27)
Fission	chem		43H4
	d 2.6^{m}Kr		43H4
	p 53^{d}Sr		40G5

90
37 53

τ	short	50d2
Fission	chem	50d2
	d 25^{s}Kr	50d2
	p 25^{y}Sr	50d2

91
37 54

τ	short	40H9, 50d1
Fission	chem	50d1
	d 9.8^{s}Kr	50d1
	p 57^{d}Y	50d1

92
37 55

τ	short	50b2, 50d1
Fission	chem	50b2, 50d1
	d 2.4^{s}Kr	50b2, 50d1
	p 3.5^{h}Y	50b2, 50d1

93
37 56

τ	short	50d1, 50d2, 50b2
Fission	chem	50d1, 50d2, 50b2
	d 2.3^{s}Kr	50d1, 50d2, 50b2
	p 10^{h}Y	50d1, 50d2, 50b2

94
37 57

τ	short	50d1, 43H9
Fission	chem	50d1, 43H9
	d 1.4^{s}Kr	50d1, 43H9
	p 16.5^{m}Y	50d1, 43H9

95 37 58	96 37 59	97 37 60
		τ short 50d1
		Fission chem 50d1
		d 1-2^{s}Kr 50d1 p 17^{h}Zr 50d1 See also 50g2

>90 37		
τ 80^s 40H4		
Fission chem 40H4		

Neutron Cross Sections for Natural Element

σ_s	coh	4.1	49S12
σ_s	bound	9.5	49S12
		$E_n = 0.025$ ev	
σ_a		1.2	49P3
		1.5	49H2
σ_s		9.5	37G1

84 (38, 46)

0.56%	38N3
0.55	48W9

85 (38, 47)

τ_1	70^m		40D5
γ	~0.17	sc	40D5
Rb-p-n	chem		40D5

τ	65^d		40D1
K			40D1
No β^+			49T14
γ	0.510	sc	49T14
	0.8	a	40D5
Auger e's from Rb L and M shells			49T14
Rb-p-n	chem		40D5
Rb-d-2n	chem		49T14, 42O3

86 (38, 48)

	9.86%	38N3
	9.75	48W9
Level	1.08	Rb^{86}
	σ's	
(th n, γ) 2.7^hSr assuming 15% internal conv.	1.3	47S33

38 STRONTIUM Sr

87 (Z = 38, N = 49)

τ	2.75^h		40D5
γ	0.37	sc	40D5
	0.386	sc	41H1
	$\alpha = .18$, K/L ~7		41H1
Sr K X-ray			40D5
Sr-d-p	chem		40D5
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^hY		40D5

	7.02%		38N3
	6.96		48W9
I	9/2	S	38H5
μ	-1.1	S	38H5
Levels	0.37		$2.75^h Sr^{87}$
	others ?		Rb^{87}
	σ's		
(~2.5Mev n,n) 2.7^hSr	0.3		40R4

88 (Z = 38, N = 50)

	82.56%		38N3
	82.74		48W9
I	0	S	38H5
Levels	1.85		Y^{88}
	2.76		
	σ's		
(th n,γ) 53^dSr		5mb	47S33
(~1Mev n,γ) 53^dSr		2.1mb	49H28

89 (Z = 38, N = 51)

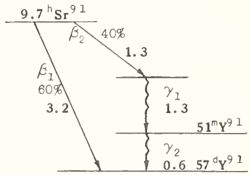
τ	53^d		50n3
	55		39S8
	54.5		46G6
β^-	1.50	s	49S10
	1.463	s	49L6
	1.5	s	50n3, 47R1
β spectrum shape consistent with $\Delta I = 2$, yes			49L6, 49S10
No γ			49S10, 39S8, 50n3
	σ's		
(th n,γ)		< 110	45S17
Fission	ms		48H25
Sr-n-γ	chem		39S8
Sr-d-p	chem		39S8
Zr-n-α ?	chem		40S8
Y-n-p			38S3
Fission	chem		49G13, 50n3
	d 15^mRb		40G5, 46G6, 40H10

90 (Z = 38, N = 52)

τ	25^y		50g3
	23		50n4
β^-	0.537	s	49J1
	0.531	s	49B11
	0.61	s	48M8
	0.6	a	50g3
β spectrum shape consistent with $\Delta I = 2$, yes			49B11, 49J1
No γ			50g3, 46PP
	σ's		
(pile n,γ) 9.7^hSr		~1	49S11
Fission	ms		48H25
	chem		46PP, 48SP, 49G13
	d 25^sKr		46PP
	p 61^hY		50n4, 46PP

91 (Z = 38, N = 53)

τ	9.7^h		50f3
	10		43H4



β_1^- 60%	3.2	a		50f3
β_2^- 40%	1.3	a		50f3
γ_1	~1.3	a		50f3
γ_2	0.6	a	α~0.1	50f3
Zr-n-α	chem			43S3
Fission	chem			40H4, 46PP, 48SP, 49G13
	d 9.8^sKr			46PP
	p 60% 57^dY			50f3
	40% 51^mY			50f3

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92 (38, 54)			93 (38, 55)			94 (38, 56)		
τ	2.7^h	41G4	τ	7^m	39L10	τ	$\sim 2^m$	43H4
β^-		41G4	β^-		39L10			
Fission	chem	41G4, 43H9, 50b2	Fission	chem	39L10, 43H9	Fission	chem	43H4, 50d1
	d 2.4^sKr	50b2, 40H4		d 2.3^sKr	42H8, 39L10		d 1.4^sKr	43H9
	p 3.5^hY	50k5, 41G4, 43H9		p 10^hY	43H9		p 16.5^mY	43H9

95 (38, 57)	96 (38, 58)	97 (38, 59)		
		τ	short	50d1
		Fission	chem	50d1
			d $1\text{-}2^s$Kr	50d1
			see also 50g2	

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

$^{84}_{39}Y_{45}$

τ	3.7^h		49S9
K			49S9
β^+	2.0	a	49S9
γ			49S9
Sr X-ray			49S9
Sr^{84}-d-2n	chem		49S9
Sr^{84}-p-n			49S9
Not produced by			
Sr^{86}-d			49S9
Sr^{87}-d			49S9

$^{87}_{39}Y_{48}$

τ_1	14^h		40D5
IT ?			40D5
K			50R3
β^+	1.1		50R3
Sr-p-n	chem		40D5
Sr-d-n	chem		40D5

τ_2	80^h		40D5
K			50R3, 40D5
β^+	0.7		50R3
γ	0.5	sc, a	50R3
Sr K_α X-ray			50R3
Sr-p-n	chem		40D5
Sr-d-n	chem		40D5
Rb-α-n			48R9
	p 2.7^hSr		40D5

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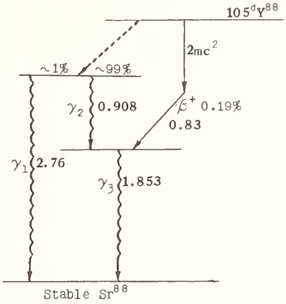
39 49

τ_1	105^d	49S9, 40D5
	104	4702



β^+ 0.19%	0.83		48P13
γ_1 ~ 1%			43G4
	2.76	s	48P13
γ_2 ~99%			43G4
	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

Y-n-2n	ms	48H25
	chem	42H2, 4605
Sr-p-n	chem	40D5
Sr-d-2n	chem	40P1, 43G4
threshold = 6, yield		46C9

$\gamma\gamma$ angular correlation consistent with I = 2, 1, 0 — 48B18

τ_2	2.0^h		39S8
β^+	1.65	a	4605
	1.2	cc	37S3

Sr-p-n	chem	40D5
Y-n-2n	chem	4605
Sr-d-n	chem	39S8

Not produced by
Y-fast n's
Sr-d
Rb-α
} 49S9

89
39 50

	100%		39D5
I	1/2	S	49C17
μ	-0.14	S	49C17

σ's

(th n,γ) 61^hY	1.24	47S33
(th n,γ)	1.38	49P3
(~1Mev n,γ) 61^hY	7mb	49H28

90
39 51

τ	61^h		46B25
	65		50n4
β^-	2.180	s	49L6
	2.25	s	49B11
	2.23	s	49J1
	2.35	s	48M8

β spectrum shape consistent with ΔI = 2, yes — 49J1, 49L6, 49B11

No γ — 49B11, 50g3

Y-d-p	chem	37S3
Y-n-γ	chem	37S3, 38S3
	σ	47S33
Zr-n-p		40S8
Zr-d-α		38S3
Nb-n-α		38S4
Fission	chem	50n4, 50g3, 49G13

d 25^ySr ms 48H25

91 (Z = 39, N = 52)

τ_1	51^m		50f3
	50		41G4
IT			50f3
γ	0.61	a	50f3
	$\alpha \sim 0.1$		50f3

See decay scheme of Sr^{91}

$51^m Y$ produced by

Zr-n-p	chem	43S3
Fission	chem	50f3, 41G4, 43H4
40% d $9.7^h Sr$		50f3
p $57^d Y$		50f3

τ_2	57^d		44J4, 40H9
	61		46G6
β^-	1.537	s	49L6
	1.54	s	49O3
	1.55	s	49W17

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

$57^d Y$ produced by

Zr-n-p	chem	43S3
Fission	ms	48H25
	chem	49G13, 50f3, 41G4
60% d $9.7^h Sr$		50f3, 41G4, 43S3

92 (Z = 39, N = 53)

τ	3.5^h		43H9, 39L10
β^-	3.5	a	50h3
	3.6	a	43B2
	3.4	a	41G4
γ	0.7-1.1	a	46PP
	0.6	a	41G4

Mass assignment from range of fission fragment — 48K9

Fission	chem	50h3, 48SP, 49B10
Zr-n-p	chem	43S3
d $2.7^h Sr$		43H4, 50h3

93 (Z = 39, N = 54)

τ	10.0^h		50b6
	11.5		39H10
β^-	3.1	a	50b6
γ	0.7	a	50b6

Mass assignment from range of fission fragment — 48K9

Fission	chem	50b6, 49G13
d $7^m Sr$		43H4
Not p $65^d Zr$		50s15

See Zr^{93}

94 (Z = 39, N = 55)

τ	16.5^m		49B10
	20		43H4
β^-	5.4	a	49B10
γ	1.4	a	49B10

Mass assignment from range of fission fragment — 48K9

Zr-n-p	chem	43S3
Fission	chem	50d3
d $2^m Sr$		43H9

95 (Z = 39, N = 56)

τ	$<1.5^h$	50s15

96 39 57	97 39 58	
	τ short 50d1	
	Fission chem 50d1	
	d 1-2^{s}Kr 50d1	
	p 17^{h}Zr 50d1	
	See also 50g2	

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					
	$E_n = 0.025$ev		K			49S9	
σ_a	0.22	49P3					
	0.4	49H2	β^+	2.0	a	49S9	
σ_s	8.2	(48WH)	γ	0.35	a	49S9	
				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	49B28, 50Ad					

89 40 49							90 40 50		
τ_1	4.5^m		40D5	τ_2	80.1^h		4301	51.46%	48W9
					78		40D5	51.7	49H39
K or IT			48H36	β^+	1.07	a	4301		
					~1	a	40D5		
e^-	0.555	s	48H36	No γ			40D5		
								Levels	Nb^{90}
								~0.04, 0.25, 1.66, 2.03 ?	
								σ's	
								(th n,γ) 0.11	49P3
Y-p-n	chem		40D5	Zr^{90}-γ-n			49B3	Zr^{91}-γ-n	49H17
Zr-n-2n			48H36	threshold = 11.9			49B3	threshold = 7.2	49H17
Zr^{90}-γ-n			49B3, 49H17	Zr-n-2n	chem		40S8	(only n's observed)	
threshold = 12.48			49H17	Y-d-2n			4301		
threshold = 12.1			49B3	Y-p-n	chem		40D5		
				Mo-n-α	chem		40S8		

91 (40, 51)

	11.23%		48W9
	10.8		49H39
I	5/2	S	49A6
	σ's		
(th n,γ)		1.52	49P3

92 (40, 53)

	17.11%		48W9
	17.1		49H39
Level	~0.7		Y^{92}
	σ's		
(th n,γ)		0.25	49P3

93 (40, 53)

τ	>4x10[6] y*	49B44
	very long *	49C20
	>40 **	48L4
	>100 **	50S15
Level	~0.7	Y^{93}

* From fission yield
** From decay of 10^hY

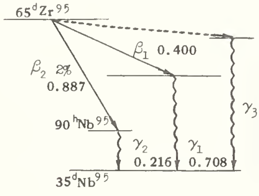
94 (40, 54)

	17.40%		48W9
	17.5		49H39
Level	1.4		Y^{94}
	σ's		
(th n,γ)		0.08	49P3
(th n,γ) 65^dZr		0.06	49L16
		0.43	47S33

95 (40, 55)

τ	65^d	50b1,43H9,46G6
	65.5	45P1
	63	40S8

Tentative decay scheme 50l3



Fission	ms	46PP
	chem	49G13,46PP,48SP,43H8,40G4,46G6
Zr-n-γ	chem	40S8
	p (1.4%) 90^hNb	49H31
	p (98.6%) 35^dNb	49H31
	p 90^hNb	50S3
	p 35^dNb	46G6,50e2,50b1

β_1		0.400	s	49L17
		0.39	s	50n1
		0.42	a	50b1
		0.4	a	48M14
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
		α=∞		49H31
		0.24	sc	50l3
		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^dNb daughter (?) 48M1

Zr-n-γ	σ	47S33
Zr-d-p	chem	50J1,40S8
Zr-n-2n	chem	40S8
Mo-n-γ	chem	40S8

$^{96}_{40}$ 56	$^{97}_{40}$ 57	?
2.8% 48W9 2.9 49H39 σ's (th n,γ) 0.10 49P3 (th n,γ)17^hZr 0.045 49L16 0.60 47S33 (pile n,γ)17^hZr 0.2 49L16	τ 17.0^h 40G4,50k3,40S8 β^- 2.2 a 50k3 1.1 cc 40S8 γ ~0.8 a 50k3 Fission chem 40G6,40H9,41A3 Zr-n-γ chem 40S8,49P16 σ 47S33 Mo-n-α chem 40S8 Not produced by Nb-n-p 50J1 d 1-2^sKr 50d1 contested by 50g2 p 76^mNb 40G4,41H5,50b3	τ 6^m 47S33,40S8 Zr-n-γ 47S33,40S8 σ(atomic) = 0.016 47S33

No $Zr^{>97}$ found in fission with τ between 2^m and 100^y 49C20 No Zr with τ <5^m found by nγ on separated Zr isotopes 49B42		

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41 NIOBIUM Nb
(Columbium)

Neutron Cross Sections for Natural Element

σ_s coh	6.0	49S12
σ_s bound	6.2	49S12
	$E_n = 0.025$ev	
σ_a	1.06	49P3
	1.48	49H2
σ_s	5	37G1
σ_t	6.4	47W8

Graphs Available

σ_t	0.008-1000 ev	50Ad, 47GIF, 47W8

90 (41 49)

τ	15^h		49K19, 49B29
	17-18		50J1
β^+	~1.7	a	49B29
	1.9		49K19
γ	~0.04	a	49B29
	0.25	a	49B29
	1.66	a	49B29
	2.03		49K19

Zr-d-2n		50J1
Mo-d-α		50J1
Mo^{92}-d-α	chem	49K19, 49B29
Zr^{90}-d-2n		49K19
Not produced by Zr^{91}-d		49K19

91 (41 50)

τ	64^d	49B29
	60	50J1
IT ?		49B29
e^-		49B29
Nb X-ray		49B29
γ	~0.05	49B29

Mo^{94}-d-αn	chem	49B29
Zr-d-n	chem	50J1

92 (41 51)

τ	10.1^d		47K1
	9.8		48M33
	11		40S6
β^-	1.38		47K1
	1.38	cc	40S6
γ	1.1		45P1
	1.0		47K1
Zr K X-ray			47K1

Nb-γ-n		48M33
Zr^{92}-d-2n		49K18
Mo^{94}-d-α	chem	49B29
Y-α-n		45P1
Nb-d-t		47K1, 46W2
Nb-n-2n		40S6
Not found from Nb-n-2n		50J1

93 (41 52)

	100%		36S4
I	9/2	S	34B1, 47M27
μ	5.3	S	47M27

σ's

(th n,γ) 6.6^{m}Nb	1.4	47A8
(~1Mev n,γ) 6.6^{m}Nb	0.052	49H5

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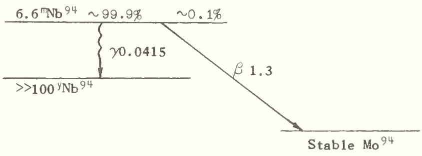
>93 / 41

τ	30^m	49B29
β^-		49B29
Mo-d-α	chem	49B29
Sample enriched in heavy Mo		
Not observed in fission		49C20

94 / 41 53

τ_1	6.6^m	40S6
τ_2	$>>100^y$ for K capture	48G2



β^-	~0.1%	1.3		46G19
γ		0.0415	sc	49C1
Nb K_α X-ray				48G2

6.6^mNb produced by

Nb-n-γ		48G2
	σ	49H5
Nb-d-p		46K1, 46W2

Mo^{96}-d-α produces no detectable Geiger activity 49B29

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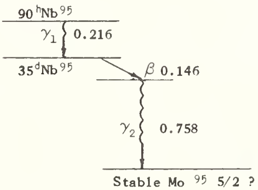
τ_1	90^h	50s3, 49H31
	73-78	50J1



No Nb K X-ray 49B29

90^hNb produced by

Fission	chem	50e4
Mo^{97}-d-α	chem	49B29
90^hyield >> 35^dyield		
Mo-d-α		50J1
Zr-d		50J1
d (1.4%) 65^dZr		49H31
d (2%) 65^dZr		50e2

τ_2	35^d		49H31, 43E8
	38.7		45P1
β^-	0.146	s	49H31
	0.15	s	50n2
	0.14	a	48M1
γ_1	0.216	sc	49H31
	α~∞		49H31
	0.24	sc	50l3
	0.23	sc	50n1
γ_2	0.758	s	49H31
	α~0.002		49H31
	0.75	s	47R1
	0.77	s	50n2
	0.92	a coin	48M1
βγ coincidences			48M1
γγ coincidences also observed			48M1

35^dNb produced by

Fission	chem	49G13, 50g14
Mo^{97}-d-α	chem	49B29
Mo-d-α		50J1
d (98.6%) 65^dZr		49H31
d (98%) 65^dZr		50b1, 50e2
d 65^dZr		46G6

96 (41, 55)

τ	23.3^h		49K19
β^-	0.67	a	49K19
γ	1.03	a	49K19
Zr^{96}-p-n	chem		49K19

97 (41, 56)

τ	76.0^m		48P3
	75		40G4, 50K3
β^-	1.4	a	50K3
γ	0.78	a	50K3
Level	~0.8		Zr^{97}
Fission	chem		40G4, 41H5
Mo-γ-p	relσ, chem		47H4, 48P3
Mo-n-p	chem		40S8
	d 17^hZr		40G4, 40S8, 41H5

?

τ	42^d		45W2
Nb-e^-			45W2
	Not produced by		
Mo^{95}-d-α	chem		49B29

?

τ	21.6^h		46W2
β^-	1.2	a	46W2
γ	0.6	a	46W2
Nb-d-t			46W2
threshold ~ 5-6			46W2
Excitation curve similar to that of 10.1^dNb			46W2
	Not produced by		
Zr^{92} or Zr^{91}-d			49K18
Mo^{94}-d-α	chem		49B29
Nb-slow n's			46W2

No Nb found in fission with τ between 10^m and 10^h, except $76^m Nb^{97}$ 49C20

Neutron Cross Sections for Natural Element

σ_s	coh	5.2	49S12
σ_s	bound	7.4	49S12
		$E_n = 0.025$ev	
σ_a		2.40	49P3
		3.01	49H2
σ_s		6.7	37G1
σ_t	MoO_3	18.5	46D13

91 (Z = 42, N = 49)

τ_1	15.5^m		49D10, 48W13
	17		39B5, 38S3, 49K19
β^+	3.7	a	49D10
	2.65	cc	40S8
No γ			49D10
Mo^{92}-n-2n			49K19
Mo-n-2n	chem		37H4, 40S8
threshold ~12-13			38S14
Mo^{92}-γ-n	chem		49D10
threshold = 13.5			45B12, 49D10
threshold = 13.28 for 15^mMo and 75^sMo			49H17
Mo-γ-n	relσ		48W13
Mo-d-p			46W2
Nb-d-2n			46W2
Not produced by Mo^{94}-fast n's			49K19

τ_2	75^s		49D10
	73		48W13
β^+	2.6	a	49D10
γ	0.3	a	49D10
Mo^{92}-γ-n	chem		49D10
Mo-γ-n	relσ		48W13
Not d 15.5^mMo			49D10

92 (Z = 42, N = 50)

	15.05%		49H3
	15.8		46W3
Levels	1.1		Nb^{92}
	1.5		Tc^{92}
	σ's		
(pile n,γ) 6.7^hMo		<0.001	47S33

93 (Z = 42, N = 51)

τ_1	6.75^h	49K27
	6.7	46K1
	7	44D9
IT		49K27
γ	0.3	49K27
	α very large	49K27
	0.7, $\alpha = 0.005$	49K27
	1.7, $\alpha = 0$	49K27
γ's in cascade		49K27
Mo K_α X-ray		49K27
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^{92}-n-γ		49D10, 49B44
$\sigma < 10^{-5}$		49B44
Mo^{94}-n-γ		49D10
Mo^{94}-γ-n		49D10
Mo^{92}-d-p		49K27

τ_2	$< 2^y$	49B44
γ		49B44
e^-		49B44
Nb K_α X-ray		49B44
Level	2.4 ?	Tc^{93}
Mo-n-γ		49B44

94 (Z = 42, N = 52)

	9.35%	49H3
	9.1	46W3
Levels	?	Tc^{94}

95 (Z = 42, N = 53)

	15.78%		49H3
	15.7		46W3
I	1/2 ?	S	34G2
	5/2 or 7/2	S	50A3
Levels	?		Tc^{95}, Nb^{95}
	σ's		
(th n, γ)	13.4		49P3

96 (Z = 42, N = 54)

	16.56%	49H3
	16.5	46W3
Levels	?	Tc^{96}, Nb^{96}
	σ's	
(th n, γ)	1	49P3
Mo-γ-n		49H17
threshold = 7.1, n's observed		

97 (Z = 42, N = 55)

	9.60%		49H3
	9.5		46W3
I	1/2 ?	S	34G2
	5/2 or 7/2	S	50A3
Level	0.78		Nb^{97}
	σ's		
(th n, γ)	2.3		49P3

98 (Z=42, N=56)

	24.00%	49H3
	23.8	46W3
Level	?	Tc^{98}
σ's		
(th n,γ) 68^hMo	0.4	47S33
(th n,γ)	<0.7	49P3
(~1Mev n,γ) 68^hMo	32mb	49H5

99 (Z=42, N=57)

τ	68.3^h	49C7
	67	50k4, 39S4
	63.5	48W13
	64	40S8

β^-		0.24	a	48M15
	~25%	~0.5	s	49M45
		1.03	a	48M15
		1.2	a	50k4
		1.22	s	49M45
βγ coincidences only for 0.24β				48M15
γ		0.141	s	49M45
	weak	0.181	s	49M45
	weak	0.360	s	49M45
	strong	0.726	s	49M45
Each 0.726 γ followed by 0.141γ				49M45
Fission	chem			49G13, 50k4, 41H7, 48SP
Mo^{98}-n-γ				47M20
Mo-n-γ	chem			40S8, 48M15
	σ			47S33
Mo-γ-n	relσ			48W13

γ	0.24 *	s	46M6
	0.75	s	46M6
	* Possibly due to impurity		46M6
	0.139	s	49C7
	0.167	s	49C7
	0.179	s	49C7
	~0.78	a	49C7
γ's of 0.770, 0.815, 0.840 found			47S12
Note γ's of Tc^{96}			
Tc K X-ray			47E1
Mo-d-p			39S4, 46W2, 47E1
Zr-α-n			47E1
Mo-n-2n	chem		40S8
	p (~10%) 5.9^hTc		39S4
	p (~90%) long Tc		39S4

100 (Z=42, N=58)

	9.68%	49H3
	9.6	46W3
σ's		
(th n,γ) 14.6^mMo	0.5	47S33
(th n,γ)	<1.0	49P3
(~1Mev n,γ) 14.6^mMo	15mb	49H5

101 (Z=42, N=59)

τ	14.6^m		41M3
	14		42H6
β^-	1.0 ?	a	42M4
	2.2	a	42M4
	1.9	a	40S8
γ	~0.3 ?	a	42M4
	0.9	a	42M4
Fission	chem		41H7
Mo-n-γ	chem		40S8, 41M3
	σ		47S33
Mo^{100}-n-γ			47M20
Not produced by Mo-fast n's			40S8, 41M3
	p 15.0^mTc		40S4, 42M4, 41H7, 41B2

102 (Z=42, N=60)

τ	12^m	41H7
	11	49B44
β^-		41H7
Fission	chem	49B44, 41H7
	p < 25^sTc	41H7

103 42 61	104 42 62	105 42 63
		τ ~5^m 47S34 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 ? (Z 43)

τ		47^m		48K26
K				48K26
e^-	5%	0.54	a	48K26
γ	15%	1.5	a	48K26
Mo K_α X-ray				48K26
Mo^{92}-p-n		chem, relσ		48K26
Mo^{92}-d-2n		chem, relσ		48K26

92 (Z 43, N 49)

τ		4.5^m		48M18, 49B45
K	20%			49B45
β^+		3.5	a	49B45
γ		1.5	a	49B45
$\beta^+/\gamma \sim 1$				49B45
Mo^{92}-d-2n		chem		49B45
threshold $\sim$ 10				49B45
		chem, relσ		48K26
Mo^{92}-p-n		chem, relσ		48K26
No Mo daughter				49B45

93 (Z 43, N 50)

τ		2.7^h		39D1, 48M18, 48K26
K	93%			48K26
β^+		0.85	a	49B45
	7%	0.83	a	48K26
γ		2.44	a	49B45
		2.0	a	48K26
$e^-/\beta^+ = 0.05$				48K26
Mo K_α X-ray				48K26
Mo^{92}-p-γ		chem, relσ		48K26
Mo^{92}-d-n		chem, relσ		48K26
		chem		48M18
Mo-d-n		chem		39S4
Not produced by Nb-α				48K26
Not p 6.7^hMo				49B45

94 (Z 43, N 51)

τ_1		53^m		47G3
IT				48H5
γ		0.0334	sc	48H5
K X-ray				49M44
Mo-p-n				48H5
Mo^{94}-d-2n				48M19

τ_2		$< 53^m$		48H5
K	65%			47G3
β^+		2.47	s	47G3
		2.5	a	48M19
γ		0.380	s	48H5
		0.873	s	48H5
		1.48	s	48H5
		1.85	s	48H5
		2.74	s	48H5
		0.9	a	48M19
Mo K X-ray				48H5
d 53^mTc				48H5

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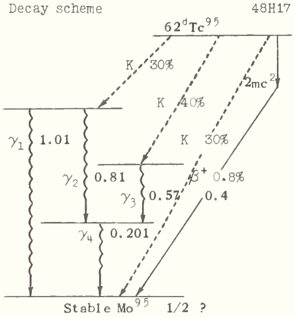
95
43 52

τ_1	20.0^h		48E3,48M19
K			48E3,48M2
γ strong	0.762	sc	48M2
	0.78	a	48E3
	0.8	a	48M19
	0.932	sc	48M2
γ	1.071	sc	48M2
X-ray			48E3,48M18
Level	0.95		Ru^{95}
Mo^{92}-α-p	chem		48E3
Mo-p-n	chem		48E3
Mo^{95}-d-2n	chem		48M19
Mo-d-n	chem		39S4
	d 1.65^hRu		48E3

τ_2	62^d		39C2,49B45
	52		47E1

Decay scheme 48H17



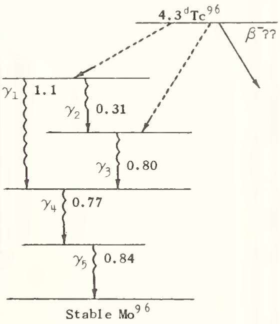
Mo^{95}-d-2n	.chem	48M6
Mo-d-n	chem	39C2,46E1
Mo-p-n	chem	47E1

β^+	0.8%	0.4	cc	48H17
γ_1	~3%	1.017	sc,s	48H17
γ_2	~30%	0.81	sc,s	48H17
		0.8	a	48M6,47E1
γ_3	40%	0.570	sc,s	48H17
γ_4	70%	0.201	sc,s	48H17
		α=0.044		48H17
		0.2		48M6,47E1
$\gamma_3\gamma_4$, $\gamma_2\gamma_4$		coincidences		48H17
γ_4 twice as intense as γ_2				48M26
Mo K X-ray				39S4

96
43 53

τ	4.3^d	47G4,47E1
	4.2	48M6

Decay scheme 48M2



K				47E1
No β^+				48M2
β^- ??*		0.82	s	48M2
		0.64	a	47E1
γ_1	weak	1.119	sc,s	48M2
γ_2	weak	0.312	sc	48M2
γ_3	strong	0.806	sc,s	48M2
		0.8	a	48M6
γ_4	strong	0.771	sc,s	48M2
γ_5	strong	0.842	sc,s	48M2
γ		0.9	a	47E1

* Possibly due to scattered electrons 48M2

$\gamma\gamma$ coincidences 48M2
Order of γ_4, γ_5 unknown 48M2

γ's of 0.815, 0.770, 0.840Mev found from spectrometer measurements. (Attributed to Mo^{99}.) 47S12

Mo X-ray 47E1

Mo^{96}-d-2n	chem	48M6
Nb-α-n	chem	47E1
Mo-p-n	chem	47E1
Mo-d-n	chem	47E1

97 (Z = 43, N = 54)

τ_1	90^d	39C2, 48M6	τ_2	$>10^{3y*}$		49B42
	91	41H1		$>15*$		41H1
	95	47E1				
IT		41H1				
			* From decay of parent			
γ	0.097 sc	41H1				
	0.097 ac	48M6				
	α very large	48M6				
	0.108 ac	47E1				
	α large	47E1				
Tc K X-ray		41H1				
Mo^{97}-d-2n	chem	48M6				
Mo-d-n	chem	37C3, 39C2				
Mo-p-n	chem	47E1, 47G4				
	d 2.8^dRu	47M5, 50s28		d 90^dTc		49B42
	p long Tc	49B42				

98 ? (Z = 43)

τ	2.7^d		50g21
	2.8		48M19
β^-	0.75	a	50g21
	1.3	a	48M19
γ	1.0	a	50g21
	0.9	a	48M19
Mo^{98}-d	chem		48M19
Ru-n	chem		50g21

98 ? (Z = 43)

τ	41^m		49B42
K			49B42
γ			49B42
Mo^{98}-d	chem		49B42

99 (Z = 43, N = 56)

τ_1	5.9^h		50g4
	6.6		39S4
IT			39S4
γ_1	0.0018	pc	49M45
γ_2	0.1412	sc	49M45
	$\alpha = 0.1$	K/L = 8.1	49M45
$\gamma_1\gamma_2$ coincidences			49M45
No $\gamma\gamma$ or γe^- coincidences			48M15
Tc K X-ray			39S4
Fission	chem		40S2, 39H8, 48SP
Mo^{98}-d-n	chem		49B42
Ru-n-p	chem		46B21
	d (~10%) 68^hMo		39S4, 41H7
	p long Tc^{99}		39S4, 41H7

τ_2	$\sim 3\times10^{5y}$		50s4
	9.4×10^5		47M15
β^-	0.30	s	49K34
	0.3	a	50I4, 50s4
	0.32	a	47M15
No γ			49K34, 47M15
Fission	ms		47I4
	chem		50I4, 50s4
Mo-n-$\gamma\beta$			47M15
	d (~90%) 68^hMo		39S4, 41H7
	d 5.9^hTc		39S4, 41H7

100 (43, 57)				101 (43, 58)				102 (43, 59)			
τ	80^{s}		48M18	τ	15.0^{m}		49B42	τ	$<25^{s}$		49B44
					14.5		48P3		$<1^{m}$		41H7
					14.0		41M3				
					16.5		48M33				
β^-	2.3	a	48M18					β^-	3.7	a	49B44
				β^-	1.3	a	42M4		~5	a	41H7
γ	0.6	a	48M18		1.2	a	40S8				
								γ			41H7
				γ	0.3	a	42M4				
				Level			Mo^{101}				
Mo^{100}-d-2n			48M18	Fission	chem		41H7	Fission			41H7
				Ru-γ-p	rel yield		48P3				
					d 14.6^{m}Mo		39S4, 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						

Neutron Cross Sections for Natural Element				95 44 51			
	$E_n = 0.025$ev						
σ_a	2.5	49P3		τ	1.65^h		48E3
	6.2	49H2			1.6		48M33
σ_s	5.6	37G1		K			48E3
σ_t	7.3	47GIF, 50Ad		β^+	1.1	a	48E3
				γ	0.95	a	48E3
	Resonances						
E_o				K X-ray			48E3
9.4ev		47GIF, 50Ad					
Others		47GIF, 50Ad					
	Graphs Available						
σ_t	0.015-500ev	50Ad, 47GIF		Mo^{92}-α-n	chem		48E3
				Ru-n-2n			48E3
				Ru-γ-n			48M33
					p 20^hTc		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}
	σ's								
(th n,$\gamma\beta$) 90^dTc	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^dTc		47M5, 50s28			

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		46S11		18.27%	44E1
				41		46B28			
				40		50g5			
				45		48M33			
			β^- ~50%	0.350	s	48H36			
			~50%	0.665	s	48H36			
			97%	0.2	a	50s5			
			3%	0.8	a	50s5			
			γ	0.239	sc	48H36			
				0.312	sc	48H36			
				0.56	a	50g5, 46G25			
				0.54	a	50s5			
			No $\beta\gamma$ angular correlation			49G21			
σ's							σ's		
(th n,γ) 42^dRu	1.2	47S33	Fission	chem		42N3, 50g6, 49G13	(th n,γ) 4.4^hRu	0.7	47S33
			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^mRh		48H36, 50g5			

105 (44 61)	106 (44 62)	107 (44 63)
τ 4.4^h 46B28 4.5 50s6, 50s7	τ 1.0^y 50g5 290^d 48G4	τ 4^m 43B3, 50g6
β^- 1.3 a 46B28 1.5 a 43B3 1.4 a 50s7	β^- 0.041 s 49M46	β^- ~4 a 43B3
γ 0.75 a 50s7 0.7 a 46B28		
No βγ angular correlation 49G21		
Ru-n-γ chem 46S11, 46B28 σ 47S33 Ru-d-p chem 50s8, 46S11, 46B28 Fission chem 49G13, 43B3, 41S6, 48SP d short Mo 43B3 d short Tc 43B3 p 36.5^h Rh 46B28, 46S11	Fission ms 48H25 chem 50g7, 49G13 p 30^s Rh 50g5	Fission 43B3 p 24^m Rh 50g6, 43B3

Neutron Cross Sections for Natural Element

	$E_n = 0.025$ ev		
σ_a	150		49P3
	171		49H2
σ_s	~6		49M31
σ_t	155		44F12
	145		49M31

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	49M31
	0.015-5 ev	50Ad, 47GIF, 47S31

99 (Z 45, N 54)

τ	5^h	49E4
β^+	0.6	49E4
γ, e^-		49E4
Ru-p-n		49E4
Ru-α-p		49E4

100 (Z 45, N 55)

τ		19.4^h		48L3
		21		50s29
K				48L3
β^+	5%	3.0	s	48L3
	25%	1.3		49E4
γ		1.2	a	48L3
		1.8	a	50s29
		1.55		49E4
e^-		0.6	s	48L3
Ru K X-ray				50s29, 49E4
Levels		0.09		Pd^{100}
		1.8		
Ru-d-n		chem		50s29
	d 4^dPd			48L3

101 (Z 45, N 56)

τ	4.3^d		48L3
	4.7		49E4
	5.9		50s30
K			48L3, 49E4
No β^+			48L3
γ	0.35	a, s	48L3
	α ~0.10 ?		48L3
	0.13	sc	49E4
	0.08	sc	49E4
K X-ray			48L3, 49E4
e^- possibly from 0.35γ			48L3
Ru-d-n	chem		50s30
Ru-p-n			49E4
Ru-α-p			49E4
d 9^hPd			49E4, 48L3

102 (Z 45, N 57)

τ	215^d		47H5
	210		48M33, 41M2
K ?			50s31
β^+	1.3	a	50s31
	1.13	cc	45H1
β^-	1.04	cc	45H1
$\beta^-/\beta^+ = 1.2$			41M2
γ	~0.46	a	50s31
	probably annihilation		50s31
Ru K X-ray			50s31
Rh-n-2n	chem		41M2
Ru-d-n			50s31
Rh-γ-n			48M33
Not produced by Fission			50s10

$^{103}_{45}Rh_{58}$

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 57^mRh by Rh-γ-γ		
	only line found	48H36	1.26		45W3
	0.03 a	50g5	1.64		
	0.042 a	47F3	2.02		
	0.0399 sc	48G19	2.37		
	0.0427 sc	48G19	2.71		
Rh K X-ray		47F3, 47H5, 48G19, 50g5	3.05		
			σ's		
			(th n,γ) 4.3^mRh	12	47S33
Fission		50g5	(th n,γ) 44^sRh	137	47S33
Rh-n-n	σ	47F3	(~1Mev n,γ) 4.3^mRh	0.016	49H5
Rh-e^--e^-		45W3	(~1Mev n,γ) 44^sRh	0.103	49H5
Rh-γ-γ		45W3	(Ra-Be n,n) 57^mRh	~1	47F3
Rh-p-p	relσ	48H36	For other fast n values see		48WH
Rh-d-pn		48H36	(50Mev d,2n) 17^dPd	0.0024	48L3
			(50Mev d,4n) 9^hPd	0.24	48L3
	d 17^dPd	47M12	(50Mev d,5n) 4^dPd	0.28	48L3
	d 42^dRu	48H36, 50g5			

$^{104}_{45}Rh_{59}$

$τ_1$	4.34^m	39R2	$τ_2$	44^s	38P2
	4.37	39C3		42	39C3
	4.3	47F3			
IT		38P2	$β^-$	2.6 s	47H5
				2.5 a	40M9
e^-	0.070 sc	47H5		2.3 cc	39C3
	0.087 ac	47F3			
	0.070 ac	43A2	γ	0.041 a	47C11
				0.18 a	47C11
	0.046 sc	40O3		0.95 a	47C11
	0.066 sc	40O3			
	0.086 sc	40O3			
γ	0.080 a	43A2			
	α~0.65	43A2			
	~0.05 a	43S4			
Rh K X-ray		43A2			
Rh-n-γ	σ	47S33	Rh-n-γ	σ	47S33
Pd-γ-p	relσ	47H4	Ru-p-n		36L1
Ru-p-n		44D9	Pd-γ-p	relσ	47H4
				d 4.3^mRh	47F3, 38P2
	p 44^sRh	47F3, 38P2			

$^{105}_{45}Rh_{60}$

τ	36.5^h		50s6, 50s11
	37		46B28
	34		41N2
$β^-$	0.78	a	46B28
	0.60	a	50s11
	0.6	a	48K1
γ	0.33	a	50s11
	α large		50s11
Level	0.7		Ru^{105}
Ru-d-n			50s11
Rh-t-p	chem		48K1
Pd-γ-p			48P3
Fission	chem		46PP
	d 4.4^hRu		46B28, 46S11

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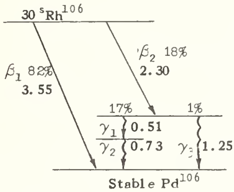
106
45 61

τ		30^s		50g5



β_1^-	82%	3.55	s	47P7
		3.5	a	49J3
		3.9	a	50g5
β_2^-	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 48B18

d 1.0^y Ru 50g5

107
45 62

τ	24^m		43B3
	26		50g6
β^-	1.2	a	43B3
γ ?			50g6

Fission chem 43B3

d 4^m Ru 50g6, 43B3

108 ?
45 63

τ	9^h		50b4
β^-	~1.3	a	50b4
γ	0.8	a	50b4

Fission chem 50b4

109
45 64

τ	$< 1^h$	50s12

No Rh with τ between 10^d and 100^y found in fission 50s10, 50s13

Neutron Cross Sections for Natural Element	100 (46 54)	101 (46 55)
σ_s coh 5.0 49S12	τ 4.0^d 48L3	τ 9^h 48L3
σ_s bound 4.8 49S12		
$E_n = 0.025$ev; σ_a 6.6 49P3; 8.8 49H2	K 48L3	K ~90% 48L3, 49E4
	γ 0.09 a 48L3; 1.8 a 48L3	β^+ ~10% 2.3 s 48L3; ~10% 0.53 49E4
σ_s 3 37G1	X-ray 48L3	No γ, no e^- 48L3
Resonances: E_o Γ; 24ev 0.14 49G9; Attributed to Pd^{108} 49G9	Relative abundances of Pd^{98} Pd^{99}, Pd^{100}, Pd^{101} <0.0007% 49D7	X-ray 48L3
	Rh-d-5n chem 48L3	Rh-d-4n chem 48L3; Ru-α-n 49E4
	p 19^hRh 48L3	p 4.3^dRh 49E4, 48L3

102 (46 56)	103 (46 57)	104 (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}
		σ's (6.6Mev p,n) 0.018 39E2
	Rh-d-2n chem,σ 48L3; Rh-p-n 47M12; Pd-n-γ 46B19	
	p 57^mRh 47M12	

105
46 59

	22.6%		36S4
Levels	0.33		Rh^{105}
	?		Ag^{105}
	σ's		
(6.6Mev p,n)		0.037	39E2

106
46 60

	27.1%		36S4
Levels	0.73 or 0.51		Rh^{106}
	1.25		Rh^{106}
	?		Ag^{106}
	σ's		
(6.6Mev p,n) $8.6^{d}Ag^{106}$		0.0013	39E2
threshold = 3.9–4.3			39E2
(6.6Mev p,n) $24.3^{m}Ag^{106}$		0.055	39E2
threshold = 3.8			39E2

107
46 61

τ	7×10^{6} y		49P17
	$>3\times10^{8}$		50g8
	$>8.6\times10^{7}$		50I5
β^-	~0.035	a	49P17
Fission	chem		49P17

108
46 62

	26.7%		36S4
	σ's		
(th n,γ) 13^{h}Pd		11	47S33
(0.9Mev n,γ) 13^{h}Pd		0.21	49B4
(6.6Mev p,n) 2.3^{m}Ag		0.081	39E2

109
46 63

τ	13.1^{h}		48W13
	12.7		48P3
	14.1		48M33
	13		50s12
β^-	0.95	s	49S23
	1.0	a	46H4
No γ			50s12
No delayed βγ coincidences			49M26
Pd-n-γ	ms		46R3
	σ		47S33
Pd-γ-n	relσ		48W13, 48P3
Pd-d-p	chem, f		37K1
Ag-n-p			38F1
Ag-d-2p			46H4
Fission	chem		50s12, 49G13
	p 39^{s}Ag		49S23, 41S6

110
46 64

	13.5%		36S4
	σ's		
(th n,γ) 26^{m}Pd		0.39	47S33
(0.9Mev n,γ) 26^{m}Pd		0.13	49B4

111 (46, 65)			112 (46, 66)			
τ	26^{m}	41S6	τ	21^{h}	50s12	
	17	37K1		17	41S6	
β^-	3.5 a	43B3	β^-	0.2 a	50s12	
			No γ		50s12	
Pd-d-p	chem	37K1				
Pd-n-γ	chem	37K1	Fission	chem	49G13, 48SP	
	σ	47S33				
Fission	chem	40N3, 41S6, 48SP				
	p 7.5^{d}Ag	37K1, 41S6		p 3.2^{h}Ag	40N3, 41S6, 50s12	

Neutron Cross Sections for Natural Element

σ_s coh	4.6	49S12
σ_s coh(Ag^{107})	8.7	49S12
σ_s coh(Ag^{109})	2.3	49S12
σ_s bound	6.6	49S12

$E_n = 0.025$ev

σ_a	60	49P3
	89	49H2
σ_s	6	48WH
σ_t	65	46H33

Graphs Available

σ_t	0.015-1,000ev	46H33, 47R6, 47GIF
	0.02-1.6Mev	49B28, 50Ad
	1-40Mev	50Ad
	0.025-11Mev	47GIF

Resonances

E_o	$\sigma_o\Gamma^2$	Γ	
5.1ev	300		47R6
5.1		0.12	49G9
5.6		~0.7	48C24
Assigned to Ag^{109}			49G9, 48C24
23		1-4	48C24
16	~24		47R6
Assigned to Ag^{107}			48C24
45	~700		47R6
90 Assigned to Ag^{109}			48C24
> 115			49H16
> 300			49H16

E_n = 1Mev

σ_t	~6.5	See graphs

$^{102}_{47}Ag_{55}$ or $^{104}_{47}Ag_{57}$

τ	73^m	39E2
K		48L4
β^+		48L4
Pd-p-n	yield	39E2
Sb-d		48L4

$^{103}_{47}Ag_{56}$

$^{104}_{47}Ag_{57}$ or $^{102}_{47}Ag_{55}$

τ	16.3^m	39E2
β^+ ?		39E2
Pd-p-n	yield	39E2

$^{105}_{47}Ag_{58}$

τ	45^d		47B16, 39E2
	40		49G24
K			39E2
γ	0.282	s	42D3
	0.345	s	42D3
	0.430	s	42D3
	0.650	s	42D3
	> 1.0	s	42D3
	0.29	s	39E2
	0.42	s	39E2
	0.51	s	39E2
	0.62	s	39E2
K X-ray			39E2
Pd-p-n	f		39E2
threshold ~4			39E2
Rh-α-2n			47B16, 47L20
threshold = 16.2			47B16

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47 59

τ_1	8.6^d		49G24
	8.2		38P3
K			44H1, 38F1
γ	0.505	s	42D3
	0.72 ?	s	42D3
	1.06	s	42D3
	1.63	s	42D3
	0.69	s	39E2
	1.06	s	39E2
$\gamma/X \sim 3$			39E2
$e^-/X = 0.2$			39E2
K X-ray			39E2
Pd-p-n	f		39E2
threshold = 3.9			39E2
Rh-α-n	f		47B16, 44H1
Ag-n-2n	chem		38P3
Cd-n-p	chem		38P3
Pd-d-n	chem		38P3

τ_2	24.5^m		38P3, 38D1
	24.3		48M33
	25		39E2
β^+	2.04	a	38F1
No γ			38F1
Pd-p-n	f		39E2
threshold = 3.8			39E2
Pd-d-n	chem		38P3
Ag-n-2n	chem		38P3
threshold = 5-7			38S14
Cd-n-p			38P3
Ag-γ-n			48M33, 39B5
threshold = 9.5			45B12
Ag-e^--e^-n	σ		48S3
threshold = 9.5			48S3
Rh-α-n			47B16, 39K1
threshold $\sim$ 11.5			47B16

107
47 60

τ	44.3^s		47B5
	40		41H3
IT			40A1
γ	0.0939	sc	47B5
	$\alpha = 16$, K/L = 0.92		47B5
	0.093	sc	39V2, 41H1
	$\alpha = 99$, K/L = 1		41H1
Ag-n-n			44F1
Ag-γ-γ			45T2, 45W1
threshold = 1.18			45W1
Ag-e^--e^-			45W1
	d 6.7^hCd		46H4, 47B5

	51.35%		48W9
I	1/2	S	49C3, 37J1
μ	-0.086	S	49C3
Levels	0.094		$44^s Ag^{107}$
	0.94		Cd^{107}
Levels found in production of 44^sAg 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^mAg	44		47S33
(th n,γ)	30		48H38
($\sim$1Mev n,γ) 2.3^mAg	0.13		49H5
Other fast n values			49B4, 48WH
(16Mev e^-,e^-n) 24.5^mAg	5.4×10^{-4}		48S3
Graphs Available			
(n,γ) 2.3^mAg	0.003-6Mev		46L7, 47GIF, 50Ad

108
47 61

τ	2.33^m		48P3
	2.3		48M33, 39B5
	2.4		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
	relσ		48P3, 48W13
Ag-e^--e^-n	σ		48S3
threshold = 9.3			48S3
Ag-d-p	chem		40K2
Cd-n-p	chem		38P3

$^{109}_{47}Ag_{62}$

τ	39.2^s		47B5
IT			41H3
γ	0.087	sc	46H4, 49S23
	$\alpha = 11.5$, K/L = 1.3		49S23
	0.0890	sc	47B5
	$\alpha = 19$, K/L = 1		47B5
Ag-n-n			44F1
Ag-γ-γ			45W1
Ag-e^--e^-			45W1
	d 330^dCd		46H4, 41H3
	d 13^hPd		49S23, 41S6

	48.65%		48W9
I	1/2	S	49C3, 37J1
μ	-0.159	S	49C3

For possible levels see Ag^{107}

σ's

(th n,γ) 24.5^sAg	97	47S33
(th n,γ) 270^dAg	2	47S33
(th n,γ)	84	48H38
(~1Mev n,γ) 270^dAg	0.23	49H5
Other fast n values		49B4, 48WH
(16Mev e^-, e^-n) 2.3^mAg	7.9×10^{-4}	48S3

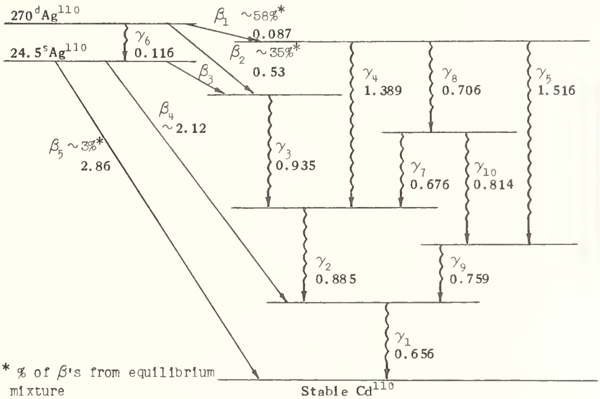
Graphs Available

(n,γ) 24.5^sAg 0.003-6Mev 46L7, 47GIF, 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

$\beta\gamma$ 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 $3\times10^{-8\,s}$ and $10^{-3\,s}$ 49M26

$270^d Ag^{110}$ in equilibrium with $24.5^s Ag^{110}$

β_1^- ~58%	0.087	s	50S1
	0.09	a	49M38
	0.09	cc	49E1
β_2^- ~35%	0.530	s	50S1
	0.57	a	49M38
	~0.59	cc	49E1
β_3^- weak	soft		50S1
	0.19 ?	a	49M38
β_4^-	~2.12	s	50S1
β_5^- ~3%	2.86	s	50S1
	>2	a	49M38

Possibly one or more very weak β's 50S1

No β^+ 50S1

$\beta^+/\beta^- < 0.002\%$ 49E1

No K X-ray 47D8

γ_1	100% *	0.656	sc, s	50S1
		$\alpha = 2.5\times10^{-3}$		50S1
	100% *	0.66	sc	47R1
		0.66	a	49Y2
γ_2	81% *	0.885	sc, s	50S1
		0.9	a	49Y2
	110% *	0.9	s	47R1
γ_3	31% *	0.935	sc, s	50S1
γ_4	33% *	1.389	sc, s	50S1
	20% *	1.4	s	47R1
γ_5	17% *	1.516	sc, s	50S1
		1.48	a	49M38
γ_6	weak	0.116	sc	50S1
		α large, K/L ~1.3		50S1
γ_7	weak	0.676	sc, s	50S1
γ_8	weak	0.706	sc, s	50S1
γ_9	weak	0.759	sc, s	50S1
γ_{10}	v. weak	0.814	s	50S1
γ		$1.63 < E_\gamma < 2.3$		49D23

* relative %

$24.5^s Ag^{110}$

β^-	2.6	a		46H6
	2.8	cc	KU	36G1

$24.5^s Ag^{110}$ produced by

Ag^{109}-n-γ		44F3
Ag-n-γ	σ	47S33
E_γ(max) = 6.5		49K15
Cd-γ-p	relσ	47H4
Cd-n-p		38P3

Not produced by

Pd-6.5Mev p 39E2

$270^d Ag^{110}$ produced by

Ag^{109}-n-γ		46G15
Ag-n-γ	σ	47S33
Ag-d-p	chem	44H2

Resonance for production of 270^dAg by n-γ same as that for production of 24.5^sAg 46G4

889592 O - 50 - 17

111 (47 64)				112 (47 65)				113 (47 66)			
τ	7.5^d		38P3	τ	3.2^h		49D6, 38P3	τ	5.3^h		49D6, 47T13
	7.6		49D6, 50S24								
β^- simple	1.06	s	49H6	β^-	3.6	a	50S12	β^-	2.1	a	49D6
	~0.2	a	50S24		2.2	cc	38P3		2.2	a	47T13
	1.0	a	50S24	γ	0.86	a	50S12	No γ			49D6, 47T13
No γ			38P3								
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, relσ		49D6
Pd-α-p	chem		38P3	In-n-α	chem		38P3	Fission	chem		47T13
Cd-n-p	chem		38P3	Cd-γ-p	chem, relσ		49D6, 47H4				
Cd-γ-p	chem, relσ		49D6, 47H4	Fission	chem		50S12, 49G13, 48SP				
Fission	chem		49G13, 50S24								
Ag-t-p			47K2								
	d 26^mPd		41S6, 37K1, 50S24		d 21^hPd		41S6, 40N3, 50S12				

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

48 CADMIUM Cd

Neutron Cross Sections for Natural Element

	$E_n = 0.025$ ev		
σ_a	3170		49H2
	3500		49P3
σ_s	~6.5		(48WH)
σ_t	2400		See graphs

Resonances

E_o	σ_o	Γ	
0.17 ev	7200	0.115	47R6
0.180	7800	0.122	47Z1
0.178	7250	0.110	47S32
Assigned to Cd^{113}			46M12, 47D2
110 ev			48C24
Assigned to Cd^{116}			48C24

	E_n = 1Mev	
σ_t	~6.7	48H15

Graphs Available

σ_t	0.008-100 ev	47GIF, 47R6
	0.023-15Mev	50Ad, 47GIF

$^{105}_{48}Cd_{57}$

τ	33^m	37P2
	38	48M33
	57	49G24
β^+	1.5	49G24

Cd-n-2n	chem	49G24, 37P2
Cd-γ-n		48M33
Pd-α	chem, relσ	49G24

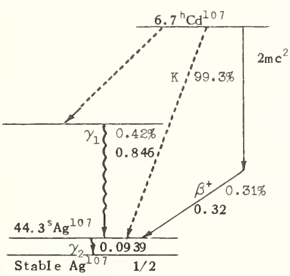
$^{106}_{48}Cd_{58}$

1.22%	49H3, 48W9
1.215	48L5

$^{107}_{48}Cd_{59}$

τ	6.7^h	39D1

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/β^+ = 320, in agreement with Fermi theory 45B4

Ag K X-ray 45E4

Cd^{106}-n-γ		46H4, 46G15
Ag-d-2n	chem	49C29, 41H3
Ag-p-n	chem	39V2, 39D1, 49C29
threshold ~2.4		39D1
Pd-α	relσ	49G24

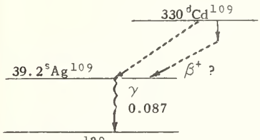
p 44.3^s Ag 46H4, 47B5

$^{108}_{48}Cd_{60}$

0.89%	49H3
0.875	48L5
0.98	48W9

109 (Z 48, N 61)

τ	330^d		46B2
	470		49G24
	158		41H3



β^+ ?			48C23
γ	0.087	sc	46H4, 49S23
	α = 11.5, K/L = 1.3		49S23
	0.089	sc	47B5
	α = 19, K/L = 1		47B5
	$\tau = 39.2^s$		47B5
Cd^{108}-n-γ			46G15, 46H4
Ag-d-2n	chem		49G24, 41H3
Ag-α-pn			46H4
Ag-p-n	chem		45B3
Pd-α	relσ		49G24
p 39.2^sAg			41H3, 46H4

110 (Z 48, N 62)

	12.43%		49H3
	12.39		48L5
	12.35		48W9
Levels	0.66		Ag^{110}
	1.42		
	1.54		
	2.22		
	2.48		
	2.93		

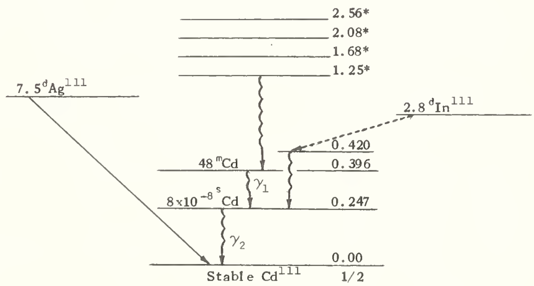
σ's

(th n,γ) 49^mCd	0.2	48G2
(6.9Mev p,n) 65^mIn	0,03	39B3

111 (Z 48, N 63)

τ	48.7^m		44W1
	48.6		49H6
γ_1	0.149	s	49H6
	α large		49H6
	0.146	sc	48H37
	α > 12, K/L ~ 1.8		48H37
γ_2	0.247	s	49H6, 40L7, 49B8
	α ~ 0.1		49H6
	K/L = 5.4		40L7
	α = 0.04, K/L = 6		49B8
	0.238	sc	48H37
	α ~ 0.19, K/L > 10		48H37
	$\tau = 0.08^{\mu s}$		49D26
	τ = 0.09		49M26
Fission	chem		40N3
Cd^{110}-n-γ			48G2, 49M26
	σ		48G2
Pd^{108}-α-n			48H22
Cd^{112}-n-2n			48H22
Ag-α-pn			48H22
Cd-γ-γ			45T2, 44W1
Cd-e⁻-e⁻			44W1
Cd-n-n			48H37

	12.86%		49H3
	12.75		38L5
	12.78		48W9
I	1/2	S	29S1, 33S2, 31S1
μ	-0.65	S	33J2, 36B6



* Levels for production of 48^mCd by Cd-γ-γ and Cd-e⁻-e⁻ 44W1

σ's

(6.9Mev p,n) 2.8^dIn	8mb	39B3

112
48 64

	23.79%	49H3
	24.07	48L5
	24.00	48W9
Level	0.86	Ag^{112}

σ's

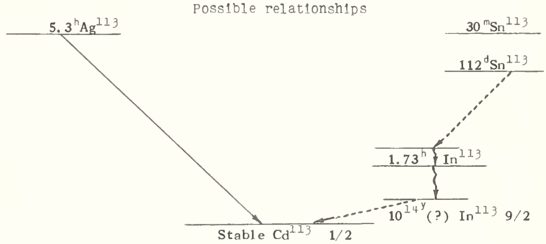
(6.9Mev p,n) 23^{m}In	0.02	39B3

Cd-γ-n n's observed 49H17
threshold = 6.4 49H17

113
48 65

	12.34%		49H3
	12.26		48L5
	12.30		48W9
I	1/2	S	29S1, 31S1, 33S2
μ	-0.65	S	33J2, 36B6

Possible relationships



σ's

(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

(6.9Mev p,n) 1.73^{h}In 0.02 39B3

113 ?
48 65 ?

τ	2.3^{m}	48H22
Cd^{113}-n-n		48H22
Cd-n-γ		47S1
	σ(atomic) = 0.05	47S33

Not produced by
Cd^{112}-n-γ 49G8

?
48

τ	5^{y}	49G24
β^- or e^-	0.45	49G24
No γ		49G24
Cd-d	chem	49G24
Cd- fast n	chem	49G24

114
48 66

	28.81%	49H3
	28.86	48L5
	28.75	48W9
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

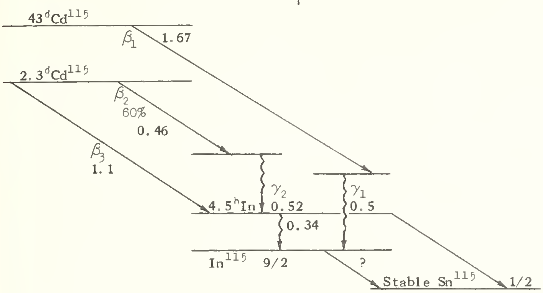
Cd-n-γ

E_γ (max) =	8.7	49M14
	7.0	49K15
	~7.9	49H9

115
48 67

τ_1	43^d	50s27
	44	50g18

τ_2	2.33^d	40L7, 50m6
	2.4	48M33



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

43^dCd^{115}

β_1^-	simple	1.67	s	49H7
		1.75	a	50g18
γ_1		~0.5	a	50s27
γ_1/β_1 ~1				50s27

No delayed coincidences with τ between $3x10^{-8s}$ and 10^{-3s} 49M26

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
48 68

	7.66%	49H3
	7.58	48L5
	7.63	48W9

σ's

(th n,γ) 2.7^hCd	1.4	47S1
(6.9Mev p,n) 54^mIn	0.03	39B3
Resonance at 110ev		48C24

117
48 69

τ	2.72^h		50m8
	2.8		40L7
β^-	1.3 - 1.7	s	40L7

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

$E_n = 0.025$ ev

σ_a	191			49P3
σ_s	2.2			44B6
σ_t	194			44F12
	190			See graphs

Resonances

E_o	σ_o	Γ	$\sigma_o\Gamma^2$	
1.44ev*			~210	47H25
1.44	26,400	0.085		46M18
1.39	>15,000	<0.15		46B26
3.8			~120	47H25
3.7				46M18
8.6			~300	47H25
9.0				46M18

* Scattering resonance also 47L21

Graphs Available

σ_t 0.017-1000 ev 47H25, 46M18, 47GIF

See also 49H16

0.02-1.6Mev 49B28, 50Ad

107 ? (Z = 49)

τ	33^m		49M20
β^+	2	s	49M20
γ			49M20
Cd^{106}-d	chem		49M20
Cd^{106}-p	chem		49M20

Not produced by

Cd^{108}-p	49M20
Cd^{108}-d	49M20

108 (Z = 49, N = 59)

Activity of half-life $< 1^h$, $\beta^+ \sim 2$, γ, produced by Cd^{108}-d and assigned to In^{108}. This activity is daughter of 4.5^hSn. 49M20

Activity of half-life $\sim 5^h$, no β^+, $\gamma \sim 0.65$, produced by Ag-α and assigned to In^{108}. 48G7

109 (Z = 49, N = 60)

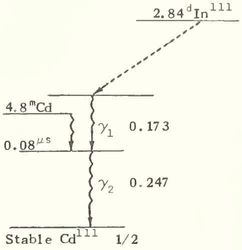
τ	4.3^h		49M20
	5.2		48G7
	6.5		47T2
K			47T2
β^+	0.75	a	49M20
γ	0.5		48G7
$K/\beta^+ = 8$			49M20
Ag-α-2n	ms, chem, f		48G7
	chem, f		47T2
threshold	~13.5		48G7
	~13		47T2
Cd^{106}-α-p	chem		49M20
Cd^{108}-d-n	chem		49M20
Cd^{108}-p-γ	chem		49M20

110 (Z = 49, N = 61)

τ	65^m		48G7, 39B3
	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	~11		48G7
	~12		47T4
Cd-p-n	chem, σ		39B3
Cd-d-2n			40L7
	d 4.5^hSn		48L4

111
49 62

τ 2.84^d 49H6
2.7 38B3, 39C4



Ag-α-2n	ms	48G7
	chem, f	47T4, 48G7
threshold = 15.5		47T4
~15		48G7
Cd^{108}-α-p	chem	49M20
Cd-p-n	chem, σ	39B3
Cd-d-n		39C4
In-n-3n		40L7

$2.84^d In^{111}$

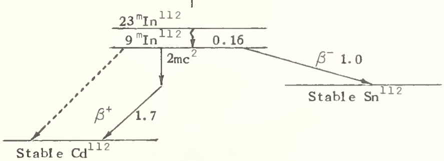
K		40L7
No β^+		48G7
γ_1	0.173 s	49B8, 49H6, 40L7
	$\alpha = 0.18$	49H6
	$\alpha = 0.09$, K/L = 9	49B8
	K/L = 7	40L7
γ_2	0.247 s	49B8, 49H6, 40L7
	$\alpha \sim 0.1$	49H6
	$\alpha = 0.04$, K/L = 6	49B8
	K/L ~ 5	40L7
	$\tau = 0.08^{\mu s}$	49D26
	0.09	49M26
Angular correlation of γ's		49B19

See also Cd^{111}

112
49 63

τ_1 23^m 47T2
20 39B3

τ_2 9^m 47T4



IT		47T4
γ	0.16 a	47T4
	α large	47T4
	0.16 sc	39B3
In K X-ray		47T4
Ag-α-n	chem, f	47T4
threshold ~ 12		47T4
In-n-2n		47T4
Cd-p-n	chem, σ	39B3
Cd-d-n	chem	40L7

K		47T4
β^+	1.7 a	47T4
	1.7 cc	40L7
β^-	1.0 a	47T4
Cd K X-ray		47T4
Ag-α-n		47T4
In-n-2n		47T4
	d $23^m In$	47T4, 48G3

113
49 64

τ_1	1.73^h		40L7
	1.75		39B3
γ	0.39	sc	40L7, 39B3
	$\alpha = 0.7$		39B3
	K/L = 5.4		40L7
In K X-ray			39B3

See Cd^{113} for possible Ag, Cd, In, Sn relationships

Cd-p-n	chem, σ	39B3
Cd-d-n	chem	40L7
In-γ-γ		45D2, 47D3
In-n-n	σ	48C19
d 112^dSn		39B3

	4.16%		49H3
	4.23		48W9
τ_2	$\sim 10^{14y}$*		49C30
I	9/2	M	42H7
		S	37B8
μ	5.46		49Po
		M	42H7, 49T1
q	1.144	M	50M2

σ's

(th n,γ) 72^sIn	2.0	48G2
(th n,γ) 50^dIn	56	47S33
(n,n) 1.73^hIn similar to that for In^{115} (n,n) 4.5^hIn		48C19
(6Mev p,n) 112^dSn	0.03	39B3
(γ,γ) 1.73^hIn same as that for In^{115} (γ,γ) 4.5^hIn		47D3

L capture*	pc	49C30
No K capture*		49C30

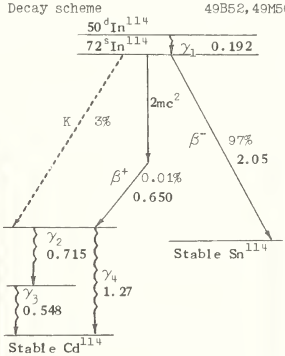
* Preliminary work

114
49 65

τ_1	50^d		49B52, 37L5
	49		48W13, 39B3
γ_1	0.192	s	40L7, 49B52
	$\alpha = 4$, K/L = 1.1		49B52
	$\alpha = \infty$, K/L = 1.0		40L7
	0.191	sc	48C23
	0.190	s	49M50
	0.196	s	49M38
	$\alpha = 9$		49M38

In-n-γ		49M38, 49M50
	σ	47S33
In-γ-n	relσ	48W13
In-n-2n	chem	40L7
In-d-p	chem	40L7
Cd-d-n	chem	40L7
Cd-p-n	chem, σ	39B3
p 72^sIn		40L7, 48G3

Decay scheme 49B52, 49M50



γ_2 and γ_3 in cascade	49B52, 49M38
No $\beta^- e^-$ coincidences	49M38
No $\beta^- \gamma$ coincidences	49M13, 49M38
$\gamma\gamma$ coincidences	49M13
$\beta^+/\beta^- = 10^{-4}$	49B52

τ_2		72^s		48W13, 39B3
K	3%			49B52
	4%			49M50
β^+	0.01%	0.650	s	49B52
β^-		2.05	a	49M38
		1.98	a	48C23
		1.89	a	49M13
γ_2	3%	0.715	s	49B52
		0.722	s	49M50
γ_3	3%	0.548	s	49B52
		0.552	s	49M50
γ_4	~0.03%	1.27	s	49M50
		1.3	a	49M38
Cd K X-ray				49B52
In^{113}-n-γ		σ		48G2
In-γ-n		relσ		48W13
In-n-2n				40L7
	threshold = 12-13			38S14
Cd-p-n		σ		39B3

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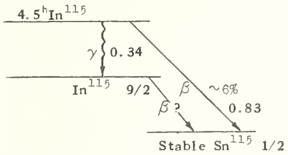
115
49 66

τ	4.50^h	47D3
	4.53	40L7

	95.84%	49H3
	95.77	48W9



Fission	chem	39G2, 40N3
In-d-d	σ	49M7
In-α-α	chem, σ	40R7
In-e^--e^-	σ	49W4
In-γ-γ		43W4, 49W4
In-p-p	chem, σ	39B3
In-n-n		39G2
	σ, f	48C19
Cd-d-n	chem	40L7
	d 2.3^dCd	39C4, 49H7

β^- ~6%	0.83	s	49B53
γ	0.338	sc	40L7, 49B53
	α~1, K/L~5		40L7
	α = 0.33		49B15
	0.337	sc	49H7
β^-/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 In-γ-γ and In-e^--e^-

1.04	49M7
1.42	49M7
2.13	43W4
2.64	43W4

I	9/2	M	42H7
		Z	38M5
		S	34P1, 33J3
μ	5.475		49P0
		M	42H7, 49T1
q	1.161	M	50M2
	1.17	Z	39H12(48F6)

β^- (preliminary result) 49C30

σ's

(th n,γ) 54^mIn	145	47S33
13^sIn	52	47S33
(~1Mev n,γ) 54^mIn	0.18	49H5
13^sIn	0.063	49H5
Other fast n values		49B4, 48WH
(~3Mev n,n) 4.5^hIn	0.36	48C19
(5.8Mev p,p)	3×10^{-5}	39B3
(2Mev d,d)	$< 10^{-6}$	49M7
(16Mev α,α)	3×10^{-4}	40R7
(1.2Mev e,e)	$\sim10^{-9}$	49W4
(γ,γ)		49M7, 47D3

Graphs Available

σ(n,γ) 54^mIn	0.003-6Mev	46L7, 47GIF, 50Ad
	0.5-4Mev	48C19

$^{116}_{49}In_{67}$

τ_1	54.31^m		45R2
	54.05		47G16
	53.93		49S2
β^-	0.85	s	39C4
simple	0.7	$a\beta\gamma$	48M11
γ	0.428	s	42D3
	1.12	s	42D3
	1.31	s	42D3
	2.32	s	42D3
	< 1% above D-γ-n threshold		47W1
	1-10% above Be-γ-n threshold		47W1
Other γ values		cc	40C8
Cd-p-n	chem, σ		39B3
In-d-p			37L5
In-n-γ	σ		47S33

τ_2	13^s		35A1, 39C4
β^-	2.95	a	40L7 (46B27)
No γ			38M2
Cd-p-n			44D9
In-d-p			37L5
In-n-γ	σ		47S33
Sn-γ-p	relσ		47H4

$^{117}_{49}In_{68}$

τ	1.95^h		40L7
	1.90		50m8
β^-	1.73	s	39C4
	1.95	a	50m8
No γ			40L7
Fission			48SP
Cd-d-n	chem		39C4, 40L7
Sn-γ-p	relσ		47H4
	d 2.7^hCd		39G2, 40N3, 40L7

$^{118}_{49}In_{69}$

τ	4.5^m	49D4
β^-	1.5	49D4
γ		49D4
Sn^{119}-γ-p		49D4

$^{119}_{49}In_{70}$

τ	17.5^m	49D4
β^-	2.7	49D4
No γ		49D4
Sn^{120}-γ-p		49D4

Neutron Cross Sections for Natural Element

σ_s coh	4.6		49S12
σ_s bound	4.9		49S12
	E_n = 0.025ev		
σ_a	0.58		49P3
	0.71		49H2
σ_s	4.3		(48WH)
σ_t	4.6	ce	See graphs
	Resonances		
E_o	6 ? ev		48H46
	50 ? ev		48H46
	100 ? ev		48H46
	E_n = 1Mev		
σ_t	6.5		See graphs
	Graphs Available		
σ_t	0.01-200ev		47GIF, 50Ad
	0.013-10,000ev		48H46
	0.023-~14Mev		47GIF
	0-1.5Mev		50Ad
	1-300Mev		50Ad

? ?, Z = 50

τ	4.5^h		49M20, 48L4
	3		39L4
K			49M20, 48L4
Cd^{106}-α		chem	49M20
Sb-d			48L4
	Not produced by		
Cd^{108}-α			49M20
Cd^{110}-α			49M20
Cd-α			39L4
	p <1^hIn		49M20
	p 65^mIn		48L4

111 ?, Z = 50, N = 61 ?

τ	35.0^m		49H10
β^+	1.45		49H10
X-ray			49H10
Cd-α-n		chem	49H10

Enriched material used but details not given. Note Sn^{113}

112, Z = 50, N = 62

	1.01%	49H3
	0.90	48W9
	0.94	48H44
	σ's	
(th n,γ) 112^dSn	1.1	47S33

113, Z = 50, N = 63

τ_1	$30\text{-}33^m$		49N10
	25		39L4
K ?			49N10
β^+	1.2	a	49N10
e^-			39L4
X-ray			49N10
Sn^{112}-n-γ			49N9
Cd-α-n		chem	39L4

τ_2	112^d		49N9
	~100		39B3
	70		39L4
K			39B3
γ	~0.09	a	49N9
	0.085	s	39B3
No γ			47C4
In K X-ray			39B3, 47S33
Sn^{112}-n-γ			49N9
Cd-α-n		chem	39L4
In-p-n		chem, σ	39B3
In-d-2n		chem	47C4
Sn-d-p		chem	47C4
Sn-n-γ		σ	47S33
Sn-γ-n			48M33
	p 1.73^hIn		39B3

See Cd^{113} for diagram of possible relationships

114
50 64

	0.68%		49H3
	0.61		48W9
	0.65		48H44

115
50 65

	0.35%		49H3,48W9
	0.33		48H44
I	1/2	S	49G2
μ	-0.86	S	49G2

116
50 66

	14.28%		49H3
	14.07		48W9
	14.36		48H44
Level	0.7		Sb^{116}
	others ?		In^{116}

117
50 67

τ	14.5^d		49M51
	14		48L4
	13		39L4
γ	0.175	sc	49M52
	$\alpha \sim 1$		49M52
	0.17	a	48L4
	0.159	a,s	49M51
	0.162	a,s	49M51
Sn X-ray			49P10,49M52
Cd^{114}-α-n	chem		49M52
Sn^{116}-d-p	chem		49M52
Sn^{118}-n-2n	chem		49M52
Sn^{117}-n-n	chem		49M52
Cd^{116}-d-n	chem		49M52
Sn^{116}-n-γ			49M51
Sb-d-α			48L4
Cd-α-n	chem		39L4

	7.67%		49H3
	7.54		48W9
	7.51		48H44
I	1/2	S	33S3,34T1
μ	-0.9948		49Po
		I	49P11
		S	34T1
Levels	0.156 ?		Sb^{117}
	~0.5 ?		

118
50 68

	23.84%		49H3
	23.98		48W9
	24.21		48H44
Levels	?		Sb^{118}
σ's			
(th n,γ)$\geq 100^d$ Sn		0.02	49M51
Sn-γ-n (n's observed) threshold = 6.5			49H17

119

50 69

τ	≥100^{d}		49M51
γ	0.069	a, s	49M51
Sn^{118}-n-γ	σ		49M51
Sn-γ-n			48M33

	8.68%		49H3
	8.62		48W9
	8.45		48H44
I	1/2	S	33S3, 34T1
μ	-1.0410		49Po
		I	49P11
		S	34T1

120

50 70

	32.75%	49H3
	33.03	48W9
	33.11	48H44
Level	1.1?	Sb^{120}

σ's

(th n,γ)27^{h}Sn	0.22	47S33
(18Mev d,p)27^{h}Sn	0.02	48L2
(18Mev d,2n)6^{d}Sb	0.1	48L2
(18Mev d,2n)17^{m}Sb	0.1	48L2
(18Mev d,3n)39^{h}Sb	~0.02	48L2

121

50 71

τ	27.0^{h}		49N1
	26.4		49L5
$β^{-}$	0.383	s	49D15
	0.35	a	49L5
	~0.4	a	49N11, 48L2
No γ			49N6, 48L2, 49D15
No e^{-}			49M51

62^{h}Sn activity reported in 46PP probably due to 27^{h}Sn^{121} activity 49S45

Sn^{120}-n-γ	chem	49L5, 49N11, 49D15
Sn^{120}-d-p	chem, σ	48L2
Sn^{122}-n-2n		49L5
Sb-n-p		49N6

Not produced by

Sn^{122}-slow n's	49L5
Sn^{124}-slow or fast n's	49L5

τ	long	49K34
β	0.41	49K34
Sn^{120}-n-γ		49K34

41^{m} activity with β~2.5, γ = 0.25 produced by

Sn^{120}-d	49N6
Assigned to Sn^{121}	49N6

Not produced by

Sn^{120}-n-γ	49N1
Sn^{120}-d-p	49L5

122

50 72

	4.74%	49H3
	4.78	48W9
	4.61	48H44

σ's

(th n,γ)40^{m}Sn	0.30	47S33

123 (50, 73)

τ_1	130^d		49L5,49M51
	136		49N1,46G6
β^-	1.42	s	49B58
	1.3	a	49L5
	~1.5	a	49N6
γ	0.394	s,a	49M51
weak			49N9
No γ			49L5,49N6
No X-ray			49N6
Sn^{122}-n-γ	chem		49L5,49N9
Sn^{124}-n-2n	chem		49L5
Sn^{122}-d-p	chem		49L5
Sb-n-p			49N6
Sb^{124}-d-t			49N6
Fission	chem		50L8,48G4,48SP

τ_2	39.5^m		49D15
	41		49N11
	40		49L5,39L4
β^-	1.26	s	49D15
	1.12	a	49N9
	1.32	a	49L5
	~1.7	a	49N6
γ	0.153	sc	49D15
	~0.17	a	49N6
	~0.4	a	49N9
Sb K X-ray			49N9,49N6
βe^- coincidences			49D15
$e^-/\beta = 0.11$			49D15
Sn^{122}-n-γ			49L5,49N9,49D15
Sn-γ-n			48M33,49H17
threshold = 8.5			49H17
relσ			48W13
Sn^{124}-n-2n			49L5
Sn^{124}-d-t			49N6
Not produced by			
Sn^{120}-slow n's			49L5
Sn^{124}-slow n's			49L5
No Sb daughter with $\tau < 10^y$			49N6

124 (50, 74)

	6.01%		49H3
	6.11		48W9
	5.83		48H44
τ	$0.4\text{-}0.9 \times 10^{16\,y}$		49F4
β^-	1.0-1.5		49F4
Double β decay			49F4
σ's			
(th n,γ) 10^mSn		0.6	47S33
		0.8	49S8
(th n,γ) 10^dSn		0.15	47S33

125 (50, 75)

τ_1	10.0^d		49L5
	9.9		49B58
	11		43H8,46S13
β^-	2.38	s	49N6
	2.34	s	49B58
	2.1	a	49L5
	2.6	a	50S16
γ ?			49N6
No γ			49B58
No X-ray			49N6
X-ray			47C4
Sn^{124}-n-γ			49N1
Sn^{124}-d-p	chem		49L5
Sn^{124}-fast n-γ	chem		49L5
Fission	chem		50S16,48S8,43H8
Sn-d-p	chem		47C4
Sn-n-γ	chem		39L4
	σ		47S33
p 2.7^ySb			49N1
No Sb daughter with $\tau < 50^y$			49N6

τ_2	9.5^m		49N9,49D27
	9.8		49L5
	10		47S21
β_1^-	2.04	s	49D27
	2.05	a$\beta\gamma$	49N9
	~2.2		47S21
β_2^-	1.17	s	49D27
β_3^-	0.51 ?	s	49D27
	0.5	a	49N1
γ_1	0.326	sc,s	49D27
	0.36	a$\beta\gamma$	49N1
γ_2	1.86	a$\beta\gamma$	49N1
	>1		49D27
Sn^{124}-n-γ			49D27,49L5,49N9,49S8
Sn-d-p	chem		39L4
Sn-n-γ	chem		47S21,39L4
	σ		47S33,49S8
Not produced by			
Sn^{120}-slow n's			49L5
Sn^{122}-slow n's			49L5

126 (50, 76)

τ		70^m	42N3,43H8
		80	45S13
β^-	60%	0.7	50S16
	40%	2.7	50S16
γ		~1.2	50S16
Any of these radiations may be due to $60^m Sb^{126}$			50S16
Fission	chem		42N3,43H8
p 60^mSb			46PP,42N3,43H8

Neutron Cross Sections for Natural Element

σ_s coh	3.7		49S12
σ_s bound	4.2		49S12
	$E_n = 0.025$ev		
σ_a	5.3		49P3
	8.3		49H2
σ_s	4.3		(48WH)
σ_t	8.3		47R6

Resonances

E_o	$\sigma_o\Gamma^2$	
5.8ev	~12	47R6
15	~35	47R6
21	~35	47R6

	E_n = 1Mev	
σ_t	~6.5	49B28

Graphs Available

σ_t	0.015-1000ev	47R6, 47GIF
	0.020-1.6Mev	49B28, 50Ad
	0.024-~14Mev	47GIF

References on fast n graphs and in 48WH

116 (51, 65)

τ	60^m		49T11
β^+	~1.45	s	49T11
γ	~0.70	s	49T11
In-α-3n	ms, chem, f		49T11
threshold	~27		49T11

117 (51, 66)

τ	2.8^h		47C4
	3		39L5
K			47C4
No β^+			49T11
γ	0.156	sc	49T11
	α large		49T11
e^-	0.46	a	47C4
Sn K X-ray			47C4
In-α-2n	ms, chem, f		49T11
threshold	~18		49T11
Sn-d-n	chem		47C4, 39L5
Sn-p-n	chem		47C4

118 (51, 67)

τ_1	5.1^h		47C4
γ	0.260	sc	49T11
	1.5	a	47C4
e^-	0.20	a	47C4
X-ray			47C4
In-α-n	ms, chem, f		49T11
threshold	~13		49T11
	chem		47C4
Sn-d-n	chem		47C4

τ_2	3.3^m		47L10
	3.9		48L2
	3.6		40R2
β^+	3.1	a	48L2
γ			48L2
In-α-n	chem		39L3
	chem, σ		40R2
Sn-p-n			44D9
	d 6^dTe		48L2

119 (51, 68)

τ	39^h		48L2, 47C4
K			47C4
No β^+			47C4
No γ			47C4
Sn K X-ray			48L2, 47C4
Level			Te^{119}
Sn-d-n	chem		47C4
Sn-p-n	chem		47C4
Sb-d-p3n	chem		48L2
Sn^{120}-d-3n	σ		48L2
	d 4.5^dTe		48L2

51 ANTIMONY Sb

120
51 69

τ_1	16.6^m		48P3
	17		37H4, 39L5
	15.4		37P2
β^+	1.5	cc	38A3
Sn^{120}-d-2n	chem, σ		48L2
Sn-d-n	chem		39L5
Sb-γ-n	relσ		48W13, 39B5, 48P3
threshold = 9.25			49M17
Sb-n-2n			44J5, 37P2
threshold = 5.5-7			38S14
Sb-d-t	chem		41K4
Sn-p-n			44D9

τ_2	6.0^d		48L2
K			48L2
γ	1.1	a	48L2
Sn K X-ray			48L2
No β^+			48L2
Sn^{120}-d-2n	chem, σ		48L2
Sb-d	chem		48L2

121
51 70

	57.25%		48W9
I	5/2	S	32B1, 34C3
μ	+3.7	S	36B6, 34C3
q	-0.3		49M48
	~0		40T3
Level	0.61		Te^{121}

σ's

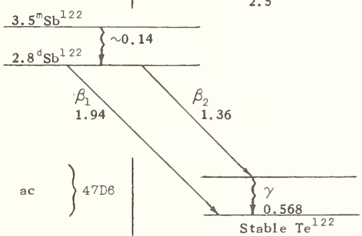
(th n, γ) 2.8^dSb	6.8	47S33
(~1Mev n, γ) 2.8^dSb	0.09	49H5

For other fast n values see 49B4, 48WH

122
51 71

τ_1	3.5^m		47D6

τ_2	2.8^d		39L11
	2.63		40M4
	2.5		35A1



IT			47D6
γ	~0.14	ac	47D6
Sb K_aX-ray			47D6

$3.5^m Sb^{122}$ produced by

Sb-n-γ		47D6

$2.8^d Sb^{122}$ produced by

Sb-n-γ		39L5
	σ	47S33
Sn-p-n		44D9
Sn-d-2n	chem	39L5
Sb-d-p	chem	48L2
Sb-γ-n	relσ	48W13

β_1^-	1.94	s	46M6
	1.77	a	48M11
	1.76	a	40M4
β_2^-	1.36	s	46M6
	1.19	a$\beta\gamma$	48M11
	~0.81	a	40M4
γ	0.568	sc	48C5, 48K4
	0.57	sc	47R1
No β^+			47B8

123
51 72

	42.75%		48W9
I	7/2	S	32B1, 34C3
μ	+2.8	S	36B6, 34C3
q	-1.2		49M48
Levels	0.15		Sn^{123}
	0.39		

σ's

(th n, γ) 1.3^mSb	~0.03	47D6
(th n, γ) 60^dSb	2.5	47S33

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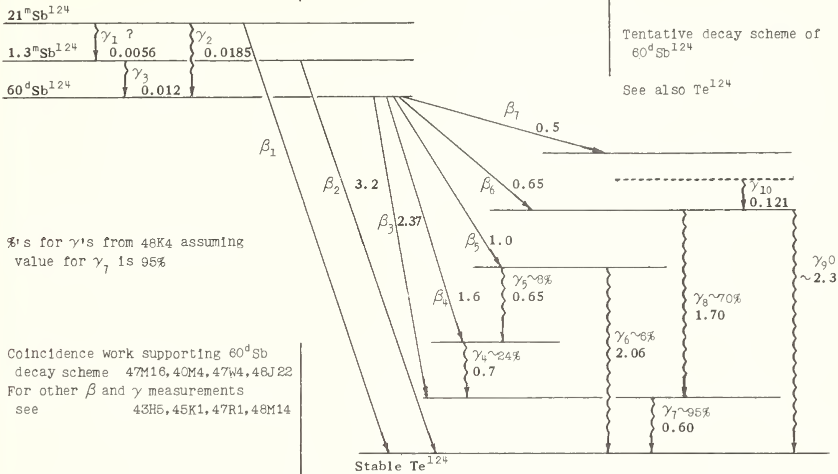
$^{124}_{51}$Sb$_{73}$

τ_1	21^m	47D6	τ_2	1.3^m	47D6	τ_3	60^d	39L5

Tentative decay scheme of $60^d Sb^{124}$ 48K4

See also Te^{124}



%'s for γ's from 48K4 assuming value for γ_7 is 95%

Coincidence work supporting 60^dSb decay scheme 47M16, 40M4, 47W4, 48J22

For other β and γ measurements see 43H5, 45K1, 47R1, 48M14

β's

$21^m Sb^{124}$				
β_1^-				49G8
$1.3^m Sb^{124}$				
β_2^-		3.2		49G8
$60^d Sb^{124}$				
β_3^-	21%	2.37	s	48K4, 48C5
	~50%	2.24	s	47M16, 48F5
β_4^-	8%	1.62	s	48K4
	7%	1.50	s	48C5
β_5^-	9%	1.0	s	48K4
	7%	0.98	s	48C5
β_6^-	44%	0.65	s	48K4
	26%	0.68	s	48C5
	~50%	0.57	s	47M16, 48F5
β_7^-	18%	0.48	s	48K4
	39%	0.50	s	48C5

$21^m Sb^{124}$ produced by

Sb^{123}-n-γ chem, σ 47D6

γ's

$21^m Sb^{124}$				
γ_1 ?		0.0056	pc	49G8
γ_2		0.0185	pc	49G8
		$\alpha\sim\infty$		49G8
$1.3^m Sb^{124}$				
γ_3		0.012	pc	49G8
		$\alpha\sim\infty$		49G8
$60^d Sb^{124}$				
γ_4	12%**	0.714	s	48K4
		0.732	s	48C5
		0.817	s	48I7
γ_5	4%**	0.650	s	48K4
		0.654	s	48C5
		0.645	s	48I7
γ_6	3%**	2.056	s	48K4
		2.04	s	48C5
		2.07	s	48I7

$1.3^m Sb^{124}$ produced by

Sb^{123}-n-γ 47D6

$60^d Sb^{124}$ (continued)				
γ_7	46%**	0.603	s	48K4
		$\alpha\sim$0.002		48K4
		0.608	s	48C5
	~100%*	0.60	s	48F5
		0.598	s	48I7
γ_8	35%**	1.708	s	48K4, 48C5
	~50%*	1.69	s	48F5
		1.67	s	48I7
		produces Be photo n's		47W1, 47H15, 4607, 42K1
γ_9	0.05%*	2.2-2.5	γn	49M8
γ_{10}		0.121	sc	48C5

* % of disintegrations

** % of γ's

60^dSb produced by

Sb-n-γ	chem	39L5
	σ	47S33
Sb-d-p	chem	45K1, 43H5, 39L5
In-n-α	chem	39L5
Sn-d-2n	chem	39L5
Te-d-α	chem	38T2

125 (51, 74)

τ		$\sim 2.7^{y}$		50l6
β_1^-		0.621	s	49K14
	~35%	0.7	a	50s14
		0.704	a	49M30
β_2^-		0.288	s	49K14
	~65%	0.3	a	50s14
$\beta_1/\beta_2 \sim 1/2$				49K14
Probably lower energy β's				49K14
γ	very weak	0.125	sc	49K14
	strong	0.174	sc, s	49K14
	strong	0.431	sc, s	49K14
	weak	0.466	s	49K14
	strong	0.609	sc, s	49K14
	weak	0.646	s	49K14
Fission	chem			50c1
Sn-n	chem			49K14, 49M30
Sn-d-n	chem			39L5

No βγ coincidences for $E_\beta > 0.3$ 49J3

β^- of 0.7 in coincidence with γ of 0.3 49M30

Levels	0.33	Sn^{125}
	?	

d 10^{d}Sn	49N1
d 10^{m}Sn	49K14, 50c1
p 58^{d}Te	48F2

126 (51, 75)

τ		60^{m}		42N3
β^-	60%	0.7	a	50s16
	40%	2.7	a	50s16
γ		1.2	a	50s16

Any of these radiations may be due to $70^{m}Sn^{126}$ 50s16

Fission	chem	42N3
d 70^{m}Sn		42N3

127 (51, 76)

τ	93^{h}		50s17
	95		46G6
	80		39A2
β^-	1.2	a	50s17
	0.8	a	46G6
γ	0.72	a	50s17
Fission	chem		39A2, 46G6

p (84%) 9.3^{h}Te	48B19
p (16%) 90^{d}Te	48B19

129 (51, 78)

τ	4.2^{h}	39A2
Fission	chem	39A2
p 72^{m}Te		39A2

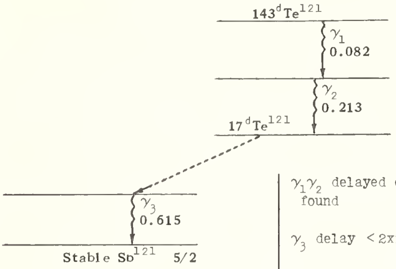
		132 51 81
		τ ~5^m 39A2 Fission chem 39A2 p 77^hTe 39A2
133 51 82	**134** 51 83	**??**
Sb parent, if any, of 21^hI has $\tau < 10^m$ 39A2	Sb parent, if any, of 51^mI has $\tau < 10^m$ 39A2	τ 28^d 46G6 β^- 1.86 a 46G6 Fission chem 46G6

Neutron Cross Sections for Natural Element		?
E_n = 0.025ev σ_a 4.53 49P3 5.87 49H2 σ_s 5.3 37G1 Resonance E_o > 300 ev 49H16		τ 2.5^h 48L2 β^+ 48L4 e^- 48L2 Sb-d chem 48L2

118 52 66	119 52 67	120 52 68
τ 6.0^d 48L2 X-ray 48L2 Sb-d-5n chem 48L2 p 3.3^mSb 48L2	τ 4.5^d 48L2 γ 1.5 a 48L2 e^- 0.2 48L2 0.5 48L2 Sb-d-4n chem 48L2 p 39^hSb 48L2	0.090% 49H3 0.091 48W9 0.09 46W8

$^{121}_{52}$Te$_{69}$

τ_1	143^d	46E3
	125	40S1
τ_2	17^d	46E3
	~16	46B6



$\gamma_1\gamma_2$ delayed coincidences not found — 49G8

γ_3 delay $< 2\times10^{-8}$ s — 46B8

143^dTe^{121} produced by

Sb-d-2n	chem	45Y1, 4202, 40S1
Sb-p-n	chem	40S1
Sn-α-n	chem	40S1

17^dTe^{121} produced by

Sb-d-2n	chem	46B6, 46E3
Sb-p-n	chem	46E3

143^dTe^{121}

γ_1	0.082	sc	42K2, 49H25
	α large		49H25
	K/L ~0.8		49H25
γ_2	0.213	sc	49H25
	α_K ~0.13, K/L=4.2		49H25
	0.211	sc	42K2
	0.225	a	46B6, 46B8
γ weak	0.032?		49H25
	0.035		49H25
these γ's not yet assigned			49H25
Te K X-ray			46E3
Xγ and e⁻γ coincidences			46B6

17^dTe^{121}

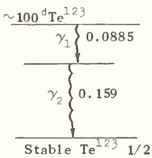
γ_3	0.615	sc	42K2
	0.61	a	46E3
	α small		46E3
Sb K X-ray			46E3

$^{122}_{52}$Te$_{70}$

	2.47%	49H3
	2.49	48W9
	2.43	46W8
Level	0.57	Sb^{122}
σ's (th n,γ) ~100^dTe	~1	49H25

$^{123}_{52}$Te$_{71}$

τ	~100^d	49H25
IT		49H25



γ_1	0.0885	sc	49H25
	K/L = 0.92		49H25
	0.0883	sc	42K2
γ_2	0.159	sc	49H25
	α_K ~0.2, K/L = 7.7		49H25
	0.157	sc	42K2

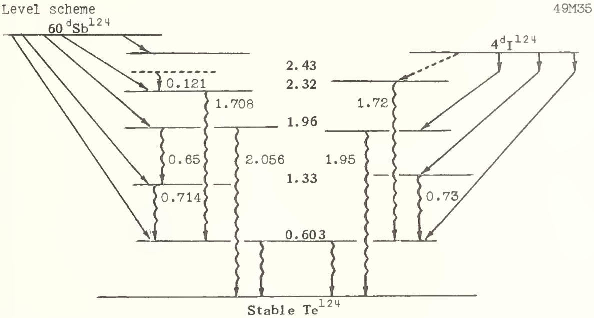
Te^{122}-n-γ — 49H25

	0.89%		49H3, 48W9
	0.85		46W8
I	1/2	S	49M47
μ	$\frac{\mu(Te^{123})}{\mu(Te^{125})} = 1.208$		49M47

124 (52, 72)

4.74%	49H3
4.63	48W9
4.59	46W8

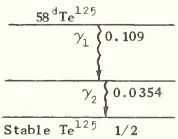
Level scheme 49M35



Short lived isomer		47H24
No short lived isomer		49B9, 49M26
	σ's	
(th n,γ) 58 d Te	~5	49H25

125 (52, 73)

τ	58 d		49H27
	~60		48F2
IT			48F2



γ_1	0.109	sc	49H27
	$\alpha \sim 1$, K/L = 1.5, L/M ~ 3.5		49H25, 49H27
	0.110	sc	49K14
	K/L = 1.2		49K14
γ_2	0.0354		49H25
	$\alpha_K \sim 3$, $\alpha_L \sim 0.41$		49B49
$\gamma_1\gamma_2$ in cascade			49B49
γ_2 delay $< 5 \times 10^{-8}$ s			49B49
Te^{124}-n-γ	σ		49H25
	d 2.7 y Sb		48F2, 49H27

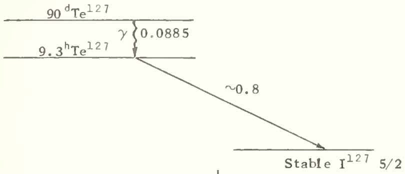
	7.03%	49H3
	7.01	48W9
	6.98	46W8
I	1/2 S	49F8
μ	$\frac{\mu(Te^{123})}{\mu(Te^{125})} = 1.208$	49M47
Levels		Sb^{125}

126 (52, 74)

18.72%		49H3, 48W9
18.70		46W8
	σ's	
(th n,γ) 9.3 h Te	0.8	47S33
(th n,γ) 90 d Te	0.07	47S33

127 (52 75)

τ_1	90^d	40S1
IT		40S1



γ	0.0885 sc	49H25
	K/L = 0.75	49H25
	0.085 sc	41H1
	$\alpha\sim\infty$, K/L = 0.75	41H1
	$\alpha \geqslant 5.7$	48W18
Te^{126}-n-γ		49H25
Te-n-γ	chem	40S1
	σ	47S33
Te-d-p	chem	40S1
I-n-p	chem	40S1
Fission	chem	39A2

d (16%) 93^hSb 48B19, 39A2

τ_2	9.3^h		40S1
β^-	~0.8	a	40S1
	0.70	a	46PP
No γ			46PP
Te-n-γ	chem		40S1
	σ		47S33
I-n-p	chem		40S1
Te-n-2n			38T2
Fission	chem		39A2
Te-d-p	chem		40S1

d (84%) 93^hSb 48B19, 39A2

128 (52 76)

	31.75%	49H3
	31.78	48W9
	31.85	46W8
τ for double β decay	$>1.3\times10^{19\,y}$	49I3

σ's

(th n,γ) 72^mTe	0.133	47S33
(th n,γ) 32^dTe	0.015	47S33

129 (52 77)

τ_1	32^d	40S1
	35.5	48W13
IT		40S1
γ	0.106 sc	49H25
	K/L = 1	49H25
	$\alpha \geqslant 1.9$	48W18
	0.102 sc	41H1
	$\alpha\sim\infty$, K/L ~ 1	41H1
Fission	chem	50n5
Te-γ-n	relσ	48W13
Te-n-γ	chem	40S1
	σ	47S33
Te-d-p	chem	40S1
Te-n-2n		38T2

τ_2	72^m		40S1
	70		39A2
	67.3		48W13
β^-	1.8	s	47R1
	1.75	a	46PP
	1.6	a	50n5
γ	0.3	a	46PP
	~0.8	a	46PP
Fission	chem		39A2
Te-γ-n			39B5
	relσ		48W13
Te-n-γ	chem		40S1
	σ		47S33
Te-n-2n			37H4, 38T2
Te-d-p	chem		40S1

d 4.2^hSb 39A2

130 (52 78)

	34.27%	49H3
	34.46	48W9
	34.51	46W8
τ for double β decay	$>8.0\times10^{19\,y}$	49I3

σ's

(th n,γ) 1.25^dTe	<0.008	47S33
(th n,γ) 25^mTe	0.22	47S33

131 (Z = 52, N = 79)

τ_1	1.25^d		39A2
	1.2		40S1
IT			40S1
γ	0.177	sc	41H1
	$\alpha \sim 0.6$		41H1
	$\alpha \geqslant 0.6$		48W18
	K/L = 2		41H1, 49H25
Te-n-γ	chem		40S1
	σ		47S33
Te-d-p	chem		40S1
Fission	chem		39A2

τ_2	25^m		40S1
	30		39A2
β^-	>1.8	a	48W18
Te-n-γ	chem		40S1
	σ		47S33
Te-d-p	chem		40S1
Fission	chem		39A2
	p 8^dI		39A2, 40S1

132 (Z = 52, N = 80)

τ	77^h		39A2
	66		39H8
β^-	0.28	a	50n6
	~0.3		43B2
γ	0.22	a	50n6
Fission	chem		39A2, 48SP
Mass assignment from range of fission fragment			48K9
	d ~5^mSb		39A2
	p 2.4^hI		39A2, 39H7

133 (Z = 52, N = 81)

τ	60^m	39A2, 45W5
β^-		39A2
Fission	chem	39A2
Mass assignment from range of fission fragment		48K9
	p 21^hI	39A2, 39H7

134 (Z = 52, N = 82)

τ	43^m	39A2
Fission	chem	39A2
Mass assignment from range of fission fragment		48K9
	p 52^mI	39H7, 39A2, 40P3

135 (Z = 52, N = 83)

Te parent, if any, of 6.68^hI has

τ	$<1^m$	40D7
	<2	50g9, 50k6

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

Neutron Cross Sections for Natural Element

σ_s coh	3.4	49S12
σ_s bound	3.8	49S12
	$E_n = 0.025$ev	
σ_a	6.1	49P3
	9.1	49H2
σ_t	11	47W8
	10.3	47J4

Resonances

E_o	$\sigma_o\Gamma^2$	
20.6ev	~4	47W8
20.3		47J4
32	~135	47W8
42	~135	47W8
Two additional resonances between 25 and 50ev		47J4

	$E_n = 2.5$Mev	
σ_t	5.4	39A5

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

119 ? (53, 66 ?)

τ	30^m	49M53
β^+	4.0	49M53
Sb-α $E_\alpha > 100$Mev	chem	49M53
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 $E_\alpha > 45$Mev	chem	49M53
p 17^dTe		49M53

122 (53, 69)

τ	4^m	49M53
β^+	2.9	49M53
Sb-α-3n	chem	49M53

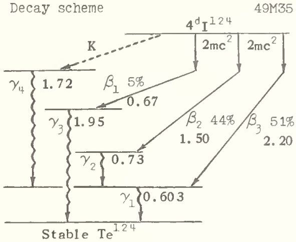
123
53 70

τ	13^h		49M35, 49M53
K or IT			49M35
γ	0.159	sc	49M35
	See also		Te^{123}
	~0.18	ac	49M53
Sb^{121}-α-2n	chem		49M35
Sb-α-2n	chem, f		49M53
Not produced by I-fast n's			49M35

124
53 71

τ	4^d		38L5, 44D9
	4.5		49M53

Decay scheme 49M35



Te X-ray		49M32
$\beta\gamma$, $\gamma\gamma$ coincidences		49M32
No βe^- coincidences		49M32
Sb-α-n	chem	49M35
	chem, yield	38L5
Sb^{121}-α-n	chem, f	49M53
Sb-α-3n	chem, f	49M53
Te-p-n		44D9

β_1^+	5%	0.67	s	49M35
β_2^+	44%	1.50	s	49M35
β_3^+	51%	2.20	s	49M35
	Spectral shape consistent with ΔI=2, yes			49M35
		2.1		49M53
γ_1		0.603	sc	49M35
γ_2		0.73	s	49M35
γ_3		1.95	s	49M35
γ_4		1.72	s	49M35

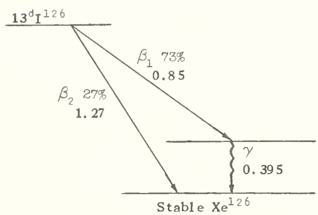
See also Te^{124}

125
53 72

τ	~56^d	46R4
K		47G5, 46R4
Te K_α X-ray		47G5
Sb-α-2n	chem, f	49M53
Te-d	chem, yield	47G5
	chem	46R4

126
53 73

τ	13.0^d	38L5
	13.1	48M33



β_1^-	73%	0.85	s	49M35
β_2^-	27%	1.27	s	49M35
		1.1	a	38L5
γ		0.395	sc, s	49M35
		0.5	a	38L5

I-γ-n		48M33
	rel yield	49P5
	threshold = 9.3	49M17
	9.45	49B3
Sb-α-n	chem, yield	38L5
	chem, f	49M53
Te-d-n	chem	38L5
Te-p-n		44D9
I-n-2n		38L5

127 (Z = 53, N = 74)

	100%		37N2
I	5/2	S	39T3, 38M6
μ	2.7944		49Po
		I	49Z2, 48P9
		S	39S15
		Mic	49G19
q	-0.75	Mic	48B23, 48S31, 48G21, 48T11
	-0.46	S	39M7, 39T3, 39S16

σ's

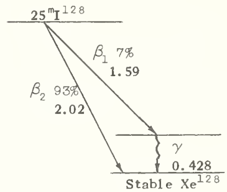
(th n,γ) 25^mI	6.3	47S33
(1Mev n,γ) 25^mI	0.11	49H5
Other fast n values		49B4, 48WH

Graphs Available

σ(n,γ) 25^mI	0.03-6Mev	46M19, 47GIF, 50Ad

128 (Z = 53, N = 75)

τ	24.99^m	41H4



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_γ(max) = 7.0				49K15
Te-d-2n		chem, yield		38L5
Te-p-n				44D9

129 (Z = 53, N = 76)

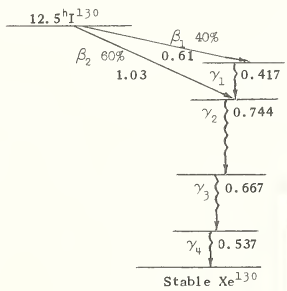
τ	$2\text{-}4\times10^{7\,y}$		49P19
	long		47K4, 50I7
I	7/2	Mic	49L9
μ	2.72	Mic	49G19 (49Po)
q	-0.43	Mic	49L9 (49Po)
β^-	~0.12		49P19
γ or X-ray	~0.03		49P19
β/γ~1			49P19
Levels	0.3		Te^{129}
	~0.8		

σ's

(th n,γ)	~15	49P19
(th n,γ) 12.5^hI	~8	47K4
Fission	chem	47K4

130 (Z = 53, N = 77)

τ	12.5^h	39T2
	12.6	38L5



I-n-γ	chem, σ	47K4
Cs-n-α	chem	40W5
Te-d-2n	chem, yield	38L5

β_1^-	40%	0.61	s	43R2
β_2^-	60%	1.03	s	43R2
γ_1		0.417	sc	43R2
		$\alpha_K = 12\times10^{-3}$		
γ_2		0.744	sc	43R2
		$\alpha_K = 3\times10^{-3}$		
γ_3		0.667	sc	43R2
		$\alpha_K = 4\times10^{-3}$		
γ_4		0.537	sc	43R2
		$\alpha_K = 7\times10^{-3}$		

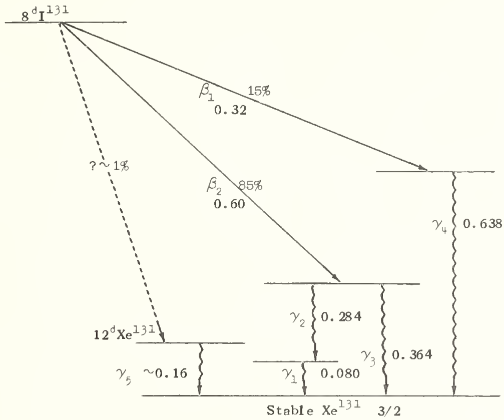
Order of $\gamma_2, \gamma_3, \gamma_4$ unknown. See Cs^{130}

$\beta\gamma$ and $\gamma\gamma$ coincidence rates support decay scheme 43R2

$\alpha_L \ll \alpha_K$ for all γ's 43R2

131
53 78

τ	8.0^d	47S28, 38L5, 50k9
	8.1	46G6



Decay scheme 48M28

About 1% of I^{131} decays to 12^dXe. Very weak γ's of ~0.165 probably due to Xe daughter 49B6

σ's

(th n,γ) 2.4^hI		~600	49Y4
Te-d-n	chem, yield		38L5
	chem		39T2
Fission	chem		39A2, 40S1, 39H7, 46G6
	d 25^mTe		39A2, 40S1
	p (1%) 12^dXe		49B6

β_1^-	15%	0.32	s	48M28
	20%	0.31	s	49F1
		0.25	s	49K14
β_2^-	85%	0.600	s	48M28
	80%	0.600	s	49F1
		0.605	s	49K14
		0.60	a	50k9
γ_1		0.080133	s cryst	49L11
	~8%*	0.080	sc	48M28
		α = 0.8, K/L = 5.5		48M28
		0.078	sc	49F1
		α = 0.7		49F1
		0.080	sc	49K14
		α = 0.2, K/L = 8.4		49K14
		0.0801	sc	49C13

γ_2		0.2841	s cryst	49L11
	8%*	0.283	sc	48M28
		α = 0.05, K/L > 2		48M28
	9%*	0.284	sc	49F1
		α ~ 0.05		49F1
		0.282	sc	49K14
		α = 0.08		49K14
		0.2841	sc	49C13
		0.284	sc	49M33
γ_3		0.3642	s cryst	49L11
	100%*	0.363	sc	48M28
		α = 0.02, K/L = 5.2		48M28
	100%*	0.364	sc	49F1
		α = 0.02		49F1
		0.363	sc	49K14
		α = 0.2, K/L = 4		49K14
		0.3642	sc	49C13
		0.364	sc	49M33

γ_4	20%*	0.638	s	48M28
		α < 0.005		48M28
	13%*	0.640	s	49F1
		0.637	s	49K14
		0.625	s	49C13
		0.638	s	49M33
γ_5	weak	~0.159	sc	49M33
		~0.163	sc	49K14
		0.164	sc	49C13
		~0.165	a	49B6
		α ~ 20		49B6
Other weak γ's				
		~0.208	sc	49M33
		0.177	sc	49C13

βγ and βe^- coincidences 48M28

* relative values

132 (53 79)

τ		2.4^h		39A2
		2.3		39H8
β^-	~50%	0.9	a	50n6
		~1.35	a	43B2
	~50%	2.2	a	50n6
γ	~50%	0.6	a	50n6
		0.85	a	43B2
	~50%	1.4	a	50n6
Level		0.22		Te^{132}
Fission		chem		39A2, 39H7, 46G6, 48SP
		d 77^hTe		39A2, 39H7

133 (53 80)

τ		21^h		49B47
		22		39A2, 40W5, 50k6
β^-	6%	~0.5	ac	49B47
	94%	1.4	ac	49B47
		1.4	a	50s19
γ	94%*	0.53	s	49B47
		0.528	s	47P13
	5%*	~0.85	s	49B47
	1%*	~1.4	s	49B47

* % of disintegrations

$\gamma\gamma$ coincidences in ~5% of disintegrations 49B47

No evidence for metastable state with $\tau > 10^{-6\,s}$ 49B47

Fission	chem	39A2, 39H7, 40W5
	d 60^mTe	39A2, 39H7
	p 5.3^dXe	45W5

134 ? (53 81 ?)

τ		50.8^m		49L19
		54		39A2
β^-		~1.6	a	49L19
		~3.9	a	49L19
γ		> 2.3		49L19
Fission		chem		39A2, 39H7, 48SP
		d 43^mTe		39A2, 39H7, 40P3

135 (53 82)

τ		6.68^h		47P13
		6.7		50g9, 50k6
		6.6		41S2, 40D7
β^-	35%	0.47	s	47P13
	40%	1.0	s	47P13
	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

1.4 β not in coincidence with γ 47P13

* % of disintegrations

Fission	chem	41S2, 40W5, 48SP, 50k6
	p (~10%) 15.3^mXe	40G2, 45W5, 50g9
	p (~30%) 15.3^mXe	47P13
	p (~90%) 9.2^hXe	45W5, 40G2, 50g9
	p (~70%) 9.2^hXe	47P13

136 (53 83)

τ		86^s		49S27
		108		40S3
β^-		6.5	a	49S27
γ		2.9	a	49S27
Fission		chem		40S3

137 53 84			138 53 85			139 53 86		
τ	19.3^{s}	49S14	τ	5.9^{s}	49S14	τ	2.7^{s}	49S14
	22	48H33						
	22.5	47R2						
	30	40S3						
			β^-		49S14	β^-		49S14
β^-		47S7, 48H33						
Delayed n emitter		47S7						
$\overline{E_n}$	0.56 a	48H33						
	0.7	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 33^{m}Cs	49T4, 49S14		p 85^{m}Ba	49S14

No I found in fission with $\tau > 8^{d}$ except I^{129} 5017		

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

126 54 72			127 54 73							
	0.088%	47L2,37N2	τ_1	75^s		40C6	τ_2	34^d		40C6
	0.098	47D9								
			IT			40C6	γ	0.9	ac	40C6
			γ	0.125	sc	40C6	Xe or I X-ray			40C6
				0.175	sc	40C6				
			Xe K X-ray			40C6				
Level	0.395	I^{126}								
			I-p-n	chem		40C6	I-p-n			40C6
							Xe-n-γ			44C11
							I-d-2n			42O3
								d 5.5^{h}Cs		49F9
			Genetic relationship between 75^s and 34^d activities not shown							40C6

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

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128 (54, 74)

	1.917%		47L2
	1.93		47D9
	1.90		37N2
Level	0.43		I^{128}

129 (54, 75)

	26.24%		47L2
	26.51		47D9
	26.23		37N2
I	1/2	S	34K2,34J1
μ	-0.9	S	34K2,34J1
Level	~0.5		Cs^{129}

130 (54, 76)

	4.053%		47L2
	3.68		47D9
	4.07		37N2
Levels	0.51	?	Cs^{130}
	0.537	?	I^{130}
	1.20	?	I^{130}
	1.95		I^{130}
	2.37		I^{130}

131 (54, 77)

τ	~12^d		49B6
	~14		47A4
	11		44C11
IT			49B6,44C11
γ	~0.165	a	49B6
	α~20		49B6
Xe K X-ray			49B6
Fission	chem		47A4
Xe-n-n			44C11
	d (~1%) 8^dI		49B6

	21.24%		47L2
	21.04		47D9
	21.17		37N2
I	3/2	S	34K2,34J1
μ	+0.8	S	34K2,34J1
q	~0		38S10
Levels	0.080	?	I^{131}
	0.145	?	Cs^{131}
	~0.16		$12^d Xe^{131}$
	0.364		I^{131}
	0.638		I^{131}

132 (54, 78)

	26.93%		47L2
	27.12		47D9
	26.96		37N2
Levels	0.6		I^{132},Cs^{132}
	1.4 ?		I^{132}
		σ's	
(th n,γ)5.3^dXe		0.2	43K5

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

133 (54, 79)

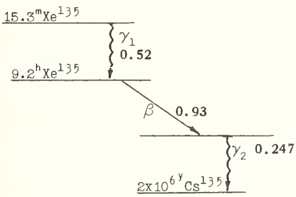
τ	5.271^d		49M25
	5.3		50e5
	5.4		41C2
β^-	0.315	s	49T4
	0.34	a	50e5
	0.26	a	45W5
	0.32	a	43S2,43B2
γ	0.085	a	50e6
	0.083	a	43B2
X-ray	0.031	a	50e6
	0.040	a	50e5
Fission	ms		49T4,49M25
Cs-n-p	chem		45W5,44C11,45S2
Ba-n-α	chem		45W5,44C11
Xe-n-2n			43R1
Xe-n-γ			43R1,44C11
Te-α-n	chem		41C2
Xe-d-p	chem		41C2
d 21^hI			45W5

134 (54, 80)

	10.52%		47L2
	10.54		47D9,37N2
Level	>2.3		I^{134} ?
	σ's		
(th n,γ)9.2^hXe		0.2	44T3

135 (54, 81)

τ_1	15.3^m		48B16
	15.6		43R1
	13		50n9
	10		40G2,45W5



γ_1	0.52	s	47P13
	0.54	ac	50n9
	~0.5	a	45W5
	0.6	ac	43S2
Fission	chem		40G2,45W5
Xe-n-γ			46R7,43R1
Xe-n-2n			43R1
d (~10%) 6.7^hI			45W5,40G2,50g9
d (~30%) 6.7^hI			47P13

τ_2	9.2^h		50n7,50g9
	9.4		40W5
	9.5		40D7
	9.6		43R1,41C2
β^-	0.93	s	49T4,47P13
	0.95	a	43B2
	0.9	a	45W5
	1.0	a	50h4
γ_2	0.247	s	47P13
	0.25	a	45W9
	0.26	a	50n7
Levels	?		I^{135}
Fission	ms		49T4
	chem		40D7,45W5
Xe-d-p	chem		41C2
Ba-n-α	chem		45W5,43S2
Xe-n-γ			43R1
	σ		44T3
Xe-n-2n			43R1
d (~90%) 6.7^hI			45W5,40G2,50g9
d (~70%) 6.7^hI			47P13
p $2x10^{6y}$ Cs			45W5,50f5,50e7

136 (54, 82)

	8.93%		47L2
	8.98		47D9
	8.95		37N2
Levels	~1		Cs^{136}
	2.9		I^{136}
	σ's		
(th n,$\gamma\beta$)37^yCs		0.15	44T3
(~1Mev n,γ)3.9^mXe		0.001	49H28

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

137 (54, 83)			138 (54, 84)			139 (54, 85)		
τ	3.9^m	48S16	τ	17^m	40G5	τ	41^s	50d1
	3.8	43S1					~30	40H4
	3.4	43R1						
β^-	~4 a	43B2	β^-		39H7	β^-		39H7
Neutrons emitted following 19^s I disintegration		I^{137}						
Fission	ms	49T4	Fission	ms	49T4			
	chem	43S1		chem	40H4,40G5, 43S2,46PP	Fission	chem	40H5,40H4
Xe-n-γ		43R1,48S16						
	d 19^s I	49S14, 43S1,49T4					p 85^mBa	50d1,39H3
	p 37^yCs	50t1,50g16		p 33^mCs	40H4,40G5,43S2		p 9.5^mCs	39H3,40H4

140 (54, 86)			141 (54, 87)			142 (54, 88)		
τ	16^s	50d1,46D14	τ	3^s	50d1			
	$<0.5^m$	40H4		1.7	50o1			
β^-		40H4	β^-		50b2			
Fission	chem	40H4,46PP	Fission	chem	50b2			
				p short Cs	50b2,50d1			
	p 12.8^dBa	40H4,50o1, 50d1,50b2		p 3.7^hLa	50b2			
				p 28^dCe	50o1,50d1			

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

143 54 89	144 54 90	145 54 91
τ ~1^s 50d1	τ ~1^s 50d1	τ 0.8^s 50d1
Fission chem 50b2	Fission chem 50d2	Fission chem 50d1
p 33^h Ce 50b2,50d1 p 13.8^d Pr 50o1	p 275^d Ce 50d2	p 1.8^h Ce 50d1

??		
τ 68^m 41C2	No Xe with τ >5^d found in fission 50h1	
Xe-d-p 41C2		

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

55 CESIUM Cs

Neutron Cross Sections for Natural Element

	$E_n = 0.025$ev	
σ_a	29	49P3
σ_t	~50	42L1

127 (55, 72)

τ	5.5^h		49F9
β^+	~1.2	a	49F9
e^- ?	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

128 (55, 73)

129 (55, 74)

τ	31^h		49F9
No β^+			49F9
γ	~0.5		49F9
e^-	0.33	a	49F9
K, L X-rays			49F9
I-α-2n	ms, chem		49F9

130 (55, 75)

τ	30^m	49F9, 48R4
γ	0.51	49F9
X-ray		49F9
I-α-n		49F9, 48R4

131 (55, 76)

τ	9.6^d		49Y1
	10		47Y1
	10.2		50K12, 47K5
K			50K12, 47K5, 47Y1
No β^+			50f7, 47F9
No γ			50K12, 47K5
γ	0.145	a, ac	47Y1
	α~32		47Y1
e^-	0.115		49Y1
Xe K X-ray			47Y1, 49Y1, 47K5, 50K12, 47F9
Levels	0.26, 0.5, ~1.2	?	Ba^{131}
Ba-n-$\gamma\beta$	ms		49K7
	d 12^dBa		50K12, 47K5, 47Y1

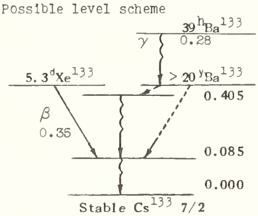
132 (55, 77)

τ	7.1[d]		44C11
K			44C11
γ	0.62	a	44C11
e^-	0.6	a	44C11
Cs-n-2n			44C11

133 (55, 78)

	100%		37N2
I	7/2	S	37F3, 34J2, 31K1
		Z	34C4
μ	2.563		49Po
		I	49B7, 49C2
		M	39K10
q	≤0.3		40S9

Possible level scheme

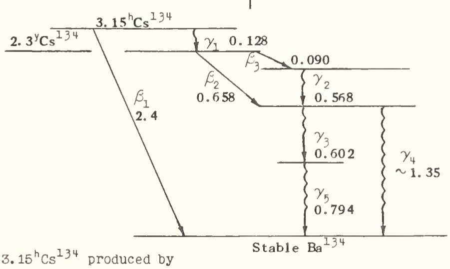


σ's

(th n,γ) 3^hCs	0.016	47S33
(th n,γ) 2.3^yCs	26	47S33
(30Mev α,2n) 19^hLa	0.03	48C3

134 (55, 79)

τ_1	3.15^h	45S2
	3	40K7
τ_2	2.3^y	50g19
	1.7	40K7
	$>254^d$	45S2



$3.15^h Cs^{134}$ produced by

Ce-n-γ	chem,σ	40K7
Cs-d-p	chem	40K7

$2.3^y Cs^{134}$ produced by

Ce-n-γ	chem,σ	40K7, 38S6
Cs-d-p	chem	40K7
Ba-d-α		43H10

Order of γ's uncertain	48S1, 47E2
γγ coincidences	48S1
γ 1.63 <E <2.3 in 7×10^{-5}% of disintegrations	49F5
No Xe K X-ray	48S1
γγ angular correlation indicates I = 4,2,0	48B18
* relative % of γ's	47E2

$3.15^h Cs^{134}$

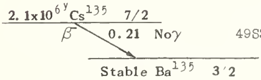
β_1^-		2.4	a	45S2
γ_1		0.128	s	49C1
		0.15	s	47P10
		0.16	a	47M21
γ ?		0.7	a	45S2

$2.3^y Cs^{134}$

β_2^-	75%	0.658	s	47E2
	95%	0.65	s	47S13
		0.635	s	47P10
β_3^-	34%	0.090	aβγ	49M36
	25%	0.09	s	47E2
γ_2	26%*	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

135 (55, 80)

τ	$2.1\times10^{6\,y}$		49S3
	5×10^{6}		49B5
I	7/2	M	49D1
μ	2.72	M	49D1



49S3

Level in Cs^{135}	0.25		Xe^{135}
σ's (th n,γ) 13.7^{d}Cs	~15		49S3
Fission	chem		49S3
d 9.2^{h}Xe			50e7, 50f5, 49S3, 45W5

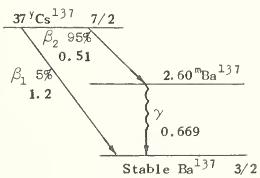
136 (55, 81)

τ	13.7^{d}		48G11
	13		50g13, 50f6
	10.2		44C11
β⁻	~0.35	a	48G11
	~0.28	a	50f6
γ	0.9	a	48G11
	1.2	a	50f6
γ/β = 2			48G11
βγ coincidences			50f6
Fission	chem		50f6, 48SP
La-n-α	chem		48G11, 44C11

137 (55, 82)

τ	37^{y}		48E5
	33		50g17
I	7/2	M	49D1
μ	2.84	M	49D1

Proposed decay scheme 49P2



Ba X-ray in 2.60^{m} activity 48T3

Fission	ms, chem		46H5
	chem		48SP, 46PP
d 3.9^{m}Xe			50t1, 50g16

β_1^-	5%	1.2	s	49P2
	<5%	1.2	s	4903
	unallowed shape?			4903, 49P2
β_2^-		0.51	s	49L6
	95%	0.521	s	49P2
		0.518	s	4903
	100%	0.55	s	48T2
		0.57	a	48E5
	spectral shape indicates ΔI=2, yes			4903, 49L6, 49P2
γ		0.669	sc	49P2
		0.663	sc	4903, 48T2
		α = 0.12		48T2
		α_K = 0.08, K/L = 5.0		4903
		0.12, K/L = 4.8		49M1
		2.60^{m} delay		Ba^{137}

138 (55, 83)

τ	33^{m}		50e8, 40H4
	32		50g16
β⁻	2.68	s	49T4
	2.65	a	40G5 (46B27)
γ	1.2	a	50g16
Fission	ms		49T4
	chem		39H7, 40G5, 40S5, 48SP
Ba-n-p			43S2
d 17^{m}Xe			40G5, 40H4

139 (55, 84)	140 (55, 85)	141 (55, 86)
τ 9.5^m 49S15 10 39A1 7 40H4	τ 66^s 49S15 40 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 p 85^{m}Ba 40H4, 40H5, 39H3	d 16^{s}Xe 50b2, 50d1, 50o1 p 12.8^{d}Ba 50b2, 50d1, 50o1	d 3^{s}Xe 50b2, 50d1 p 28^{d}Ce 50o1, 50d1 p 3.7^{h}La 50b2

142 (55, 87)	143 (55, 88)	144 (55, 89)
τ ~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 p 13.8^{d}Pr 50o1 p 33^{h}Ce 50b2, 50d1	d short Xe 50d2 p 275^{d}Ce 50d2

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$^{145}_{55}Cs_{90}$		
τ	short	50d1
Fission	chem	50d1
	d 0.8^{s}Xe	50d1
	p 4.5^{h}Pr	50d1
	p 1.8^{h}Ce	50d1

Neutron Cross Sections for Natural Element		129 56 73
E_n = 0.025ev σ_a 1.05 49P3 1.38 49H2 σ_s 8 37G1		

130 56 74	131 56 75	132 56 76
0.101% 38N3 0.103 49H38	τ 12.0^d 50k12, 47K5 11.7 47Y1	0.097% 38N3 0.096 49H38
	K 50k12, 47K5	
	No β^+ >0.1 47Y1 No β^+ 50f7, 47F9	
	e^- <0.20 47Y1	
	γ 0.26 a 50k12, 47K5 0.22 47Y1	
	strong 0.5 a 50k12, 47K5 strong 0.5 47Y1	
σ's' (th n,γ) 12^{d}Ba 6 47K5 (th n,$\gamma\beta$) 10^{d}Cs 24mb 49Y1	weak ~1.2 a 50k12, 47K5 weak 1.7 47Y1	σ's (th n,γ) 20^{y}Ba ≥6 50k13, 47K5
	Cs K X-ray 50k12, 47K5	
	Ba-n-γ ms 49K7 chem 47Y1, 47K5 Ba-d-p chem 47Y1 p 10^{d}Cs 50k12, 47K5, 47Y1	

133 (Z = 56, N = 77)

τ_1	38.9^h	48Y1	τ_2	$>20^y$	50k13, 47K5
	38.8	43W3			
	38	48M33			
IT		48Y1	K		50k13, 47K5
γ	0.276 sc	41C3	γ	0.085 a, cc	48Y1
	$\alpha = 2.45$, K/L = 3.2			$\alpha = 0.34$ K/L = 10	48Y1
				0.320 a, cc	48Y1
				$\alpha = 0.02$	48Y1
				0.36 a	47K5
			Cs K X-ray		47K5
			See Cs^{133}		
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
				d 39^d Ba	48Y1
	p $> 20^y$ Ba	48Y1		Not p active Cs	47K5, 50k13

134 (Z = 56, N = 78)

	2.42%	38N3
	2.39	49H38
Levels		Cs^{134}
	0.79	
	1.40	
	1.96	

135 (Z = 56, N = 79)

τ	28.7^h	48Y1		6.59%	38N3
				6.56	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}
Ba-d-p		48Y1			
Ba-n-γ		48Y1			
Ba^{134}-n-γ	chem	49R5			
	Not produced by				
Cs-d-n, 2n		49R5			
Cs-α-p		49R5			

136 (Z = 56, N = 80)

	7.81%	38N3
	7.74	49H38
Levels	?	Cs^{136}

137 (Z = 56, N = 81)

τ	2.60^m		49M1
	2.63		48T3
	2.5		48E5
IT			48T3
γ	0.669	sc	49P2
	0.663	sc	49O3, 48T2
	$\alpha = 0.12$		48T2
	$\alpha_K = 0.08$, K/L=5.0		49O3
	0.12, K/L=4.8		49M1
Ba K X-ray			48E5
e^-X coincidences			48T3
See Cs^{137}			
Ba-n-γ	chem		40K7
	d 37^yCs		48E5, 48T3

	11.32%	38N3
	11.25	49H38
I	3/2 S	37B9, 32M6, 49A10
μ	0.936	41H14

138 (Z = 56, N = 82)

	71.66%	38N3
	71.83	49H38
Levels	0.88	La^{138}
	1.2	Cs^{138}

σ's

(th n,γ)85^mBa	0.5	47S33
(~1Mev n,γ)85^mBa	2.6mb	49H5
Values at other energies		49B4, 48WH

139 (Z = 56, N = 83)

τ	85^m		50d4
	84		48S27
β^-	2.27	s	48S27
	2.2	a	50k8
γ	0.165	sc	49L14
26%*	0.163	sc	48S27
	$\alpha = 0.20$	K/L = 6	48S27
0.6%*	1.05	a	48S27

*% of disintegrations

σ's

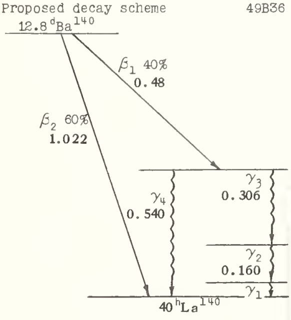
(th n,$\gamma\beta$)40^hLa	3.8	45K17
(pile n,$\gamma\beta$)40^hLa	4.7	49Y3

Ba-d-p	chem	37P3, 40K7
Ba-n-γ	σ	47S33
Ce-n-α		43W1
Fission	chem	50k8, 39H7, 39H3
	d 9.5^mCs	39H7, 39H3

140 (Z = 56, N = 84)

τ	12.8^d	50e9, 47S25
	12.5	42G2

Proposed decay scheme 49B36



β_1^-	40%	0.48	s	49B36
		0.465	s	49L14
	25%	~0.4	a	50e3
β_2^-	60%	1.022	s	49B36
		0.990	s	49L14
		1.05	s	50w5
	75%	1.0	a	50e3
γ_1		0.076	not observed	
γ_2		0.160	sc	49B36
		0.160	s	49L14
γ_3		0.306	sc	49B36
		0.310	s	49L14
γ_4		0.540	sc	49B36
		0.535	s	49L14
		0.54	s	50w5
		0.52	a	50e3
$\beta\gamma$ coincidences				49M13

Fission	ms	48H25
	chem	39H7, 42H6, 46PP, 48SP
	d 66^sCs	42H6, 50b2, 50d1, 50d2, 50o1
	p 40^hLa	39H4, 46PP

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, 50o1, 50d1, 48SP	Fission	chem	42H6, 48SP	Fission	chem	42H6, 48SP
	d short Cs	50b2, 50o1, 50d1		d $1-2^m$Cs	42H6		d short Cs	50b2, 50o1, 50d1
	p 3.7^hLa	42H6		p 74^mLa	42H6		p 19^mLa	42H6

144 (56, 88)			145 (56, 89)					
τ	short	50d2	τ	short	50d1			
Fission	chem	50d2	Fission	chem	50d1			
	d short Xe	50d2		d 0.8^sXe	50d1			
	p 275^dCe	50d2		p 1.8^hCe	50d1			

57 LANTHANUM La

Neutron Cross Sections for Natural Element

	$E_n = 0.025$ev		
σ_a	8.8		49P3
σ_t	26		42R2
	10		42B4
	Graphs Available		
σ_t	0.01-1000ev		50Ad,47GIF

133 (57 76)

τ	4.0^h		49N8
K			49N8
β^+ few %	1.2		49N8
e^-	0.26	s	49N8
γ	0.8	a	49N8
K X-ray			49N8
Cs-α-4n	ms,chem		49N8

134 (57 77)

135 (57 78)

τ	19.5^h		48C3
K			48C3
γ	0.76	a	48C3
X-ray			48C3
$X/\gamma = 50$			48C3
Cs-α-2n	ms		49N8
	chem,σ		48C3

136 (57 79)

τ	9.5^m		49N8
	9.0		49R7
	10		47M2
K ~67%			49N8
β^+ ~33%	2.1	s	49N8
	2.1	a	47M2
	1.8	a	49R7
γ			49R7
No γ			47M2
X-ray			49N8,49R7
Ba^{135}-d-n			49R7
Ba^{136}-d-2n			49R7
Ba-d-n	chem		47M2
Cs-α-n	chem		49N8
	chem,σ		48C3

137 (57 80)

τ	$>400^y$		48C3
	>30		48I5
	d 36^hCe	ms	48I5

138 (57, 81)

τ	17.5^h	43W2, 49B3
K		43W2
γ	0.88 a	43W2
Ba K X-ray		43W2
La-γ-n	threshold = 12.9	49B3
Ba-d-n	chem	43W2
Ba-p-n	chem	43W2

0.089%	47I9
No observable activity	47I9

139 (57, 82)

	99.911%		47I9
I	7/2	S	34A2
μ	2.760		49Po
		I	49C2, 49D13
		S	40W8
Levels	0.163		Ba^{139}
	1.05		
	0.184		Ce^{139}
	0.8 } ?		
	1.8 } ?		

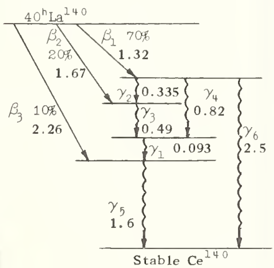
σ's

(th n,γ)40^hLa	8.4	47S33
	>7	46B25
(th n,γ)	8.8	49P3
(1Mev n,γ)40^hLa	5mb	49H28
(20Mev d,4n)36^hCe	0.002	48C3
(40Mev d,4n)36^hCe	0.06	48C3
(60Mev d,4n)36^hCe	0.04	48C3
(20Mev d,2n)140^dCe	0.09	48C3

140 (57, 83)

τ	40.0^h	50b7, 43W2
	39.5	46B25

Proposed decay scheme 49B36



Fission	ms	48H25
	chem	50b7, 48SP
La-d-p	chem	43W2
La-n-γ	chem	42G1, 43W2
Ce-n-p	chem	43W2
	d 12.8^dBa	42H6, 50f4

β_1^-	70%	1.32	s	49B36
	20%	0.90	s	46O1
β_2^-	20%	1.67	s	49B36
	70%	1.40	s	46O1
		1.45	s	47R1
β_3^-	10%	2.26	s	49B36
	10%	2.12	s	46O1
γ_1		0.093?	sc	49B36
γ_2		0.335	sc	49B36
		0.333	s	46O1
	2%*	0.335	s	47R1
	1%*	0.335	s	46M6
γ_3		0.490	sc	49B36
		0.505	s	46O1
	5%*	0.49	s	47R1
	7%*	0.49	s	46M6
γ_4		0.820	s	49B36
		0.832	s	46O1
	10%*	0.87	s	47R1
	15%*	0.83	s	46M6

γ_5		1.6	s	49B36
		1.61	s	46O1
	77%*	1.65	s	47R1
	74%*	1.63	s	46M6
γ_6		~2.5	s	49B36
		2.52	s	46O1
	6%*	2.3	s	47R1
	4%*	2.3	s	46M6
	3%**	2.49	γn	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, 46O1, 47M3

Levels in La^{140} 0.54 Ba^{140}
others ?

σ's

(th n,$\gamma\beta$)28^dCe ~3 49K4

* % of γ's
** % of disintegrations

57 LANTHANUM La

141 (57, 84)

τ	3.7^h	50k7
	3.5	42H6
β⁻	2.8 a	50k7
No γ ?		50k7
Fission	chem	50k7,42H6,48SP
	d 3^sXe	50b2
	d 18^mBa	42H6
Probably	p 28^dCe	42H6,50b8,50k7

142 (57, 85)

τ	74^m	42H6
	77	50k7
β⁻		50k7
γ		50k7
Fission	chem	50k7,42H6,48SP
	d 6^mBa	42H6

143 (57, 86)

τ	19^m	50g10
	15	43H8
Fission	chem	39H4,39H5
	d 1^sXe	50b2
	d $<0.5^m$Ba	39H4,39H5
	p 33^hCe	50g10

144 (57, 87)

τ	short	50d2
Fission		50d2
	d $\sim 1^s$Xe	50d2
	p 275^dCe	50d2

145 (57, 88)

τ	short	50d1
Fission		50d1
	d 0.8^sXe	50d1
	p 1.8^hCe	50d1

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Neutron Cross Sections for Natural Element

	$E_n = 0.025$ev	
σ_a	0.65	49P3
	0.64	49H2
σ_t	~3	42R2
	~15	42B4
	Other energies	
σ_t		49H16

135 (58, 77)

τ	$\sim 16^h$	48C3
β^+	~0.4	48C3
La-d-6n		48C3
	p 19.5^hLa	48C3

136 (58, 78)

0.193%	47I9
0.195	49H3

137 (58, 79)

τ	36^h		48C3
K			48C3
No β^+			48C3
γ	0.28	ac	48C3
	0.75	a	48C3
La K X-ray			48C3
La-d-4n	σ		48C3
	p $>400^y$La		48I5

138 (58, 80)

0.250%	47I9
0.265	49H3

139 (58, 81)

τ	140^d		48C3, 48P1
K			48P1, 47M12
γ	0.18	sc, ac	48C3
	0.184	sc	48P1
	0.8	a	48P1
	1.8	a	48C3
La K X-ray			47M12, 48P1
La-d-2n	chem, σ		48P1, 48C3
Ba-α-2n	chem		48P1

$^{140}_{58}Ce_{82}$

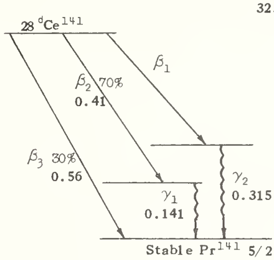
	88.48%	47I9
	88.45	49H3
Levels	1.6	La^{140}
	2.5	
	others ?	La^{140}, Pr^{140}

σ's

(th n,γ) 28^dCe	0.31	49K4
	<0.4	46B25
(1Mev n,γ) 28^dCe	4.8mb	49H28

$^{141}_{58}Ce_{83}$

τ	28^d	50b8
	30	46B25
	30.6	48P1
	32.2	48S28



Fission	ms	46H5
Ce-n-γ	ms	48I5
	chem	50b9, 46B25
Fission	chem	50b9, 48SP
Ba-α-n	chem	48P1
Ce-d-p	chem	50b8, 50b9, 48P1
Ce-n-2n	chem	50b9, 48P1
Pr-n-p	chem	43P3
	d 3.7^hLa	50k7, 50b8

β_1^-		Not observed		
β_2^-	70%.	0.41	s	48S28
		0.4	a	46B25
		0.44	a	49M15
β_3^-	30%	0.56	s	48S28
		0.55	a	50b8
		0.66	a	48P1
γ_1		0.141	sc	48S28
		α = 0.2		48S28
		0.13	a	49M15
		0.21	a	50b8
γ_2		0.315	s	49T12
		0.4	a	49M15
		impurity ?		49M15

βγ coincidences only for $E_\beta < 0.25$. No γγ — 49T12

$3\times10^{-7s} >$ βγ delay $> 10^{-3s}$ — 49B9

βγ delay of $70^{\mu s}$ — 47H24

βe^- coincidences — 49M15, 48S28

$^{142}_{58}Ce_{84}$

	11.07%	47I9
	11.10	49H3

σ's

(th n,γ) 33^hCe	0.95	49K4
	1.1	46B25
(~1Mev n,γ) 33^hCe	3.6mb	49H28

$^{143}_{58}Ce_{85}$

τ	33^h		42E3, 50b9, 46B25
	34		48P1
β^-	1.36	a	50b9
	1.3	a	48P1, 46B25
γ	0.5	a	50b9
	0.6	a	48P1

Ce-n-γ	ms	48I5
	chem,σ	46B25
Ce-d-p	chem	48P1, 50b9
Fission	chem	50b9
	Not produced by	
Ce-n-2n		50b9
Ba-α		48P1
	d 19^mLa	50g10
	p 13.8^dPr	50b9

$^{144}_{58}Ce_{86}$

τ	275^d		50b10
	290		44J4
	310		43B2, 43H8
β^-	0.348	s	50n8
	0.30	s	47P10
	0.3	a	50b10
No γ			43B2, 50S23

Fission	ms	48H25
	chem	50b10, 48SP
	d $\sim1^sXe$	50d2
	p 17.5^mPr	43H8, 50n8

$^{145}_{58}Ce_{87}$			$^{146}_{58}Ce_{88}$			
τ	1.8^h	50b11	τ	14.6^m	46PP	
				11	46G7	
				15	43H8	
Fission	chem	46PP	Fission	chem	46PP, 46G7	
	d 0.8^sXe	50d1				
	p 4.5^hPr	50b11, 50k10		p 25^mPr	46PP, 46G7	

Neutron Cross Sections for Natural Element

	$E_n = 0.025$ev	
σ_a	11.2	49P3

140 (59, 81)

τ	3.6^m		45H2
	3.4		42D7
	~1.5		49W2
β^+	2.5	a	45H2
	~2.4	a	49W2
	2.4	cc	42D7
K ~66%			49W2
γ ~2%	1.2	a	49W2
X-ray	0.038	a	49W2
Pr-γ-n	relσ		49P5,48W13
threshold = 9.4			49H17
	9.8		49B3
Pr-n-2n			42D7
	d 3.3^dNd		49W2

141 (59, 82)

	100%		42H2,48I2
I	5/2	S	29W1
Levels	0.141		Ce^{141}
	0.315	?	
	1.05		Nd^{141}
σ's			
(th n,γ)19^hPr		13	46B25
		8.5	48W16
(th n,γ)		11.2	49P3
(~1Mev n,γ)19^hPr		11mb	49H28
(9Mev d,2n)2.4^hNd		0.9	49W2
(19Mev d,2n)2.4^hNd		0.3	49W2
(19Mev d,3n)3.3^dNd		0.08	49W2
(10Mev p,n)2.4^hNd		0.03	49W2
(9Mev d,p)19.3^hPr		0.1	49W2
(19Mev d,p)19.3^hPr		0.06	49W2

142 (59, 83)

τ	18.9^h		48K21
	19.2		46B25
	19.3		42D7
β^-	0.215	aβγ	49M12
	0.35	aβγ	49J3
	2.23	s	47P10
	3 groups present		47P10
	2.14	s	42D7
β/γ ~5			47P10
β/γ ~25			42D7
γγ coincidences			49J3,49M12
No ββ coincidences			49M12
No γ in coincidence with 2.2β			49M12
Pr-n-γ	chem		48K21
	σ		48W16,46B25
Ce-d-2n			48P1

γ	~0.17	a	49M12
	0.134	sc	48C23
	0.329	sc	48C23
	0.490	sc	48C23
	0.624	sc	48C23
	~1.3	s	47P10
	~1.65	s	47P10
	1.53	a coin	49J3
	1.74	a coin	49M12
γ's do not produce Be-γ-n			47W1
La-α-n			42D7
Ce-p-n			42D7
Pr-d-p			42D7

143 (59, 84)

τ	13.8^d		50b13
	13.7		49B56
	13.5		48P1
β^-	0.932		49F18
	0.922		49B56
	0.920	s	49T12
	0.93	s	48S28
Absorption values in agreement:			49M15,48P1,46B25,44J4
No γ			50s20,50b12,48P1
No delayed coincidences			49B9
Level	0.5		Ce^{143}
Fission	ms		46H5
	chem		43H8,50b12
Ce-d-n			48P1
	d 33^hCe		50b9,50b12,50s21,46PP,46B25

144 (59, 85)			
τ	17.5^{m}		50n10,50s23
	17		46G6,43H8
	18		43G14
β^-	3.07	s	50n8
	2.99	s	47P10
	3.1	a	43B2,43H8, 46G6
γ	0.135	sc	50n8
weak	0.22	a	50s23
weak	1.25	a	50s23
Fission	ms		48H25
	chem		50n10,48SP
	d 275^{d}Ce		43H8,50n10

145 (59, 86)			
τ	4.5^{h}		50k10
	4.7		50b11
β^-	3.2	a	50k10
No γ			50k10
Fission	chem		50b11,50k10
	d 1.8^{h}Ce		50b11,50k10

146 (59, 87)			
τ	24.6^{m}		46PP
	25		46G7
β^-	~3	a	46PP
γ	1.4	a	46PP
	hard		46G7
Fission	chem		46G7,46PP
	d 15^{m}Ce		46G7

Neutron Cross Sections for Natural Element

	$E_n = 0.025ev$	
σ_a	45	49P3
	54	49H2
σ_t	65	42R2
	72	42B4
	Graphs Available	
σ_t	0.04-10ev	47S30,47GIF

139 (60, 79)

140 (60, 80)

τ	3.3^d	49W2
K		49W2
γ weak	1.2	49W2
Probably belongs to Pr^{140}		49W2
K X-ray		49W2
Pr-d-3n	chem,σ	49W2
	p 3.6^mPr	49W2

141 (60, 81)

τ	2.42^h		49W2
	2.5		42K3
K ~98%			49W2
β^+ ~2%	0.7	a	49W2
	0.78		42K3
γ ~2%	1.05	a	49W2
Pr K X-ray			49W2
Pr-p-n	σ		49W2,42K3
Nd-n-2n			42K3
Nd-γ-n			42K3
Pr-d-2n	chem,σ		49W2

142 (60, 82)

	27.13%	48I2
	26.80	48M27
Levels	~1.3	Pr^{142}
	~1.65	
	others ?	
	σ's	
(pile n,γ)	<12	49H12

143 (60, 83)

	12.20%	48I2
	12.12	48M27
	σ's	
(pile n,γ)	240	49H12

144
60 84

	23.87%	48I2
	23.91	48M27
Levels	0.135	Pr^{144}
	1.25	
	others ?	
	σ's	
(pile n,γ)	<15	49H12

145
60 85

	8.30%	48I2
	8.35	48M27
	σ's	
(pile n,γ)	<30	49H12

146
60 86

	17.18%	48I2
	17.35	48M27
Level	1.4	Pr^{146}
	σ's	
(th n,γ)11^dNd	1.4	46B25
(pile n,γ)	<20	49H12

147
60 87

τ		11.0^d		47M28,50m1
		11.1		46B25
		12.1		47M22
β^-	40%	~0.4	a	47M28,50m1
	60%	0.90	a	47M28,50m1
		0.76		47M22
		0.8		46B25
γ	40%	~0.58	a	47M28,50m1
		0.45	a	47M22
e^-		0.03	a	47M28,50m1
X-ray		~0.040	a	47M28,50m1
Nd-n-γ		chem		50m1,48K21, 47M28
		σ		46B25
Fission		chem		47M28,50m1
	p 4^yPm			50m3

148
60 88

	5.72%	48I2
	5.78	48M27
	σ's	
(th n,γ)2^hNd	2.8	46B25
(pile n,γ)	<45	49H12

149
60 89

τ	1.7^h		47M28,50m5
	2.00		46B25
β^-	1.5	a	47M28,50m5
	1.6	a	46B25
γ or X-ray			47M28,50m5
Nd-n-γ	chem		47M28,50m5
	σ		46B25,49H12
Nd-γ-n, threshold = 7.4			49H17
p 47^hPm			47M28,50m5

150 60 90		151 60 91
5.60% 48I2 5.69 48M27	τ <8x10^{10} y 34L3	τ short 50m5
	β^- ~0.011 a 34L3	
σ's (pile n,γ) <45 49H12		
	Natural source 34L1 Mass assignment 48K22	Nd-n-γ 50m5
		p 12^{m}Pm 50m5

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143
61 82

τ	~200[d]		42W2
	~1[y]		48W14
K			48W14
γ	0.67	a	42W2
Pr-α-2n			48W14
Nd-d-n			43K1
Pr-α			42W2

144
61 83

145
61 84

Levels	0.242	Sm^{145}
	0.95	

146
61 85

τ	2.7[h]	43K1
β^-	2	43K1
γ		43K1
Nd-d-n		43K1
Nd-p-n		43K1
Nd-α-p		41L2

147
61 86

τ	4[y]		50m3, 50b15
	3.7		50S26
β^-	0.223	s	49P20, 46L6
	0.227	s	49L23
No γ			50S26, 50m3, 47M28
Level	~0.5		Nd^{147}
	σ's		
(th n,γ)5.3[d]Pm	60		47P4
Fission	ms		48H25
	chem		50m3
Nd-n-γβ	chem		47M28, 50m3
	d 11[d]Nd		50m3, 48H25

148
61 87

τ	5.3[d]		43K1, 47P4
β^-	~2.5	a	47P4
	2		43K1
γ	~0.8	a	47P4
Pm^{147} (from fission)-n-γ	ms, σ		47P4
Nd-p-n			43K1
Nd-d-2n			43K1

61 PROMETHIUM Pm

149 (61, 88)

τ	47^h		47M28, 50m4
	47.5		46B25
	49		48K21
β^-	1.1	a	50m4, 46B25, 47M28
	0.98	a	49M19
γ weak	0.25	a	47M28, 50m4
	~0.2	a	49M19
X-ray ?			50m4

Coincidences between 0.98β and 0.2γ 49M19

$\beta\beta$ coincidences 49M19

Fission	ms	47I6
	chem	47M28, 50m4
Nd-n-$\gamma\beta$	chem	50m5, 48K21, 47M28
	d 1.7^hNd	47M28, 50m4

150 (61, 89)

151 (61, 90)

τ	12^m	50m5
β^-	1.9	49K2
γ		49K2
Nd-n-$\gamma\beta$		49K2, 50m5

152 (61, 91)

153 (61, 92)

τ	$< 5^m$	50W6
	p 47^hSm	50W6

154 (61, 93)

155 61 94	156 61 95	
	τ <5^{m} 50W9 p ~10^{h} Sm 50W9	

Neutron Cross Sections for Natural Element

	$E_n = 0.025$ev			
σ_a	8100			49H2
	10,600			49P3
σ_t	8800			
Averaged over Maxwell distribution with kT = 0.025ev. From data of 47S31				

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		0.1	49G9
Assigned to Sm^{152}			49G9
33			47S31

Graphs Available

σ_t	0.02-70ev	47S31,47GIF
	0.02-0.17ev	46B26,47GIF

α activity of Sm

Natural element α emitter		32H1, 36H4,33L1
τ (total Sm)	$0.93\times10^{12\,y}$	48L9
	1.0×10^{12}	36H4
Radioactive isotope assigned to Sm^{152}		48D2
α	2.14 photographic plate	46C1
	2.2 cc	36H4
No α activity found from Sm-200Mev p		49T13

144 (62, 82)

3.16%	48I1
2.95	48M27

145 (62, 83)

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

146 (62, 84)

147 (62, 85)

15.07%	48I1
14.62	48M27

148 (Z = 62, N = 86)

	11.27%		48I1
	10.97		48M27
Level	~0.8		Pm^{148}

149 (Z = 62, N = 87)

	13.84%		48I1
	13.56		48M27
Levels	0.25		Pm^{149}
	~0.5 ?		Eu^{149}

σ's

(th n,γ)	65,000	

Averaged over Maxwell distribution kT = 0.025ev. From data of 47S31, 47L19, 48I1

150 (Z = 62, N = 88)

	7.42%		48I1
	7.27		48M27
Sm-n-γ			49K15

E_γ (max) = 6.6

151 (Z = 62, N = 89)

τ	$\sim 10^3$ y		49M5
	~20		47I7
β^-	0.074	s	49M5
	0.079	s	49K5
	0.06	a	48P7
No γ ?			48P7
No γ			49M5
γ	0.021	pc	49S35

β spectrum may have forbidden shape 49M5

L X-ray			49S35
Sm-n-γ	ms		47I7
Fission	chem		49M5

152 (Z = 62, N = 90)

	26.63%		48I1
	27.34		48M27

α activity assigned to this isotope 48D2

See α activity box

Levels ?		Eu^{152}
		$Eu^{152,154}$

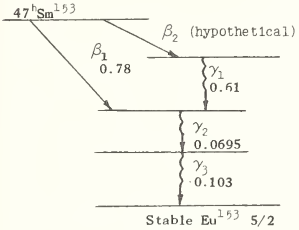
σ's

(th n,γ)47^hSm	135	47S33
	280	46B25

153 (Z = 62, N = 91)

τ	47^h			46B25,42K3,50w6

Proposed decay scheme 49M2



β_1^-		0.78	a	48B5
		0.73	a	50w6
γ_1	weak	0.61	a coin	48B5
		~0.6	s	46M6
		0.57	a	50w6
γ_2		0.0695	sc	48H18
		$\alpha\sim\infty$	K/L ~0.5	49M2
γ_3		0.103	sc	48H18
		0.102	sc	48C9
		0.11	s	46M6
		0.11	a coin	48B5

Eu K,L X-rays	46B25,48B5
(K X-ray)/β ~0.7	46B25
No coincidences delayed $>1.5^{\mu s}$	48B5

βe^-, βX, $0.11\gamma\beta$, $0.11\gamma X$, XX coincidences 48B5

Sm-n-γ	ms	46H8
	σ	46B25,47S33
Fission		50w6,48SP
Sm-γ-n		41L2

Sm-n-2n		42K3
Sm-d-p		42K3
Nd-α-n		42K3
	d <5^mPm	50w6

154 (Z = 62, N = 92)

22.53%	48I1
23.29	48M27

Levels ?	Eu^{154}
	$Eu^{152,154}$

	σ's	
(th n,γ)25^mSm	5.5	47S33

155 (Z = 62, N = 93)

τ	25^m		50w7
	21		42K3,38P5
β^-	1.9	a	50w7
	1.8		42K3
γ	~0.3	a	50w7

Sm-n-γ		41L2,38P5,36H1
	σ	47S33
Sm-d-p		42K3
Fission		50w7

Assignment on basis of fission yield and decay energy

156 (Z = 62, N = 94)

τ	~10^h		50w9
β^-	~0.8	a	50w9
Fission	chem		50w9

Neutron Cross Sections for Natural Element

$E_n = 0.025$ev

	Value	Ref.
σ_a	4200	49P3
σ_t	4800	47S31
	4120	42R2

Resonances

E_o	σ_o	Γ	Ref.
-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, 47GIE, 50Ad

146
63 83

147
63 84

τ	53^d	50m9
	40	43E6
γ	0.42	50m9
	1.0	50m9
γ's ~ equal intensity		50m9
Sm-d-2n		50m9, 43K1

148
63 85

149
63 86

τ	14^d	50m9
γ or X-ray		50m9
e^-	~0.5	50m9
Sm-d-n		50m9

150
63 87

τ	27^h	38P5
β^+		38P5
Eu-n-2n		38P5

151 (Z = 63, N = 88)

	47.77%		48H31
I	5/2	S	35S1
μ	3.4	S	38S9
q	$\sim$+1.2	S	38S10

σ's

(th n, γ) 9^{h}Eu	1400	47S33
	1500	46B25
(pile n, γ)	5200	49H4
(th n, γ) long Eu	2500 per Eu atom	46B25
(th n, γ) long Eu	1500 per Eu atom	47S33

152 (Z = 63, N = 89)

τ_1	9.2^h		38P5
	9.3		46B25
K			46B25, 47M23
β^-	0.36	a	47M23
	1.8	a	47M23
	1.88	s	39T1
γ	0.123	sc	39T1
	0.163	sc	39T1
	0.725	sc	39T1
	1.0	a	47M23
K/β = 0.6			46B25
0.22			49H4
Eu-n-γ	ms, σ		49H4, 46H8
	chem, σ		48K21, 41F3
Eu-n-2n			38P5
Eu-d-p	chem		41F3

τ_2		5.3^y		49H4
K				49M5, 49H4
β^-	80%	0.9	a	49M5
	20%	1.7	a	49M5
γ		$\sim$0.3	a	49M5

probably corresponds to soft γ's of $Eu^{152,154}$ 49M5

	$\sim$1.2	a	49M5

probably associated with K capture 49M5

K/β = 5 49H4(49M5)

σ's

(pile n, γ)	3200	49H4
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 radiation of mixture with that of fission product Eu^{154}. See also $Eu^{152,154}$.

152, 154 (Z = 63, N = 89, 91)

K			47M23, 46B25
β^-	0.75	s	48S24
	0.751	s	48C9
	1.575	s	48S24
	1.57	s	48C9
	1.4	a	48K7

γ	48C9		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

γ	1.23	a	48C9
	0.9	a	48K7
See also			48C26
Eu-n-γ			48S24
Eu-d-p	chem		41F3, 48K7

153 (Z = 63, N = 90)

	52.23%		48H31
I	5/2	S	35S1
μ	1.5	S	38S9
q	$\sim$+2.5	S	38S10
Levels	0.102		Gd^{153}, Sm^{153}
	0.172		Sm^{153}
	0.78		Sm^{153}

σ's

(pile n, γ) 5.4^{y}Eu	240	49H4

154 (Z = 63, N = 91)

τ		5.4^y		49H4
β^-	50%	0.3	a	49H4(49M5)
	40%	0.7	a	49H4(49M5)
	10%	1.9	a	49H4(49M5)
γ		$\sim$1.2	a	49H4, 49M5

0.3 and 0.7 β's probably in coincidence with $\sim$1.2γ 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 $Eu^{152,154}$.

σ's

(pile n, γ)	880	49H4
Eu-n-γ	ms, σ	49H4
Eu^{153} (fission)-n-γ		49M5

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155 (63 92)

τ		1.7^{y}	49H4
		2	50W10
β^-	80%	0.154 s	49M5
	20%	0.243 s	49M5
		2.23 a	50W10
γ	60%*	0.085 sc	49M5
	40%*	0.099 sc	49M5
		0.0844 critical a	50W10

*% of γ's

0.154 β in coincidence with γ 49M5
No $\gamma\gamma$ coincidences 49M5
No delayed $\beta\gamma$ coincidences 49M5

σ's

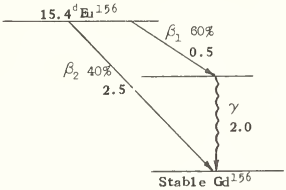
(pile n,γ)	7,900	49H4
	14,000	47I7
	~30,000	49M5

From expected and observed fission yields.

Sm-n-$\gamma\beta$	ms	47I7
Fission	chem	48SP, 50W10
Eu-n-γ, n-γ		49H4

156 (63 93)

τ	15.4^{d}	50W9, 49H4



β_1	~0.5	a	50W9
β_2	2.5	a	50W9
γ	2.0	a	50W9
Eu^{155}-n-γ	ms		47I7
Eu-n-γ	ms		49H4
Fission	chem		50W9, 48SP
	d 10^{h}Sm		50W9

157 (63 94)

τ		15.4^{h}		50W8
β^-	75%	~1.0	a	50W8
	25%	~1.7	a	50W8
γ		0.2	a	50W8
		0.6	a	50W8

Fission chem 50W8, 48SP
Mass assignment from fission yield and decay energy.

158 (63 95)

τ	60^{m}	50W8
β^-	~2.6	50W8

Fission chem 50W8
Mass assignment from fission yield.

Neutron Cross Sections for Natural Element	α activity of Gd or Tb	151 (64, 87)
E_n = 0.025ev	τ ~7^m 49T13	
σ_a 36,700 49H2	α 4.2 49T13	
σ_t 48,000 47B15		
42,000 47S31	τ ~4^h 49T13	
See also 48WH	α ~4 49T13	
Resonance	α/K capture ~1% 49T13	
E_o σ_o Γ	Both activities produced by	
0.028ev 45,000 0.24 47B15	Gd-200Mev p 49T13	
0.044 32,000 0.10 47S31	Dy-200Mev p 49T13	
	Not produced by	
	Sm-200Mev p 49T13	
	No α activity with τ <$10^{12 y}$ found in natural Gd 48K27	
Graphs Available		
σ_t 0.002-0.2ev 47B15,47GIF		
0.005-0.2ev 47S31,47GIF		

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}
		~1.2 Tb^{154},Eu^{154}
	Levels ~0.2 ? Tb^{153}	See also $Eu^{152,154}$
	~0.45 ?	
σ's		
(th n,γ)225^dGd <125 47S33		
No activity found	Gd-n-γ ms,σ 47I7	
	chem 49K1	
	Eu-d-2n chem 41F3,48K7	
	* Probably in Tb^{161} 50S7	

155 (Z = 64, N = 91)

	14.78%	48H31
	15.61	41W13
Levels	0.085	Eu^{155}
	0.099	
	σ's	
(pile n,γ)	69,000	47L19

156 (Z = 64, N = 92)

	20.59%	41W13,48H31
Level	2.0	Eu^{156}

157 (Z = 64, N = 93)

	15.71%	48H31
	16.42	41W13
Levels	0.2	Eu^{157}
	0.6	
	σ's	
(pile n,γ)	240,000	47L19

158 (Z = 64, N = 94)

	24.78%	48H31
	23.45	41W13
	σ's	
(pile n,γ)18^hGd	4.5	49B1
	4	47S33
Gd-n-γ		49K15
E_γ(max) = 6.3		

159 (Z = 64, N = 95)

τ	18.0^h		48K3,49B1
	17.9		48K21
	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			49M26
Gd-n-γ	chem,σ		49K1,49B1
Gd-d-p			48K3
Not produced by Tb-n-p			48K3
	Not p 6.7^d Tb chem		48K21

160 (Z = 64, N = 96)

	21.79%	48H31
	20.87	41W13
	σ's	
(pile n,γ)3.6^mGd	0.18	49B1
	0.1	49D17
(pile n,γβ)6.7^dTb	0.16	49B1

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

Neutron Cross Sections for Natural Element	α activity of Tb or Gd	151 (65, 86)
$E_n = 0.025$ev σ_a 55 49P3	τ ~7^m 49T13 α 4.2 49T13 τ ~4^h 49T13 α ~4 49T13 α/K capture ~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 K 48W12 K X-ray 48W12 Eu-α-3n chem 48W12	τ 5.1^d 48W12 K 48W12 e^- 0.15 a 48W12 0.4 a 48W12 K,L X-rays 48W12 Eu-α-2n chem 48W12	τ 17.2^h 48W12 K 48W12 β^+ 2.6 a 48W12 γ 1.4 a 48W12 e^- ~0.22 a 48W12 ~1.0 a 48W12 K,L X-rays 48W12 Eu-α-n chem Eu-α-3n chem Gd-p-n chem } 48W12

155 (Z = 65, N = 90)

τ	$\sim 1^{y}$		48W12
K			48W12
e^-	0.1	a	48W12
K,L X-rays			48W12
Eu-α-2n	chem		48W12

156 (Z = 65, N = 91)

τ	5.9^{d}		49B1
γ	~0.3	a	49B1
	1.1	a	49B1
e^-	soft		49B1
Gd-d ?			49B1
Gd-p			49B1

157 (Z = 65, N = 92)

158 (Z = 65, N = 93)

τ	3.6^{m}		38P5
β^+			38P5
Tb-n-2n			38P5

159 (Z = 65, N = 94)

	100%		48H31
I	3/2	S	34S2
Levels	0.055	?	Gd^{159}
	0.35	?	
	σ's		
(th n,γ) 73^{d} Tb	>22		46B25
(th n,γ)	55		49P3

160 (Z = 65, N = 95)

τ	72.5^{d}		48K21
	73.5		46B25
	77.3		48C9
β^-	0.546	s	48C9
	0.882	s	48C9
	0.71	a	48K3
	0.75	a	46B9
γ	0.086	s	48C9
	0.195	s	48C9
	0.212	s	48C9
	0.297	s	48C9
	1.15	a	48C9

3.3^{h} activity formerly assigned here shown to be Dy^{165} 49F7

Tb-n-γ	ms		47I7
	σ		46B25
Gd-d-2n			48K3

161 65 96		
τ 6.75[d] 49B1 7.0 49K1 β^- 0.52 a 49B1 0.5 a 49K1 γ 0.026? pc 50S7 0.05 a 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	No long lived Tb with half life between 0.3[y] and 30[y] formed in fission. 49M5	

Neutron Cross Sections for Natural Element	α activity of Dy or Ho	155 66 89
$E_n = 0.025$ev	τ 20^m 49T13	
σ_t 1150 47B15	α 4.1 49T13	
Resonances		
E_o σ_o Γ		
-1.01ev 79,000 0.20 47S31		
1.74 ⎫		
5.5 ⎬ 47S30		
~20 ? ⎭		
Graphs Available	Produced by	
σ_t 0.007-0.2ev 47GIF, 47B15	Dy-200Mev p 49T13	
0.07-20ev 47GIF, 47S30	Not produced by	
0.02-0.4ev 47GIF, 47S31	Sm or Gd-200Mev p 49T13	

156 66 90	157 66 91	158 66 92
0.052% 49I2		0.0902% 49I2

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66 DYSPROSIUM Dy

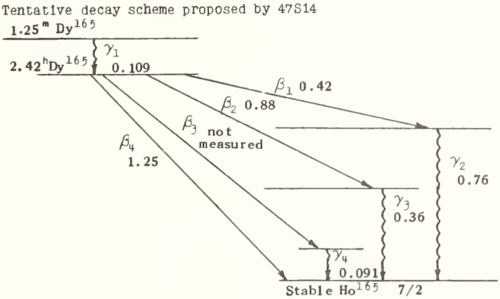
159 66 93	160 66 94	161 66 95
τ 146^{d} 49K2 K 49K2 Tb K,L X-rays 49K2 e^{-} soft 49K2 Dy-n-γ 49K2	2.29% 49I2 Levels 0.086, 0.195, 0.212, 0.297, 1.15 ? Tb^{160}	18.88% 49I2 Levels ~0.05 Tb^{161} ~0.2 Ho^{161} ~0.65 Ho^{161}

162 66 96	163 66 97	164 66 98
25.52% 49I2 Level 1.1 Ho^{162}	24.97% 49I2 Level ~0.45 Ho^{163}	28.18% 49I2 σ's (th n,γ) 1.3^{m}Dy 2860 47G14 (th n,γ) 2.4^{h}Dy 2200 46B25 2620 47S33

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



$Dy^{164}(n,\gamma)$ cross sections ~ 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 Ho^{165}. 47I3

1.25^mDy produced by		
Dy^{164}-n-γ		47I3
Dy-n-γ	σ	47G14, 46B25, 47S33

2.42^hDy produced by		
Dy-n-γ	ms	47I8
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) 81^hDy	5000	49K22

166
66 100

τ	81^h		49K22
β^-	0.4	a	49K22
Dy-n-γ, n-γ	chem, σ		49K22
	p 27.3^hHo		49K22

Neutron Cross Sections for Natural Element			α activity of Ho or Dy			159 (67, 92)
	$E_n = 0.025$ev		τ	20^m	49T13	
σ_a	67	49P3	α	4.1	49T13	
σ_t	52	42B4				
	47	42R2				
			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	~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	48W12	e^-	0.3	a	48W12
				0.6	a	48W12	γ	1.1	a	48W12
			γ			48W12	K, L X-rays			48W12
			K, L X-rays			48W12				
Tb-α-3n		48W12	Tb-α-2n	chem		48W12	Tb-α-n	chem		48W12
			Dy-d-n, 2n, 3n	chem		48W12	Dy-p-n	chem		48W12
			Dy-p-n	chem		48W12				

163 (Z = 67, N = 96)

τ	7^d		48W12
K			48W12
e^-	0.4	a	48W12
K,L X-rays			48W12
Dy-p-n	chem		48W12

164 (Z = 67, N = 97)

τ	38.6^m		48W13
	35		48W12
	47		38P5
β^-	0.7	a	48W12
Dy-p-n	chem		48W12
Ho-n-2n			38P5
Ho-γ-n	rel σ		48W13

165 (Z = 67, N = 98)

	100%		34A1
I	7/2	S	35S2
Levels	0.091		Dy^{165}
	0.36		
	0.76		
σ's			
(th n,γ) 27^hHo	60		47S33
	49		46B25
(th n,γ)	67		49P3
(38Meva,3n)7.7^hTm	1.1		49W3
(30Meva,3n)7.7^hTm	5×10^{-4}		49W3
(38Meva,2n)9.6^dTm	7×10^{-3}		49W3
(30Meva,2n)9.6^dTm	0.1		49W3
(19Meva,2n)9.6^dTm	10^{-3}		49W3
(38Meva,n)85^dTm	10^{-4}		49W3
(30Meva,n)85^dTm	3×10^{-3}		49W3
(19Meva,n)85^dTm	0.2		49W3

166 (Z = 67, N = 99)

τ	27.3^h		46B25, 48K21
	27.7		49C15
	26.8		49G1
β^-	1.8	a	49K22, 46B25
	1.88	s	49G1
	1.64	a	49C15
γ	0.073	s	49K2
	0.080	sc	49G1
	0.081	sc	49C15
1.5%	1.2	a	49G1
	0.92	a	49C15
No delayed coincidences			49M26
Ho-n-γ	ms		47I2
	σ		46B25, 47S33
	chem		49C15, 48K21
Dy-n-γ,n-γβ	chem		49K22
	d 81^hDy		49K22

Neutron Cross Sections for Natural Element		161 68 93
$E_n = 0.025$ ev σ_a 166 49P3 σ_t ~165 (extrapolation) 49B2 185 42B4 233 42R2 Resonance E_o σ_o ~0.5ev ⩾1700 49B2 Graph Available σ_t 0.03-0.7 ev 49B2		

162 68 94	163 68 95	164 68 96
0.1% 41W8		1.5% 41W8

165 (Z = 68, N = 97)

166 (Z = 68, N = 98)

	32.9%	41W8
Levels	0.073	Ho^{166}
	~1.0	Ho^{166}
	1.7	Tm^{166}
	others ?	

167 (Z = 68, N = 99)

	24.4%	41W8
Levels	0.22 ?	Tm^{167}
	0.95 ?	

168 (Z = 68, N = 100)

	26.9%	41W8
Levels	0.21 ?	Tm^{168}
	0.85 ?	

169 (Z = 68, N = 101)

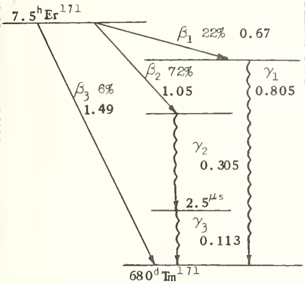
τ	9.4^d	48K11
β^-	0.33 s	48K11
No γ		48K11
Er-n-γ	chem	48K11

170 (Z = 68, N = 102)

	14.2%	41W8
	σ's	
(th n,γ) 7^h Er	>7	46B25

171 (Z = 68, N = 103)

τ	7.5^h	48K11
	5.7-7.1	46B25
	5.1	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	sc	48K11
		$\alpha = 1.3$		48D5
		$2.5^{\mu s}$ delay		48D5
other γ's ?				49C5

Er-n-γ		38P5
	chem	48K11
	σ	46B25

172 (Z = 68, N = 104)

? (Z = 68)

τ	2.5^s	49D16
IT		49D16
e^-	$\sim$0.180	49D16
Er-n-γ		49D16
σ(atomic) = 3		49D16

Long and short lived conversion electrons assigned to Er from K, L, M differences 49C5

Neutron Cross Sections for Natural Element

	$E_n = 0.025$ ev	
σ_a	118	49P3
σ_t	114	42B4
	69	42R2

165 (69 96)

166 (69 97)

τ	7.7^h		49W3
β^+	2.1	a	49W3
K			49W3
e^-	0.24	a	49W3
β^-?	~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)

τ	9.6^d		49W3
K			49W3
e^-	0.21	a	49W3
γ	0.22	a	49W3
	0.95	a	49W3
Er K X-ray			49W3
Er L X-ray (20% of K)			49W3

Ho-α-2n	chem, σ	49W1
Er-p-n	chem	49W1

168 (69 99)

τ	85^d		49W3
K			49W3
e^-	0.16	a	49W3
β^- ?	0.5	a	49W3
γ	0.21	a	49W3
	0.85	a	49W3
Er K X-ray			49W3
Er L X-ray (20% of K)			49W3

Ho-α-n	chem, σ	49W1
Er-p-n		49W1
Tm-n-2n		49W1

169 (69 100)

	100%		34A1
I	1/2	S	34S3
Levels	?		Yb^{169}

σ's		
(th n, γ) 129^dTm	126	47S33
	95	46B25
(th n, γ) -	118	49P3
(38Mev α, 3n) 2.1^dLu	0.01	49W12

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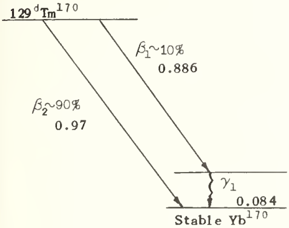
$^{170}_{69}$Tm$_{101}$

τ	129^{d}	48K21
	127	46B9
	125	46B23



$\beta\gamma$ coincidences	49G10, 49K2
No delayed coincidences	49M26

β_1^-	~10%	0.886	s	49F13
β_2^-	~90%	0.970	s	49G10, 49F13
		0.97	s	49S5
		0.98	s	48K21
γ_1		0.0839	sc	49F13
		α_K = 0.4 α_L = 2.75		49F13
		α_M = 0.85		49F13
		0.0855	sc	49S5*
		K/L = 0.71		49S5
		0.0827	sc	49G10
		α_K = 0.4**		49G10
	~25%	0.0826	s	49G3
		α_L~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.

**Independent of decay scheme but definition not clear.

Tm-n-γ	chem	48K21
Tm-d-p		48K18

$^{171}_{69}$Tm$_{102}$

τ	680^{d}		48K21
β^-	0.10	s	48K21
No γ			48K21
Levels	0.113		Er^{171}
	$2.5^{\mu s}$ delay		
	0.418		
	0.805		
	d of an Er		48K11

Neutron Cross Sections for Natural Element	167 70 97	168 70 98
$E_n = 0.025$ev σ_a 36 49P3 σ_t 46 42R2 50 42B4	<0.002% 49H8	0.14% 49H8 0.06 38D5, 41W9 σ's (th n, γ) 33^d Yb 18,300 46B25 35,000 46A2

169 70 99	170 70 100	171 70 101
τ 33^d 46B9 33.5 47I13 32.5 48K18 K 46B9 γ sc 48I7 / 49C23 0.064 0.095 / 0.094 0.110 / 0.110 0.121 0.133 / 0.130 0.142 0.160 0.178 / 0.178 0.199 / 0.198 0.308 / 0.308 Tm X-ray 46B9 No $\beta\gamma$ delay 49M26 Yb-n-γ chem 48K21 σ 46B25, 46A2	3.03% 49H8 4.21 41W9 Levels 0.084 Tm^{170} ~2.5 Lu^{170}	14.34% 49H8 14.26 41W9 I 1/2 S 38S10 μ 0.45 S 38S11 Levels ? Lu^{171}

172
70 102

	21.88%	49H8
	21.49	41W9
Levels	?	Lu^{172}

173
70 103

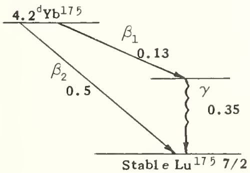
	16.18%		49H8
	17.02		41W9
I	5/2	S	38S10
μ	-0.65	S	38S11
q	+ 3.9		38S10

174
70 104

	31.77%	49H8
	29.58	41W9
	σ's	
(th n, γ) 4^dYb	74	46B25
	24	46A2

175
70 105

τ	4.2^d		46A2, 48K21
	4.1		46B9



β_1^-	0.13	a	46B9
β_2^-	0.50	a	46B9
	0.45	cc	46A2
γ	0.35	a	46B9
$\beta\gamma$ coincidences			46B9
Yb-n-γ	ms		47I8
	chem		48K21
	σ		46B25, 46A2

176
70 106

	12.65%	49H8
	13.38	41W9
	σ's	
(th n, γ) 1.8^hYb	6.7	46B25
(th n, γ) 1.8^hYb	4.5	46A2

177
70 107

τ	1.8^h		49M41
	2.4		46B9
	1.9		46A2
β^-	1.3	a	46B9
	1.2	cc	46A2
γ	0.15		49M41
	$0.13^{\mu s}$ delay		
No other γ follows the delay			49M41
Yb-n-γ	chem		48K21
	σ		46B25, 46A2

? 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 σ(atomic) = 0.34		49D17	Yb-n-γ σ(atomic) = 0.4		49D17	

Neutron Cross Sections for Natural Element	170 71 99	171 71 100
$E_n = 0.025$ev	τ 2.1^d 49W12	τ 8.5^d 49W12
σ_a 108 49P3		
σ_t 99 42R2		
165 42B4	K 49W12	K 49W12
	γ ~2.5 a 49W12	e^- 0.17 a 49W12
		~0.5 a 49W12
	e^- 0.1 a 49W12	
	K,L X-rays 49W12	K,L X-rays 49W12
	Tm-α-3n chem, relσ 49W12	Tm-α-2n chem, relσ 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
β^+ ~20% 1.8 a 49W12	γ Possibly annihilation 49W12	e^- ~0.1 a 49W12
		~0.16 a 49W12
K X-ray 49W12		K,L X-rays 49W12
Tm-α-n chem, relσ 49W12	Tm-α-n chem, relσ 49W12	Tm-α-n chem, relσ 49W12
Yb-p-n chem 49W12	Yb-p-n chem 49W12	Ta-d 49W12
d>50^dHf 49W12		d of a Hf 49W12

$^{173}_{71}$Lu$_{102}$?

τ	6.7^d		49W12
K			49W12
γ			49W12
e^-	0.13	a	49W12
	~0.6	a	49W12
K, L X-rays			49W12
Yb-p-n	chem		49W12
	d ~ 5^yHf		49W12

$^{174}_{71}$Lu$_{103}$?

τ	160^d		49W12
K ~75%			49W12
β^- ~25%	0.6	a	49W12
γ			49W12
e^-	0.16	a	49W12
K, L X-rays			49W12
Lu-n-2n	chem		49W12
Hf-d-α	chem		49W12
Lu-d-p2n	chem, σ		49W12

$^{175}_{71}$Lu$_{104}$

	97.5%		39M3
I	7/2	S	35S3
μ	2.6	S	36G3
q	+5.9		36G3
Levels	0.35		Hf^{175}, Yb^{175}
	1.5		Hf^{175}
σ's			
(th n, γ) 3.7^hLu		16	47S33
		27	46B25
		45	46A2
(10Mev p, n) 70^dHf		0.03	49W11
(19Mev d, 2n) 70^dHf		0.05	49W11
(19Mev d, p) 3.7^hLu		0.044	49W12
(~1Mev n, γ) 3.7^hLu		0.10	49H28

$^{176}_{71}$Lu$_{105}$

τ	3.75^h		49W12
	3.67		46A2
	3.7		46B9
β^-	1.04	a	48W12
	1.15	a	46B9
	1.25	cc	46A2
No γ			46B9
Lu-n-γ			46B9
	chem		48K21
	σ		47S33, 46B25, 46A2
Lu-γ-γ	σ		47D4
Lu-d-p	σ		49W12

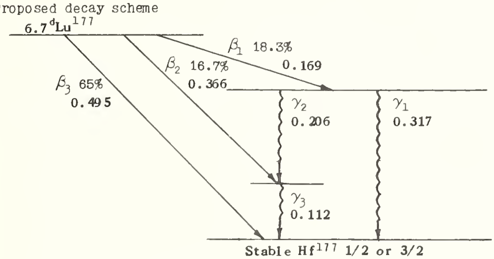
Mass assignment from yield relative to 6.7^dLu in d-p and fast n-γ reactions 49W12, 46A2

	2.5%		39M3
τ	$2.4\times10^{10\,y}$		39L13 (47F7)
I	≥7	S	39S14
μ	3.8	S	39S14
q	+6-8		39S14
σ's			
(th n, γ) 6.7^dLu		3640	47S33
		3600	46B25
		4400	46A2
(~1Mev n, γ) 6.7^dLu		0.30	49H28
(19Mev d, p) 6.7^dLu		0.04	49W12

K 67%			47F7
β^- 33%	0.40	a	43F2, 47F7
	0.22	a	39L13
γ 67%	0.26	a	47F7
K X-ray			47F7

177
71 106

τ	6.70^d	49W12
	6.8	46B9, 49C15
	6.6	46A2, 43F2
	7.0	49D5
Proposed decay scheme		49D5



No delayed $\beta\gamma$ coincidences ($3x10^{-7}$ to 10^{-3^s})		49B9
Lu-n-γ	ms	47I8
	σ	47S33, 46A2, 46B25
	chem	48K21
Lu-d-p	σ	48W12
Hf-d-α		49W12

β_1^-	18.3%	0.169	s	49D5
β_2^-	16.7%	0.366	s	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
Level in Lu^{177}		0.15		Yb^{177}

Neutron Cross Sections for Natural Element

$E_n = 0.025$ev

σ_a	103	49P3
	157	49H2
σ_t	175	42L1

Resonance

E_o	~1.0ev	49B2

This resonance formerly attributed to Zr.

Graphs Available

σ_t	0.02-1.5ev	49B2

170
72 98

172 ?
72 100 ?

τ	$>50^d$	49W12

3.4^d Lu shown to grow from long-lived Hf parent, but presence of 67^d Hf prevents identification. 49W12

p 3.4^d Lu 49W12

172 ?
72 100 ?

τ	22.0^h	49W12
K or IT		49W12
e^-	0.12	49W12
	0.22	49W12
K, L X-rays		49W12
Yb-α-2n,3n	chem	49W12

Not p 6.7^d Lu 49W12

173 ?
72 101 ?

τ	$\sim 5^y$	49W12
K		49W12
No e^-		49W12
K, L X-rays		49W12
Yb-α-n,2n,3n	chem	49W12
Ta-d	chem	49W12

p 6.7^d Lu 49W12

174
72 102

0.18%	44M2, 49H3

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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	49W11						
	α~0.4	49W11						
	1.5	49W11						
Lu K,L X-rays		49W11						
			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		13.78%	49H3
	27.10	44M2					13.84	44M2
			IT		46F1	I	1/2 or 3/2 S	35R1
			γ	0.15 sc	48H37			
				α>19, K/L = 0.9				
				0.19 a	46F1			
Levels	?	Ta^{178}						
			Hf-n-γ		48H37,46F1			

$^{180}_{72}Hf_{108}$

	35.44%	49H3
	35.11	44M2
σ's		
(th n,γ)46^dHf	10	47S33

$^{181}_{72}Hf_{109}$

τ	46^d	47S33
	47	48H55

β^-	0.405	s	49C11
	0.460	s	48H55
	0.41	s	49J5

βγ delay of $20.1^{\mu s}$ 48B14

βγ delay of $22^{\mu s}$ 48D5

~0.5 γ in parallel with delayed γ. 48D5

No $\beta\gamma_s$ delay between $3x10^{-8s}$ and 10^{-3s} other than $22^{\mu s}$. 49M26

γ_2 and γ_5 follow the delay, γ_3 and γ_4 do not. 49H34

No delayed γγ coincidences 49W20

Hard γ's not in coincidence 48H55

βγ and γγ coincidences 49M6

Delayed e⁻'s of γ_2 and γ_5 in instantaneous coincidence. 49B9,48B14

Hf^{181} produced by

Hf-n-γ	σ	47S33
Ta-n-p ?		47N4

γ_1		0.087	s	49J5
Possibly in parallel with γ_3				
γ_2		0.133		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		49H34
		0.134	s	49C11
γ_4		0.344		49H34
		0.337	s	49C11
			α~0.02,K/L = 4	49C11
	22%*	0.347	s,K/L = 5	49J5
		0.342		48H55
γ_5		0.480		49H34
	78%*	0.471	s	49C11
			α~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		
$E_n = 0.025$ev		K 49W13
σ_a 21 49P3; 36 49H2		No β^+ 49W13
σ_s 4.9 (48WH)		β^- or e^- ~1 49W13
σ_t 26 47H25		γ 2 a 49W13
		e^- 0.12 a 49W13; 0.18 a 49W13
Resonances: E_o / $\sigma_o\Gamma^2$: 4.1ev ~44; 10.0 ~25; 13.0 ~3; 22 ~18; 37 ~400 — 47H25		K,L X-rays 49W13
		Lu-α-3n chem 49W13
Graphs Available: σ_t 0.025-600ev 47H25, 47GIF; 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; Hf-p-n; Ta-d — 49W13	Lu-α-n, 2n chem 49W13; Hf-p-n chem 49W13	Lu-α-n chem; Ta-d-p3n chem; Ta-p-p2n chem; Hf-p — 49W13
d 2.2^hW 49W13		d 21^dW 49W13

180 (Z = 73, N = 107)

τ	8.00^h		49W13
	8.2		38O1
K			49W13, 38O1
β^-	0.7		49W13
β^- or e^-	0.48		38O1
γ	1.3		49W13
Hf K X-ray			49W13
Ta-n-2n			38O1, 37P2
	chem		49W13
Ta-γ-n	threshold = 7.7		49M17
Ta-d-pn	chem		49W13
Ta-p-pn	chem		49W13
	threshold = 6		49B34

181 (Z = 73, N = 108)

	100%		39D5, 48W9
I	7/2	S	33M1, 33G2
μ	2.1	S	35G1
q	~+6	S	43S15
Levels	? ?		Hf^{181}
$\beta\gamma$ delay of $20^{\mu s}$ in Hf^{181}			
σ's			
(th n,γ) 117^dTa	21		47S33
	7		41H8(48WH)
(th n,γ) 16.4^mTa	0.034		47S33
(19Mev d,2n) 140^dW	0.05		49W14

182 (Z = 73, N = 109)

τ_1	16.4^m		48H37
	16.2		47S2
IT			48H37
γ	0.18	s	48H37
	K/L = 0.25		
β^-	0.2	a	47S33
16^m activity from Ta-fast n's with β^- of 0.6, e^-, and X			49W13
Ta-n-γ	chem, σ		47S33
Not d 117^dTa			47S2

τ_2	117^d		47S33, 43Z1
	123.5		49C19
	99		40H8
β^-	0.25 ?	s	49B21
	0.53	s	47R1, 49B21
	0.50	s	47J1

γ: 49C19	49B21	49G14	47R1
0.0462			
0.0583			
0.0647			
0.0668			
0.0761		0.071	
0.0837	0.082	0.084	
0.0931			
0.0992	0.098		
0.107		0.103	
0.109			
0.112	0.112		
0.118			
0.123	0.122		
0.138	0.132		
0.150	0.141	0.151	0.15
0.158	0.157		
0.159	0.165		
0.171	0.172		
0.178		0.180	
0.197	0.198		
0.212		0.209	
0.220	0.222	0.220	0.22
0.227			
	0.243		
	0.255		
0.261	0.264	0.261	
	0.290?		
0.301	0.299?		
0.307			
0.328	0.324		
	1.133	1.12	1.13
	1.219	1.19	1.22
	1.237	1.23	

1.13, 1.22, and 1.24 γ's most intense. 0.157, 0.165, and 0.222 γ's also prominent — 49B21

βe^- coincidences		48S17
No delayed coincidences		49B9, 49M26
Ta-n-γ		38O1
	chem, σ	47S33
Ta-d-p		43Z1

Neutron Cross Sections for Natural Element

σ_s coh	3.3	49S12
σ_s bound	5.7	49S12
	$E_n = 0.025$ev	
σ_a	17.7	49P3
	28.0	49H2
σ_s	5	(48WH)
σ_t	23	47H25

Resonances

E_o	$\sigma_o\Gamma^2$	
4.0ev	~13	47H25
7.4	~5	47H25
18	~3,000	47H25
45	~400	47H25
180	~10,000	47H25

Graphs Available

σ_t	0.014-5000ev	47H25, 47GIF
	See also 49H16	
	0.023-4Mev	47GIF
	0.023-1.4	50Ad

177 (Z = 74, N = 103)

τ	2.2^h		49W13
K			49W13
γ	~0.45	a	49W13
	1.2	a	49W13
e^-	0.13	a	49W13
	~0.4	a	49W13
K,L X-rays			49W13
Ta-d-6n	chem		49W13
Ta-p-5n	chem		49W13
	p 2.5^dTa		49W13

178 (Z = 74, N = 104)

<0.001% if stable form exists — 49D7

179 (Z = 74, N = 105)

τ_1	30^m	49W13
K		49W13
K,L X-rays		49W13
No γ, no e^-		49W13
Ta-d-4n		49W13
Ta-p-3n		49W13

τ_2	21.0^d	49W13
K		49W13
e^-	0.1	49W13
	~0.5	49W13
K,L X-rays		49W13
Ta-d-4n		49W13
Ta-p-3n		49W13
	p 120^dTa	49W13

$^{180}_{74}W_{106}$

	0.126%	48W9
	0.122	46I1
	0.135	46W3
	0.16	48M27
	0.143	49H3

$^{181}_{74}W_{107}$

τ	140^d		47W3
K			47W3
γ	1.83	a	47W3
e^-	0.07	s	47W3
	0.09	a	47W3
Ta K,L X-rays			47W3
Ta-d-2n			47W3
Ta-p-n	threshold < 4		49B34

$^{182}_{74}W_{108}$

	26.31%	48W9
	25.77	46I1
	26.41	46W3
	26.35	48M27
	26.09	49H3
Levels	? ?	Re^{182}, Ta^{182}

$^{183}_{74}W_{109}$

τ	5.5^s		49D16
IT			49D16
e^-	0.080	a	49D16
W-n-γ			49D16

	14.28%	48W9
	14.24	49H3, 46I1
	14.40	46W3
	14.32	48M27
I	1/2 ?	34G2

$^{184}_{74}W_{110}$

	30.64%		48W9
	30.68		46I1
	30.64		46W3
	30.68		49H3, 48M27
Levels	?		Re^{184}
		σ's	
(th n,γ)73^dW		2.1	47S33

185
74 111

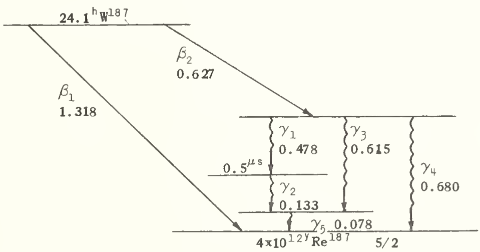
τ	73.2^d		48S18
	74.5		40F1
	76		49C7
β^-	0.428	s	48S24
	0.43	s	48P2, 48S18
No γ			48P2, 47C2
γ	0.134	sc	49C7
No delayed coincidences			49B9, 49M26
Re-d-α	chem		40F1
W-n-γ	chem		40F1, 40M5
	σ		47S33
W-n-2n	chem		40F1, 40M5
W-d-p	chem		40F1

186
74 112

	28.64%	48W9
	29.17	46I1
	28.41	46W3
	28.49	48M27
	28.85	49H3
Levels	?	Re^{186}
	σ's	
(th n,γ) 24^hW	34	47S33
	57	41H8 (48WH)
(~1Mev n,γ) 24^hW	0.066	49H5
Other fast n values		48WH, 49B4

187
74 113

τ	24.1^h	40F1
	24.0	40M5
	25.0	49C7



Half life of metastable state;

$0.53^{\mu s}$	49B9
$0.55^{\mu s}$	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
	$E_\gamma(max) = 7.1$	49K15
W-d-p	chem	48P2

β_1	≥12%	1.318	s	49L10
	30%	1.33	s	48P2
		1.34	s	48H52
β_2	≥65%	0.627	s	49L10
	70%	0.63	s	48P2
		~0.65	s	48H52
γ_1		0.478	s	49L10
		0.462	s	48H52
γ_2		0.133	s	49L10
		0.138	s	49B23
		0.129	s	48H52
		$0.5^{\mu s}$ delay		
γ_3		0.615	s	49L10
		0.652	s	48H52
γ_4		0.680	s	49L10
		0.696	s	49B23
γ_5		0.078	s	49B23
		0.086	sc	41V1

β^- ~0.38, ≤23%; γ's 0.204, 0.767 also found — 49L10

Neutron Cross Sections for Natural Element				?		
	E_n = 0.025ev			τ	30^m	40C5
σ_a	84	49P3			30-55	44D9
σ_t	98	47GIF				
	Resonances					
E_o	Γ					
2.30ev		47GIF				
~27	~3	49G9				
Probably more than one		49G9				
	Graphs Available					
σ_s	0.015-10ev	47GIF, 50Ad		W-p-n	chem	40C5, 44D9
	See also	49H16				

$^{182}_{75}$Re$_{107}$									$^{183}_{75}$Re$_{108}$			
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			K, L X-rays			49W14
	0.346	sc			1.6	a						
	1.5	a		K, L X-rays			49W14					
K, L X-rays			49W14									
Ta-α-3n	chem, relσ		49W14	Ta-α-3n	chem, relσ		49W14		Ta-α-2n	chem, relσ		49W14
W-p-n	chem		49W14	W-p-n	chem		49W14		W-p-n	chem		49W14

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75 RHENIUM Re

184 (Z = 75, N = 109)

τ_1		50^d		49W14,46S6
		52		40F1
		54		40C5
No β^-				49W14
K or IT				49W14
γ		0.043	sc	49W14
		0.159	sc	49W14
		0.205	sc	49W14
		0.285	sc	49W14
		1.05	a	46S6
		0.75		47C2
		0.85	a	40F1
		1	a	49W14,40C5
K,L X-rays				49W14
Ta-α-n		chem,rel σ		49W14
Re-n-2n		chem		40F1,49W14
W-p-n		chem		40C5,48W12
W-d-p				40F1

τ_2	2.2^d		49W14
K or IT			49W14
γ	0.043	sc	49W14
	0.159	sc	49W14
e^-	0.2	a	49W14
	1.1	a	49W14
K,L X-rays			49W14
Ta-α-n	chem,rel σ		49W14
W-p-n	chem		49W14

185 (Z = 75, N = 110)

	37.07%		48W9
I	5/2	S	31M1,31Z1
μ	3.3	S	38S10,38S9
q	+2.8		38S10
Level	0.75		Os^{185}

186 (Z = 75, N = 111)

τ		92.8^h		47G1
		91		48C23,49G3
		90		40F1,39S5
β^-	~3%	0.64	s	49G3
	~30%	0.95	s	49G3
	~67%	1.09	s	49G3
		1.07	s	49B21
		1.068	s	49L6
		Fermi plot straight		
No γ's				47G1
γ		0.138	sc	49B21
		$\alpha_K = 0.029, K/L = 0.4$		
	37%	0.132	sc	49G3
		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

187 (Z = 75, N = 112)

	62.93%		48W9
τ	$4x10^{12\,y}$		48N1,48S25
I	5/2	S	31M1,31Z1
μ	3.3	S	38S10,38S9
q	+2.6	S	38S10
Levels	0.078		W^{187}
	0.211		
	$0.5^{\mu s}$ delay		
	0.680		
β^-	0.043	a	48N1

$^{188}_{75}Re_{113}$			
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	46M6, 49B21
	0.95	s	46M6, 49B21
	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

Neutron Cross Sections for Natural Element

E_n = 0.025ev

σ_a	15		49P3
σ_s	11		37G1
σ_t	29	ce	47W8

Resonances

E_o	$\sigma_o\Gamma^2$	
6.5ev	~10	47W8
8.8	35	47W8
20	25	47W8
28	8	47W8
42	10	47W8
86		47W8

Graph Available

σ_t	0.1-5000ev	47GIF, 47W8

183 (Z = 76, N = 107)

184 (Z = 76, N = 108)

0.018% 37N3

Levels	0.043 ?	Re^{184}
	0.159 ?	
	others?	

185 (Z = 76, N = 109)

τ	97^d		48K8
	95		47G1
K			48K8, 47G1
γ	0.75	a	48K8
K, L X-rays			48K8
γ/X~1			48K8
Re-d-2n	chem		46G3, 48K8
Os-n-γ	chem, σ		48K8

186 (Z = 76, N = 110)

1.59% 37N3

Levels	0.138 ?	Re^{186}
	others?	

187 (Z = 76, N = 111)

1.64% 37N3

188 (76, 112)				189 (76, 113)				190 (76, 114)			
	13.3%		37N3		16.1%		37N3		26.4%		37N3
				I	1/2	S	38K3				
Levels	0.16 ??		Re^{188}					Level	0.25 ?		Ir^{190}
	others ?										
									σ's		
								(th n,γ)15^d Os		8	47S33

191 (76, 115)				192 (76, 116)				193 (76, 117)			
τ	15.0^d		48K8		41.0%		37N3	τ	32^h		47G1,41S7
	16.1		48S18						30		47S33,40Z1
	17		41S7								
β^-	0.142	s	48S18					β^-	1.15	a	48M1
	0.15	a	48M1						0.95	a	47G1
	0.35	a	41S7						1.5	a	41S7
	0.64	a Ir?	47W4								
								e^-	0.14	a	48M1
γ	0.039	sc	48S18					γ	1.58	a	48M1
	0.127	sc	48S18						1.17	a	47G1
	K/L = 1.4		49S28								
	0.129	sc	47C5					βe^- coincidences			48M1
								No delayed βγ coincidences			49B9
K?,L X-rays			48K8								
(X+γ)/β~1			48K8		σ's						
				(th n,γ)32^hOs		1.6	47S33				
Os-n-γ	chem		41S7, 40Z1					Os-n-γ	chem		47G1,41S7
	σ		47S33						σ		47S33
Os-fast n's, see Os^{193}			41S7					Os-d-p	chem		47G1
								Ir-d			47G1
								Os-fast n's			41S7
								32^h activity twice 15^d			41S7

Neutron Cross Sections for Natural Element

$E_n = 0.025$ev

σ_a	464	49P3
	472	49H2
σ_t	430	47R6

Resonances

E_0	$\sigma_0\Gamma^2$	σ_o	Γ	
0.64ev	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

188 77 111

189 77 112

190 77 113

τ	10.7^d		47G1
e^- or β^-	0.091	a	47G1
γ	0.25	a	47G1
X-ray			47G1

Os-d-n	chem	47G1
Ir-n-2n		47G1
Not produced by Ir-n-γ or Ir-d		47G1

191 77 114

	38.5%	36S4
I	1/2 S	35V1
μ	negative	39S17
μ	$\frac{\mu(Ir^{191})}{\mu(Ir^{193})} = -0.92$	39S17
Levels	?	Os^{191}, Pt^{191}

σ's

(th n,γ)1.4^mIr	~250	47G6
(th n,γ)70^d+1.4^mIr	1000	47S33
(19Mev d,2n)3^dPt	~0.09	49W8
(38Mev α,3n)4.0^hAu	~1.5	49W8

$^{192}_{77}$Ir$_{115}$

τ_1	1.42^m	48H37
	1.5	37M4
IT ?		47G6
γ	0.0574 sc	49C1
	0.0555 sc	48H37

Softer γ's with ~ half above energy possibly due to 2-quantum transitions 47G6

Ir L X-ray 47G6

τ_2	70^d	47S33
	75	47G1
	68	48M14

β^-	0.67	s	47L6
	0.62	s	47J1

Conversion lines obscure end point.

γ	48H3	47L6	47C12	43D1
	0.137			
	0.208	0.209		
			0.269	
	0.296	0.295	0.294	
	0.308	0.307	0.306	0.307
	0.317	0.316	0.315	
		0.468	0.466	0.467
		0.488	0.477	
		0.591	0.586	
		0.607	0.601	0.603
		0.615	0.610	
			0.651	

Suggested level scheme	47C12
$e^-/\beta = 0.29$	47W5
0.32	48S17
E_γ per $\beta = 0.6$	48M14
βe^- coincidences	48S17
No delayed $\beta\gamma$ coincidences	49B9, 49M26

Ir-n-γ	ms	46R3
	σ	47S33
Ir-n-2n		37M4, 47G1
Ir-d-p	chem	48W1
Pt-d-α	chem	48W1

$^{193}_{77}$Ir$_{116}$

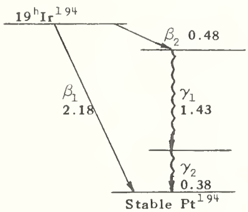
	61.5%		36S4
I	3/2	S	35V1
μ	$\frac{\mu(Ir^{191})}{\mu(Ir^{193})} = -0.92$		39S17
Levels	?		Os^{193}, Pt^{193}

σ's

(th n,γ)19^hIr	130	47S33
(19Mev d,2n)4.3^dPt	~0.07	49W8
(38Mev α,2n)185^dAu	~0.1	49W8
(38Mev α,3n)39^hAu	~1	49W8

$^{194}_{77}$Ir$_{117}$

τ	19.0^h	47G1
	20.7	47S33
	19.5	41W7



β_1^-	2.18	s	41W7
	2.1	a	47G1, 37M4
β_2^-	0.48	a$\beta\gamma$	48M14
γ_1	1.43	a coin	48M14
	1.35	s	43M4
	1.65	a	47G1
γ_2	0.38	a	47G1

See also Pt^{194}

$\gamma\gamma$ coincidences	48M14
No delayed $\beta\gamma$ coincidences	49B9

Ir-n-γ	ms	46R3
	σ	47S33
Ir-d-p	chem	48W1
Pt-d-α	chem	48W1

Neutron Cross Sections for Natural Element

	$E_n = 0.025$ev		
σ_a	8.1		49P3
	13.3		49H2
σ_s	12		(48WH)
σ_t	16.6	ce	47H25

Resonances

E_o	$\sigma_o\Gamma^2$	
11.5ev	~55	47H25
18.2	~30	47H25
100 ?		47H25

Graph Available

σ_t	0.004-5000 ev	47GIF, 47H25

190 (Z = 78, N = 112)

~0.006%	49D8

191 (Z = 78, N = 113)

τ	3.00^d		49W8
K			49W8
γ	0.57	a, ac	49W8
	1.5	a	49W8
K, L X-rays			49W8
Ir-d-2n	chem, σ		49W8
Pt-n-2n	chem		49W8
	d 1^dAu		49W8

192 (Z = 78, N = 114)

	0.78%		47I12
	0.8		36S4
Levels	many low		Ir^{192}
	~2		Au^{192}

σ's

(th n, γ) 3.3^dPt	150 ?	47S33
40% may be due to Au^{199} growth		47S33
(19Mev d, p) 4.3^dPt	~0.05	49W8
(19Mev d, 2n) 4.0^hAu	~0.1	49W8

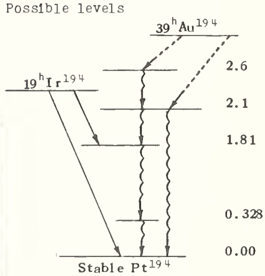
193 (Z = 78, N = 115)

τ	4.33^d		49W8
	3.5		48H37
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
K, L X-rays			49W8, 48M7
(K X-ray)/(L X-ray) ~0.5			49W8
$\gamma\gamma$ or γX coincidences			48M7
Pt-n-γ	chem		48M7, 49W8
Pt-n-2n			48H37, 49W8
Pt-d-p	chem		49W8
Ir-d-2n	chem, σ		49W8
Ir-α-pn	chem		49W8
	d 16^hAu		49W8

194 (Z = 78, N = 116)

32.8%	47I12
30.2	36S4

Possible levels



195 (Z = 78, N = 117)

Isomer (80m)

τ	80^m		41S8
	78		48H37
	87		48M33
IT			48H37
γ	0.337		48H37
	α = ∝, K/L = 1.3		48H37

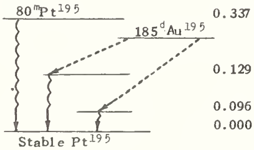
Hg-n-α chem 41S8
Pt-d-p 41S8
Pt-fast n's 48H37, 41S8
Pt-γ 48M33
Not produced by Pt-n-γ 48H37, 41S8

No active daughter 48H37

Stable

	33.7%		47I12
	35.2		36S4
I	1/2	S	36J1, 37T3
μ	0.6	S	36S8

Levels



196 (Z = 78, N = 118)

	25.4%	47I12
	26.6	36S4

Levels 0.358, 0.688 — Au^{196}

σ's

(th n,γ) 18^hPt	1.1	47S33
(9Mev d,p) 18^hPt	16mb	42K7

197 (Z = 78, N = 119)

τ	18^h		48W13, 37M4
	19		41S8
β^-	0.65	a	41S8
	0.72	a	41K5

No delayed βγ coincidences 49B9

Pt-d-p	chem, σ	42K7
Pt-n-γ	chem	37M4
Hg-n-α	chem	41S8
Pt-n-2n		41S8
Pt-γ-n	rel σ	48W13

198 (Z = 78, N = 120)

	7.23%	47I12
	7.2	36S4

σ's

(th n,γ) 29^mPt	3.9	47S33
(~1Mev n,γ) 29^mPt	0.06	49H5
Other fast n values		49B4
(9Mev d,p) 29^mPt	29mb	42K7

199 (Z = 78, N = 121)

τ	29^m		41S8
	31		37M4
β^-	1.8	a	41S8

Pt-d-p	chem, σ	42K7
Pt-n-γ	chem	37M4
	σ	47S33
Hg-n-α	chem	41S8
Not produced by Pt-fast n's		41S8

D 3.3^dAu 48M7, 37M4

889592 O - 50 - 30

Neutron Cross Sections for Natural Element			
σ_s	coh	7.5	49S12
σ_s	bound	~9	49S12
	E_n = 0.025ev		
σ_a		See Au^{197}	
σ_s		6.5	(48WH)
		7.6	49C21
σ_t		104	49C21, 44A2
		100	47B15
		99	47S31
Resonances			
E_o	$\sigma_o\Gamma^2$	Γ	
4.8 ev	600		47H25
4.8		0.15	49G9
4.6		0.5	48C24
> 300			49H16
Graphs Available			
σ_t	0.015-0.3ev		47GIF, 44A2
	0.01-0.13ev		47GIF, 47B15
	0.03-10 ev		47GIF, 47S31
σ_a	0.03-3Mev		47GIF, 50Ad

${}_{79}$185-188			
τ	4.3^m		49T13
K			49T13
β^+			49T13
α	5.2	ic	49T13
α/K capture	$\sim10^{-4}$		49T13
Au-d	chem		49T13

${}_{79}$191 112			
τ	$\sim1^d$		49W8
K			49W8
Pt-d-3n	chem		49W8
Ir-α-4n	chem		49W8
	p 3.0^dPt		49W8

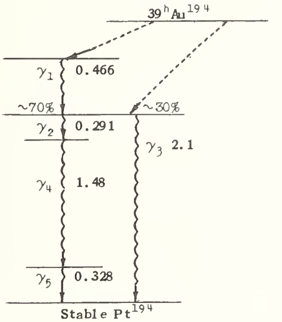
${}_{79}$192 113			
τ	4.0^h		49W8
K			49W8
β^+	1.9	a	49W8
γ	2-3	a	49W8
e^-	0.4	a	49W8
	1.5	a	49W8
K, X-ray			49W8
Pt-d-2n	chem		49W8
Ir-α-3n	chem		49W8

${}_{79}$193 114			
τ	15.8^h		49W8
K			49W8
e^-	<0.2	a	49W8
K, L X-rays			49W8
Pt-d-3n	chem		49W8
Ir-α-2n	chem		49W8
	p 4.3^dPt		49W8

194
79 115

τ		39.5^h		49W8
		39		49S17

Proposed decay scheme 49S17



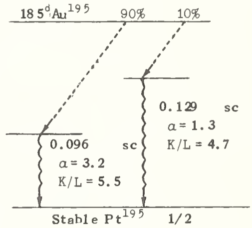
γ_1	weak	0.466	sc	49S17
γ_2	70%	0.291	sc	49S17
		$\alpha = 0.054$, K/L = 2		49S17
γ_3	30%	2.1	s	49S17
γ_4		1.48	sc	49S17
		$\alpha = 0.0026$		49S17
γ_5		0.328	sc	49S17
		$\alpha = 0.19$, K/L = 2		49S17
β^+	3%	1.8	a	49W8

Ir-α-3n	chem	49W8
Pt-d-2n, 3n	chem	49W8
Pt-p-n	chem	49S17

195
79 116

τ	185^d	49W8
	180	49S17

Proposed decay scheme 49S17



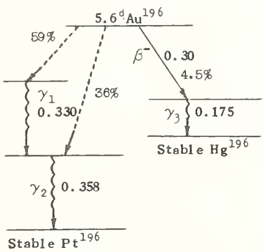
γ	0.19	a	49W8
	1.6	a	49W8

Ir-α-2n	chem	49W8
Pt-d-n	chem	49W8
Pt-p-n	chem	49S17

196
79 117

τ_1	14.0^h	49W8
	13	37M4
K or IT		49W8
X-ray		49W8
e^-		37M4
Au-n-2n	chem	37M4, 49W8

τ_2	5.55^d	49W8
	5.60	49S17



β^-	4.5%	0.30	s	49S17
		0.34	a	49W8
γ_1	59%	0.330	sc	49S17
		$\alpha = 0.087$		
		K/L = 1.7		49S17
γ_2	95%	0.358	sc	49S17
		$\alpha = 0.087$		
		K/L = 1.7		49S17
γ_3		0.175		49S17
		$\alpha = 0.15$, K/L = 3.4		49S17
γ		1.6	a	49W8

Pt-d-n, 2n	chem	49W8, 40L2
Au-n-2n		49W8, 49S17
Pt-p-n		49S17
Au-γ-n	relσ	48W13
threshold = 8.0		49S17

197
79 118

τ	7.4^s	48F12, 47F4
	7.5	45W2
IT		45W2
γ	0.273 sc	48H24
	0.25 a	45W2

e^-e^- coincidences in 7.4^s activity but second γ not found 48H24

Au-γ-γ 45W2

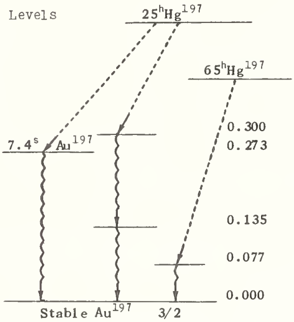
Au-n-n 45W2

d 25^hHg 47F4

100% 35D2

I	3/2	S	39E3
μ	0.195	S	39E3

Levels



$25^h Hg^{197}$ goes to level in Au^{197} with
$\tau = 8 \times 10^{-9\,s}$ 49D22
7×10^{-9} 49M42

This level does not appear in decay of Pt^{197} 49D22

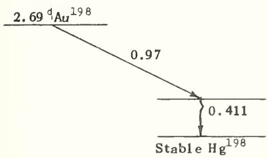
Levels in Au^{197} which combine with 7.4^s level 0.25, 1.22, 1.68, 2.15, 2.56, 2.97 45W2

σ's

(th n,γ) 2.7^dAu	96	47S33
($\sim$1Mev n,γ) 2.7^dAu	0.12	49H5
Other fast n values		49B4, 48WH
(fast n,γ)	graph	47GIF, 50Ad

198
79 119

τ 2.69^d 49S18, 49S2



Half life of 0.411 γ $<4\times10^{-9\,s}$ 49D12
$<3\times10^{-9}$ 49B39

No $\beta\gamma$ coincidences delayed from 3×10^{-7} to $10^{-3\,s}$ 49B9

Au-n-γ	σ		47S33
E_γ(max)	=	7.3	49K15
Pt-p-n	chem		49S17
Au-d-p	chem		48P2
Hg-n-p	chem		41S8

K $\leqslant$0.4% from search for Pt X-ray 49R6

β^-	0.966	s	49L7
	0.956	s	49L6
	0.975	s	49S17
	0.955	s	49D20
	0.970	s	49S33
γ	0.4112	cryst	48D3
	0.411	sc	49S17, 49S19
	0.415	sc	49S33, 49S18
	0.410	sc	49D20
	0.408	sc	48P2, 49L7

α_K	α_L	α_M	
0.028	0.013	0.003	49S17
0.026	0.012	0.003	49S33
0.03	0.01	0.003	49S19

$\alpha = 0.048$ K/(L+M) = 2.7 49S18

γ 18% 0.070 a 49S17
involved in $\gamma\gamma$ coincidences

γ's of 0.157, 0.208 found 49L7, 48D3
Not found 49S17, 49S18, 49S19
See Au^{199}

$\gamma\gamma$ coincidences found 48M35, 49S17
Not found 48J7, 49S19

No $\beta\gamma$ angular correlation 49G21, 49F16

Decay energy of 0.79 found by calorimetric measurement 47C13

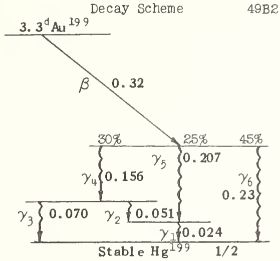
γ's of 0.67 and 1.09 found in low intensity 49C24

79 GOLD Au

$^{199}_{79}$Au$_{120}$

τ	3.3^d		37M4

Decay Scheme 49B21



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 0.156γ. No L line. 49B21

βγ coincidences independent of β energy. γγ coincidences observed 49M32

No delayed coincidences 49B9

Pt-n-γβ	chem	49B21
Hg-n-p	chem	41S8
d 31^mPt		37M4
Not p 43^mHg		49M32

$^{200?}_{79}$Au$_{121?}$

τ	48^m		41S8
β^-	2.5	a	41S8
Hg-n-p	chem		41S8, 42M3
Tl-n-α			42M3

Neutron Cross Sections for Natural Element

	$E_n = 0.025$ev	
σ_a	349	49P3
	360	49H2
σ_t	400	46H26, 45B13

Resonance

E_o	
-2.0 ev	46H26

Graphs Available

σ_t	0.01-0.25ev	47GIF, 45B13
	0.01-75ev	47GIF, 46H26
See also		49H16

?

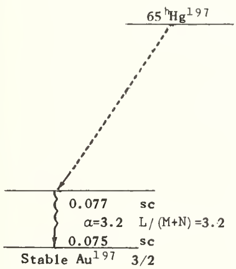
τ	0.7^m		49T13
α	5.7	ic	49T13
Au-d			49T13
chemistry suggests Hg			49T13

196 (80, 116)

	0.16%		49H3
	0.155		47I14
	0.15		37N2
Level	0.175		Au^{196}
	σ's		
(pile n,γ)		3100	47I14

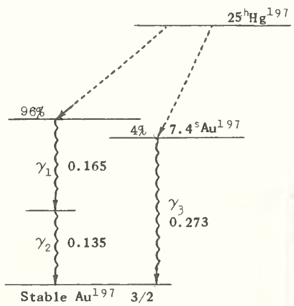
197 (80, 116)

τ_1	65^h	48H24
	64	43F1, 42D8



Au K X-ray		43F1
Au-d-2n	chem	43F1
Hg-n-2n	chem	43F1
Au-p-n		48H24, 42D8

τ_2	25^h	48H24, 42D8
	23	43F1



$25^h Hg^{197}$ goes to level in Au^{197} with $\tau = 8\times10^{-9}$ s (49D22), 7×10^{-9} (49M42)

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)

γ_1		0.165	sc	48H24
		0.161	sc	42H4
		K/L < 1		42H4
		0.157	sc	41V2
γ_2		0.135	sc	48H24
		0.130	sc	42H4
		K/L < 1		42H4
		0.125	sc	41V2
γ_3	4%			47F4, 48F12
		0.273	sc	48H24
		7.4^s delay		
γ	weak	0.38	a	47F4
Au K X-ray				43F1
Hg-n-γ		σ		47I14
Hg-n-2n		chem		43F1
Pt-α-n				41S8
Au-d-2n		chem		43F1
Hg-d-p		chem		40K8
Au-p-n				42D8, 48H24

198
80 118

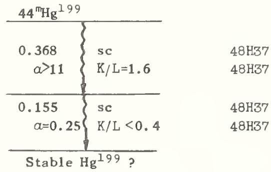
	10.02%	49H3
	10.12	47I14
	10.1	37N2
Levels	0.411	Tl^{198}, Au^{198}
	1.3	Tl^{198}

σ's

(9Mev d,p)44^mHg	0.07	42K7

199
80 119

τ	43.5^m	48H48
	44.4	48M33
	43	37M4,37H4



Order of γ's unknown 48H37

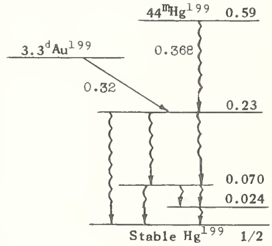
Hg K X-ray 43F1

Hg-fast n's	ms	49B13
	chem	48H48,43F1,37M4
Hg-γ		45W2,48M33
Pt-α-n		41S8
Hg-d-p	σ	42K7

Not d 3.3^dAu^{199} 49M32

	16.92%		49H3
	17.01		47I14
	17.0		37N2
I	1/2	S	31S3,32S1
μ	0.547	S	40M10

Possible level scheme



See also Tl^{199}

σ's

(pile n,γ)	2500	47I14

200
80 120

	23.10%	49H3
	23.21	47I14
	23.3	37N2
Level	~0.4	Tl^{200}
	1.6 ?	

σ's

(th n,γ)	<60	47I14

Hg-γ-n	49H17
threshold = 6.25	49H17
Hg-n-γ	49K15
$E_γ$(max) = 7.1	49K15

201
80 121

	13.22%		49H3
	13.5		47I14
	13.2		37N2
I	3/2	S	31S3,32S1
μ	-0.607	S	40M10
Level	~0.2		Tl^{201}

σ's

(th n,γ)	<60	47I14

202
80 122

	29.72%	49H3
	29.66	47I14
	29.6	37N2
Level	0.40	Tl^{202}

σ's

(th n,γ)44^dHg	2.5	47S33
(th n,γ)	<60	47I14

203 (80 123)

τ	43.5^d		48S30
	51.5		43F1
	50		41S8

$43.5^d Hg^{203}$

0.208	s	49S16
0.205	s	48S30
0.279	sc	49S16
α=0.27	K/L=3	49S16
0.286	sc	48S30
α=0.24	K/L=3	48S30
0.265	sc	48K25

Stable Tl^{203} 1/2

βγ coincidences		49S16
No X-ray		43F1
No delayed coincidences		49B9, 49M26, 49D22
See also Tl^{203}		
Hg-n-γ	ms	49S16, 47I14
	chem	43F1
	σ	47S33
Hg-n-2n	chem	43F1
Hg-d-p	chem	40K8
Tl-n-p		42M3
	No active Tl daughter	43F1

204 (80 124)

6.84%		49H3
6.69		47I14
6.7		37N2

σ's

(th n,γ)5.5^mHg	0.3	47S33
(~1Mev n,γ)5.5^mHg	0.88mb	49H5
(9Mev d,p)5.5^mHg	13.5mb	42K7

205 (80 125)

τ	5.5^m		40K8, 42M3
β^-	1.62	a	40K8
Hg-n-γ			43F1
	σ		47S33
Tl-n-p			42M3
Pb-n-α			42M3
Hg-d-p	σ		42K7
	Not produced by		
Hg-fast n's			42K7

Neutron Cross Sections for Natural Element

	$E_n = 0.025$ ev	
σ_a	3.27	49P3
	3.29	49H2
σ_s	14	37G1
σ_t	11.6	See graphs
	Resonances	
E_o	230	48R7
	~990	48R7
	~4300	48R7
	$E_n = 3$ Mev	
σ_t	5.2	48B28
	Graphs Available	
σ_t	0.015-10,000 ev	47W8, 47GIF, 50Ad

^{198} (81, 117)

τ	1.8^h		4901
K			4901
γ	1.3	a	4901
e^-	~0.4	a	4901
L X-ray			4901
K X-ray obscured by e^-'s and γ's			4901
Au-α-3n	chem		4901
	d ~ 25^mPb		49N5, 49K11
Probably	d 7^mBi		49N5

^{199} (81, 118)

τ	7^h		4901
K			4901
γ	>1	a	4901
e^-	0.5	a	4901
L X-ray			4901
K X-ray obscured by e^-'s and γ's			4901

Tl activities of 10.5^h and 44^h from Hg-d (40K8) are possibly mixtures of Tl^{198} and Tl^{201}

Au-α-2n	chem		4901
	d ~ 80^mPb		49N5
	d 25^mBi		49N5

^{200} (81, 119)

τ	27^h		4901
K			4901
γ	~0.35	a	49N5
	1.6	a	49N5
e^-	~0.4	a	4901
	~0.35	a	49N5
Au-α-n	chem		4901
	d 18^hPb		49N5
	d 35^mBi		49N5

^{201} (81, 120)

τ	72^h		49N5
K			49N3
γ	~0.21	s	49N5
	α~0.6		49N5
K X-ray			49N5
	d ~ 2^hBi and 60^mBi		49N5
	d 8^hPb		49N5

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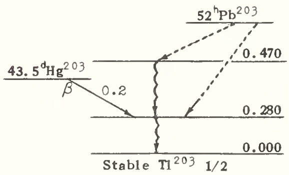
202
81 121

τ	11.8^{d}		41F4
	13		42M3, 40K8
K ?			42M3, 40K8
γ	0.40	a	42M3
X-ray	~0.068	a	42M3
Tl-n-2n	chem		41F4
Hg-d-2n	chem		40K8

203
81 122

	29.52%		49H3
	29.46		48W9
	29.1		38N3
I	1/2	S	31S2, 32J2
μ	1.596		49P0
		I	49P7, 49P8

Possible relationships 49S16



σ's

(th n,γ) 2.7^{y}Tl	7.5	47S33

204
81 123

τ	2.7^{y}		45V1
	3.5		41F4
$β^-$	0.783	s	49S36
	0.770	s	47P10
	0.87	cc	41F4
No γ			41F4

No delayed βγ coincidences 49B9

β spectrum has forbidden shape 49S36

Tl-d-p	chem	41F4, 40K8
Tl-n-γ		41F4
Tl-n-γ	σ	47S33
Tl-γ-n (n's observed)		49H17
threshold = 7.5		49H17

205
81 124

	70.48%		49H3
	70.54		48W9
	70.9		38N3
I	1/2	S	31S1, 32J2
μ	1.612		49P0
		I	49P7, 49P8

σ's

(th n,γ) 4.23^{m}Tl	0.11	47S33
	0.07	41M6
(9Mev d,p) 4.23^{m}Tl	28mb	42K7

206
81 125

τ	4.23^{m}		40F4
	4.4		40K8
$β^-$	1.65	a	41F4
	1.77	a	40K8
	1.8	a	46B7
No γ			41F4
Tl-n-γ	chem		41F4
	σ		47S33, 41M6
Tl-d-p	chem		40K8, 40F4
	chem, σ, f		42K7
Pb-γ-p	chem		46B7

d $4.85^{d}Bi^{210}$ (RaE) 47B6

AcC″ 207
81 126

τ	4.76^{m}		39S11, 31IR
	4.77		40F2
$β^-$	1.47	a	39S12
	1.45	a	49E3

γ in AcC + AcC″

0.5%	0.870	41S16

Pb-n-p	chem	40B2
Pb-γ-p	chem	46B7

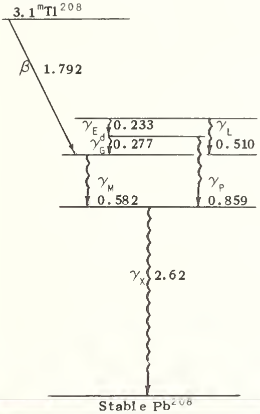
4.5^{m} activity found probably mixture of Tl^{206} and Tl^{207} 46B7

d $2.16^{m}Bi^{211}$ (AcC)

ThC" $^{208}_{81}$ 127

τ 3.1^{m} 31IR

Proposed decay scheme. 48R12



β^- complex	1.792	s	48M29
	1.805	sβγ	48F9
	1.72	sβγ	47S37

Shape of β spectrum consistent with proposed decay scheme 48R12
Possible weak high energy β 48M29

γ	E_d	G	L	M	P	X	
hν	0.233	0.277	0.510	0.582	0.859*	2.62	32E1
			0.51	0.57		2.58	47J5
Rel γ intensities			0.51	1.01		1.00	47J5
% K e$^-$'s per disintegration		2.50	1.77	1.49†	0.26	0.18	48M29
		2.73	2.26	1.75†	0.26	0.23	39F4
	0.20	3.2	1.7	1.5 †·	0.30	0.35	32E1
% L e$^-$'s per disintegration		0.35		0.38			48M29
		~0.42		0.36			39F4
		0.65					32E1

3.2Mev γ not found 48B27,46B36

† Includes L conversion of γ_L
* Assigned to ThC" 48M29

d 60.5^{m}Bi^{212} (ThC)

$^{209}_{81}$ 128

τ	2.2^{m}		48H10
β^-	1.8	a	48H10

d 47^{m}Bi^{213} 48H10
p 3.3^{h}Pb 44F11,48H7

RaC" $^{210}_{81}$ 129

τ	1.32^{m}		31IR
	1.3		37D3
β^-	1.8	cc	38L7
	1.9	a	37D3
γ	~5	a	37D3

γ's in Ra (C + C' + C" + D)

3.1	cc	37N4
4.0	cc	37N4
4.9	cc	37N4

d 19.7^{m}Bi (RaC)
p 22^{y}Pb (RaD)

Neutron Cross Sections for Natural Element

σ_s	coh	**11.5**	49S12
σ_s	bound	**11.6**	49S12
		$E_n = 0.025$ev	
σ_a		**0.19**	49P3
		0.18	49H2
		0.12	49W22
σ_t		**8.5** ce	See graphs
		$E_n = 0.4-100$ev	
σ_t		**~13**	See graphs
		Resonances	
E_o		**350kev**	49B31
		525	49B31
		750	49B31
		Graphs Available	
σ_t	**0.003-10ev**		50Ad, 47GIF, 47H28
See also			49H16
	0.2-14Mev		47GIF
	1-300 Mev		50Ad
	0.2-1.6 Mev		50Ad, 49B28, 49B31

198 (Z = 82, N = 116)

τ	~25^m	49K11, 49N5
Tl-p		49K11
	p 1.8^hTl	49N5, 49K11

199 (Z = 82, N = 117)

τ	~80^m	49N5
K		49N5
	d 25^mBi	49N5
	p 7^hTl	49N5

200 (Z = 82, N = 118)

τ	18^h	49N5
K		49N5
	d 35^mBi	49N5
	p 27^hTl	49N5

201 (Z = 82, N = 119)

τ	8^h	49N5
	~5	46H15
K		46H15
γ		46H15
e^-		46H15
Tl-d-4n		46H15
	d 62^mBi and 2^hBi	49N5
	p 72^hTl	49N5

202 (Z = 82, N = 120)

	< 0.0004%	49D7
τ	> 500^y	49N5, 47T3

203
82 121

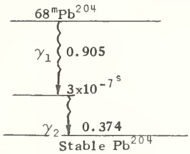
τ	52^h		46B7, 41F4
	54		40K8, 42D8
K			42M3
γ	0.270	s	44L1, 42M3
	0.470	s	44L1, 42M3
	~1.45	a	40K8, 41F4
Pb or Tl K X-ray			42M3, 40K8

See Tl^{203} for probable decay scheme

Tl^{203}-d-2n		47T3
Tl-d-2n	chem	41F4, 46H15
threshold > 7		40K8
Pb^{204}-n-2n		47T3
Tl-p-n		42D8
Pb-n-2n		42M3
Pb-γ-n		46B7

204
82 122

τ	68^m		42M3
	65		41F4
	69		46B7
IT			42M3, 41F4, 47T3



γ_1	0.905	s	49S34
	α = 0.10, K/L ~ 1.5		
	0.9	a	42M3
	1.1	a	41F4
γ_2	0.374	s	49S34
	α = 0.05, K/L ~ 2		
	$\tau = 3x10^{-7s}$		
More than one e^-			40K8

1.37%	48W9
1.5	38N4

68^mPb^{204} produced by

Tl-d-n	chem	41F4
Tl-d-3n		47T3
Pb-n-n		42M3, 39D3
Pb-γ		46B7
	d 12^hBi	49N3, 47T3
	d 4^hPo	49K11

205
82 123

206
82 124

25.15%	48W9
23.6	38N4

Levels	?	Bi^{206}, Po^{210} (RaF)

σ's

(α,3n)5.7^hPo	1-2	47T3
Pb-γ-n	n's observed	49H17
threshold = 6.9		49H17

207
82 125

	21.11%		48W9
	22.6		38N4
I	1/2	S	32K1, 36C3
μ	0.588	I	49P11
Levels	0.87 ?		Tl^{207}(AcC")

208
82 126

	52.38%		48W9
	52.3		38N4
Levels	2.62		Tl^{208}(ThC")
	3.2		
	3.5		
	3.7		
σ's			
(th n,γ)3.3^hPb	~1mb		42M3
	0.45mb		43L4
(~1Mev n,γ)3.3^hPb	1.8mb		49H5
(9Mev d,p)3.3^hPb	14.1mb		42K7
(40Mev α,pn)5^dBi	8mb		47T3
(40Mev α,2n)$138^d Po^{210}$	0.4		47T3
(40Mev α,3n)$5.7^h Po^{207}$	1-2		47T3

209
82 127

τ	3.32^h		41F4
	2.75		40K8
β^-	0.68	s	47R1
	0.71	s	44L7
	0.75	a	42M3
	0.70	a	41F4,40K8
No γ			44L7
Pb-d-p	chem		41F5,41F4
	chem,σ,f		42K7
Pb-n-γ	chem		42M3
Bi-n-p	chem		42M3
	d $3x10^{-6\,s} Po^{213}$		47E3,47H2,49M16

RaD 210
82 128

τ	22^y		31IR
β^-	0.026	s	39L14
	0.029	s	46S1

γ ~10% *	7.3kev		46T4
~0%	18-19		46T4
~1%	23.2		46T4
0.4%	32		46T4
0.2%	37		46T4
0.2%	43		46T4
2.8%	46.7	α_L = 2.9	46T4
e^- 1%			37R5
L X-ray ~30%			44T4
K X-ray ~1%			44T4

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.

γ (7)*	7.8kev	pc	49C4
(0.4)	25.8	pc	49C4
(3)	46.0	pc	49C4
L X-ray (33)			49C4

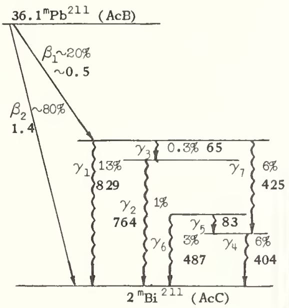
* Relative intensities of unconverted γ's

γ	47kev	
	$\alpha_L:\alpha_M:\alpha_N$ = 1:0.26:0.08	50C1
	α_L = 16	50C1

d $1.3^m Tl^{210}$ (RaC")
d $1.5x10^{-4\,s} Po^{214}$ (RaC')
p $5.0^d Bi^{210}$ (RaE)

AcB 211
82 129

τ	36.1^m	39S11



γ energies in kev

β_1^-	~20%	~0.5	39S12
β_2^-	~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

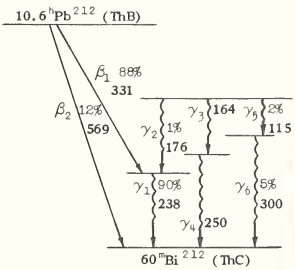
0.05±0.02 quanta of 829kev γ per disintegration — 44M7

d $1.8\times10^{-3\,s}$ Po^{215} (AcA)
p 2^m Bi^{211} (AcC)

ThB 212
82 130

τ	10.6^h	31IR

Proposed decay scheme — 46S23



γ's sc — 37S7, 38S12

additional γ's at 113 and 135 — 37S7, 38S12

Intensities — 32E1, 46S23

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
	$H\rho(F)^*$ =	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
	$H\rho(I)^{**}$ =	1750		44S30
		1747		39A6
		1751		32E1

Bi K X-ray — 28M3

* F is K conv line
** I is L conv line

d 0.16^s Po^{216} (ThA)
p 60^m Bi^{212} (ThC)

RaB 214
82 132

τ	26.8^m		31IR
β^-	0.72		41C1
	0.65		33Sar
γ kev	52.8	sc	44S30
1.6 γ's per disintegration			43T3
	241.0	sc	44S30
	257.8	sc	44S30
	294.2	sc	44S30
	350.9	sc	44S30

γ values in close agreement with above — 34E1, 41H9

d 3.05^m Po^{218} (RaA)
p 19.7^m Bi^{214} (RaC)

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

198 83 115	199 83 116	200 83 117
τ 7^m 49N5 9 48T1 K ? 48T1 α 5.83 ic 49N5 ~5.5 ic 48T1 K/α = 2×10^3 49N5 Pb-d chem 49N5, 48T1 Pb-p chem 49N5 p 25^mPb 49N5 Probably p 1.8^hTl 49N5	τ 25^m 49N5 27 48T1 K 49N5 α 5.47 ic 49N5 ~5.5 ic 48T1 K/α = 8×10^3 49N5 Pb-d chem 49N5, 48T1 Pb-p chem 49N5 p 80^mPb 49N5 p 7^hTl 49N5	τ 35^m 49N5 K 48T1 No α observed 49N5 Pb-d chem 49N5 p 18^hPb 49N5 p 27^hTl 49N5

201 ?
83 118 ?

τ	62^m		49N5
	~100		48T1
K			48T1
α	5.15	ic	49N5
	~5.5	ic	48T1
$K/\alpha = 3\times10^4$			49N5
Pb-d	chem		49N5, 48T1
Pb-p	chem		49N5
	p 8^hPb		49N5
	p 72^hTl		49N5

201 ?
83 118 ?

τ	~2^h	49N5
K		49N5
Pb-d	chem	49N5
Pb-p	chem	49N5
	p 8^hPb	49N5
	p 72^hTl	49N5

202
83 119

τ	2^h	49K11
K		49K11
	d 40^mPo	49K11

203
83 120

τ	12^h	49N5
K		49N5
	d 37^mPo	49K11
	p 52^hPb	49N5

204
83 121

τ	12^h		47T3
K			47T3
e^-	0.2	s, a	47T3
weak	~0.8	s, a	47T3
γ	0.217	s	49S34
Pb^{204}-d-2n			47T3
Tl-α-3n			47T3
	d 4^hPo		49K11
	p (4%) 68^mPb		47T3

205
83 122

τ	~14^d	49K11
K		49K11
γ	1.7	49K11
	d 1.5^hPo	49K11

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206 (Z = 83, N = 123)

τ	6.4^d		40K8
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^dPo			47T1

207 (Z = 83, N = 124)

No activity found from bombardment of Tl, Pb, Bi with 20Mev d and 40Mev α — 47T3

208 (Z = 83, N = 125)

τ	$< 30^s$	49N3
	or very long	49N3
	$> 100^y$	47T1

209 (Z = 83, N = 126)

	100%		38N3
I	9/2		28B1
μ	3.45	S	40W8
q	-0.4	S	36S6
σ's			
(th n,γ)5^dBi		0.015	47S33
(1Mev n,γ)5^dBi		0.003	49H5
(α,2n)7.5^hAt		f	49K10
(α,3n)8.3^hAt		f	49K10
(9Mev d,p)5^dBi		6.6mb	42K7
(20Mev d,p)5^dBi		0.13	47T1
threshold = 5.3		f	49K10, 47T17
(20Mev d,n)138^dPo		0.036	47T1
threshold = 6.5		f	49K10, 47T17
(20Mev d,3n)3^yPo		1.1	47T1
threshold = 12.5		f	49K10
(9Mev d,n)138^dPo		1.2mb	42K7
(γ,n)		f	49M17
threshold = 7.45, n's detected			
(20Mev γ,n) no activity			48M33

RaE 210 (Z = 83, N = 127)

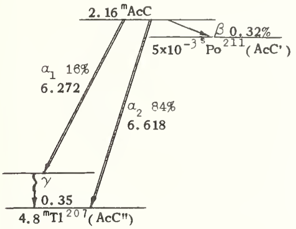
τ_1	long	49N3
α	5.02	49N3
Bi-n-γ		49N3
	p 4^mTl	49N3

τ_2	4.85^d		46S22
	5.15		44H7
	5.0		31IR
β^-	1.17	s	39F2, 40N4
	unallowed shape		49L6, 40N4, 49L3, 49M18
	shape at low energies		49W6
No γ			47L22, 36G2
Bremsstrahlung studied			47S29
No βe^- coincidences			48H42
$\alpha \sim 5 \times 10^{-5}$%			47B6
Pb^{208}-α-pn	chem, σ		47T3
Bi^{209}-d-p	chem, σ		47T3
Bi-n-γ	σ		47T3
Bi-d-p	chem, σ, f		42K7
	d $22^y Pb^{210}$ (RaD)		
	p $138^d Po^{210}$ (RaF)		
	p $4^m Tl^{206}$		47B6

AcC 211 (Z = 83, N = 128)

See next page for Bi^{212} (ThC)

τ	2.16^m	31IR



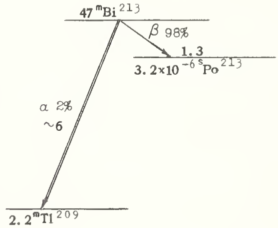
β^-		not observed		
	0.32%	from ratio of Po^{211} α's to Bi^{211} α's		31IR
α_1		6.272		38HL
	16%			31R2
	23%			36R5
α_2		6.618		38HL
	84%			31R2
	77%			36R5
γ		0.350	a	37S4, 39S12
		0.354	a	25H1
γ/α = 0.14				42S9
Other γ's attributed to AcC				
		0.460		25H1
		0.480		25H1

Proposed cycle scheme for AcC → AcC', AcC" → AcD — 46S23

d $38^m Pa^{227}$
d $2^m Ac^{223}$ } 48G5
p $4.8^m Tl^{207}$ (AcC")
p $5\times10^{-3\,s} Po^{211}$ (AcC')

213 (Z = 83, N = 130)

τ	47^m	47H2
	46	47E3



β^- 98%	~1.3		a	47E3
96%	~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 $3.2\times10^{-6\,s} Po^{213}$ — 47E3, 47H2

RaC 214 (Z = 83, N = 131)

τ	19.7^m	31IR

β^- 99.96%				31IR
	1.650	s	~77%	41C4
	3.173	s	~23%	41C4
	3.15	a		33Sar

For discussion of β energies and %'s see 48F14

α 0.04%				31IR
	5.333	s	17%	48C22
	5.444	s	55%	34LB
	5.466	s	46%	48C22
	5.505	s	45%	34LB
	5.517	s	37%	48C22

γ — hν (34E1 sc, 47L24 s); Rel. Intensity (46S23 *, 47L24 **)

34E1 sc	47L24 s	46S23 *	47L24 **
0.426			
0.498			
0.607	0.606	8.9	
0.766		0.88	
0.933		0.90	
1.120	1.120	2.9	1.76
1.238	1.234	0.85	0.41
	1.290 }		
1.379	1.370 }	0.86	1.32
1.414	1.414		
	1.520		0.56
	1.620 }		
	1.690 }		
1.761	1.761 }	2.8	2.51
	1.820		3.2
	2.090 }		
2.193	2.200 }	1.0	1.0
	2.420		0.34

α's from ground and excited states of daughter Po^{214} (RaC') — 34LB

Energy	Rel. Number
7.683	10^6
8.280	0.43
8.941	0.45
9.069	22
9.315	0.38
9.492	1.35
9.660	0.35
9.781	1.06
9.908	0.36
10.077	1.67
10.149	0.38
10.329	1.12
10.509	0.23

* Estimated from data of 34E1 on number of conversion e^-'s per disintegration assuming quadrupole transitions

** Relative intensities of groups indicated from recoil spectrum. Results from conversion e^+'s in good agreement. All transitions appear quadrupole.

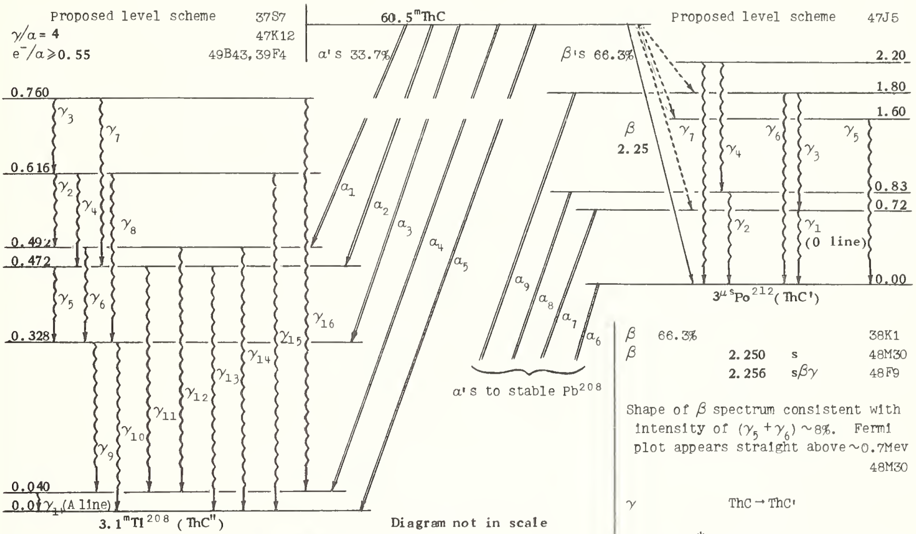
d $26.8^m Pb^{214}$ (RaB)
p $1.47\times10^{-4\,s} Po^{214}$ (RaC')
p $1.32^m Tl^{210}$ (RaC")

Proposed cycle scheme for RaC → RaC', RaC" → RaD — 46S23

ThC

$^{212}_{83}$ 129

τ 60.5m 31IR



γ	ThC→ThC" sc		37S7
Following values confirm older work			
	hν	K line inten.*	
γ_1 (A line)	0.0398		
γ_2	0.124	<0.05	
$\gamma_3, \gamma_4, \gamma_5$	0.144	0.1	
γ_6	0.162	0.05	
$\gamma_7, \gamma_8, \gamma_9$	0.287	0.2	
γ_{10}	0.327	0.07	
γ_{11}	0.431	<0.05	
γ_{12}	0.451	<0.05	
γ_{13}	0.471	<0.05	
γ_{14}	0.491	<0.05	
γ_{15}	0.616	<0.05	
γ_{16} ?	0.719	0.1 ?	

Note γ_1 in ThC→ThC'

* Relative to 100 for F line of ThB

α 33.7%			38K1
α_1	5.601	1.10%	34LB
α_2	5.620	0.16%	34LB
α_3	5.762	1.80%	34LB
α_4	6.044	69.8%	34LB
	6.074	~77%	48C21
α_5	6.083	27.2%	34LB
	6.113	~23%	48C21
	ThC' → Pb^{208}		
α_6 (10^6)*	8.776		38HL, 36B5
α_7 (34)*	9.488		38HL, 32R1
α_8	9.600 ?		32R1
α_9 (190)*	10.538		38HL, 32R1
	10.55		48C21

* Relative numbers of α's 34LB

β	66.3%			38K1
β		2.250	s	48M30
		2.256	sβγ	48F9

Shape of β spectrum consistent with intensity of $(\gamma_5+\gamma_6)$ ~8%. Fermi plot appears straight above ~0.7Mev 48M30

γ		ThC→ThC'			
γ_1	18.5%*	0.72**	s	(0 line)	47J5
		0.719	s		46S23
γ_2	16%*	0.83	s		47J5
		0.779	s		46S23
γ_3	5.5%*	1.03	s		47J5
γ_4	4.5%*	1.34	s		47J5
	1.8%*	1.35	s		47L24
γ_5	7%*	1.61	s		47J5
	5%*	1.60	s		47L24
γ_6	7%*	1.81	s		47J5
	3%*	1.80	s		47L24
		1.793	s		46S23
γ_7		2.20	s		47J5
	2.5%*	2.20	s		47L24
γ		1.50	s		47L24

* % of β branch disintegrations, calculated from recoil electrons and above βα branching ratio

** Note γ_{16} in ThC→ThC"

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
Bi-p	49K11	Bi-p-7n	49K11	Bi-p-6n	49K11
		p 12^hBi	49K11	p 18^h Pb^{200} p 12^h Bi^{204} p 68^m Pb^{204}	49K11
p 2^hBi	49K11	p 52^hPb	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 a	47T1	γ 1.3 a	47T1
		weak ~0.3 a	47T1	L X-ray	47T1
α 5.2 ic	49K11	α ~10% 5.2 ic	47T1	α ~0.01% 5.1 ic	47T1
Bi-p-5n	49K11	Pb^{204}-α-2n chem	47T1	Pb^{206}-α-3n chem,σ	47T1
Pb-α-3n	49K11				
p ~14^dBi	49K11	p 6.4^dBi	47T1		

208 (Z 84, N 124)

τ	3.0^{y}		49K10
	~3		47T1
α	5.14	ic	47T1
No γ			47T1
Bi-d-3n	chem, σ		47T1
	f		49K10
Pb^{206}-α-2n	chem		47T1
Pb^{207}-α-3n	chem		47T1
Bi-p-2n			46L1
	No daughter activity		47T1
	d $7.0^{h}At^{208}$		49B12
	d $1.7^{h}At^{208}$	chem	49H13
	d $23^{m}Em^{212}$	chem	49H13

209 (Z 84, N 125)

τ	$\sim 200^{y}$	49K10
α	4.95	49K10
Bi-d-2n		49K10

RaF 210 (Z 84, N 126)

τ	138.3^{d}		49B54
	140		31IR
γ	0.773	s	47S4
	0.8	a	47D1
$\gamma/\alpha = 10^{-5}$			48Z3
α	5.298	s	38HL
	5.303	s	46C6
No α fine structure			48W17
Pb^{208}-α-2n	chem, σ		47T1
Bi-d-n	chem, σ		47T1
	chem, σ, f		40C2, 42K7
	f		49K10
	d $5^{d}Bi^{210}$ (RaE)		
	d $8.3^{h}At^{210}$		49K10

AcC' 211 (Z 84, N 127)

τ	5×10^{-3} s		31IR
α	7.434	s	34LB
Long range α ?			
~0.01%	~9.2		33C3
	d $2.1^{m}Bi^{211}$ (AcC)		
	d $7.5^{h}At^{211}$		40C10

ThC' 212 (Z 84, N 128)

τ	3.04×10^{-7} s		49B9
	3.0×10^{-7}		48H21
	3.4×10^{-7}		48J5
	2.2×10^{-7}		49V1
Levels			Bi^{212} (ThC)
α (10^{6})*	8.776	s	38HL, 36B5
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 $60.5^{m}Bi^{212}$ (ThC)		
	d $9.3^{m}U^{228}$		49M16

213 (Z 84, N 129)

τ	3.2×10^{-6} s		47E3
	4.2×10^{-6}		48J5
α	8.336	ic	47E3, 48C12
	8.30	ic	47H2
	d 10^{-3} s Em^{217}		49M16
	d $47^{m}Bi^{213}$		47H2, 47E3
	p $3.3^{h}Pb^{209}$		47H2, 47E3

RaC′ 214 (Z 84, N 130)

τ	1.47×10^{-4} s		48B14
	1.40×10^{-4}		48R8
	1.48×10^{-4}		42W4
	1.45×10^{-4}		41R6
	1.55×10^{-4}		43J1
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
(0.38)	9.315	(0.38)	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 Em^{218} — 46S14
p 22^y Pb^{210} (RaD)

AcA 215 (Z 84, N 131)

τ	1.83×10^{-3} s		42W4
β^-	5×10^{-4}%		44K2
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}

ThA 216 (Z 84, N 132)

τ	0.158^s		42W4
β^-	0.014%		43K2
α	6.774	s	38HL

d 54^s Em^{220} (Tn)
p 10.6^h Pb^{212} (ThB)
p $3 \times 10^{-4\,s}$ At^{216}

217 (Z 84, N 133)

RaA 218 (Z 84, N 134)

τ	3.05^m		31IR
β^-	0.04%		43K4
α	5.998	s	38HL

d 3.8^d Em^{222} (Rn)
p 26.8^m Pb^{214} (RaB)
p short At^{218}
p 0.019^s Em^{218} — 49W5

$\leqslant 205$ (85)	$\leqslant 206$ (85)	207 ? (85, 122 ?)
τ 10^m 49B40	τ 25^m 49B40	τ 1.7^h 48T6 1.8 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 49B12 4.5^h 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^m Fr^{212} chem 49H13 p 3^y Po^{208} 49H13	p 3^y Po^{208} 49B12	

210 85 125			211 85 126			212 85 127		
τ	8.3^h	49K10	τ	7.5^h	40C10	τ	0.25^s	48W6
K		49K10	K 60%		40C10			
γ, e^-	1 a	49K10						
Po K X-ray								
α/K	$<10^{-4}$	49K10	α	5.89 ic	48T6	α		48W6
			40%	5.94 a	40C10			
Bi-α-3n	chem	49K10	Bi-α-2n	chem	40C10	Bi-α-n		48W6
threshold ~29		49K10						
				d 8^m Fr^{211}	49H13			
	p 138^d Po^{210}	49K10		p $5x10^{-3\,s}$ Po^{211}	40C10			

213 85 128			214 85 129			215 85 130		
			τ	short	49M16	τ	$\sim10^{-4\,s}$	49M16
							short	44K1
			α	8.78 ic	49M16	α	8.00 ic	49M16
							8.43 ic	44K1
							d $1.8x10^{-3\,s}$ Po^{215} (AcA)	
				d 1.7^m Pa^{226} ?	49M16		d 3.9^s Em^{219} (An)	44K1
							d 2^m Ac^{223}	48G5

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216 (85, 131)			217 (85, 132)			218 (85, 133)		
τ	$\sim 3\times10^{-4}$ s	49M16	τ	0.018 s	47H2	τ	1.5 - 2.0 s	49W5
	short	44K1		0.021	47E3			
						β^-	0.1%	49W5
α	7.79 ic	49M16	α	7.00	47H2	α	6.76 ic	44K1
	7.66 ic	44K1		7.02	47E3		99.9% 6.7 ic	49W5
							Not found from Fr separated from Rn	46K6
	d 54 s Em^{220} (Tn)	44K1		d 4.8 m Fr^{221}	47H2, 47E3		d 3.05 m Po^{218} (RaA)	49W5
	d 2.9 h Ac^{224}	48G5		p 47 m Bi^{213}	47H2, 47E3		d 3.8 d Em^{222} (Rn)	44K1

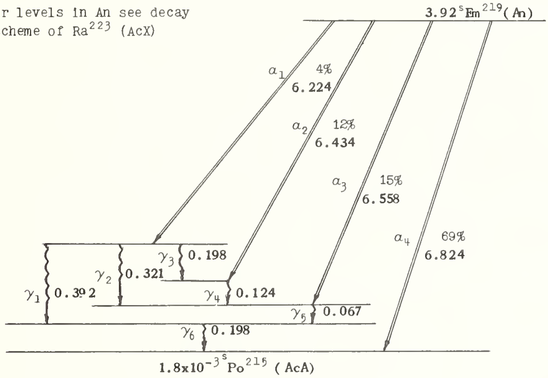
210 ? 86	211 86 125	212 86 126
τ 2.3^h 49G16		τ 23^m 49H13, 49G16
α 49G16		α 6.17 49H13
Th-p 49G16		Th-p 49G16
		d $19.3^m Fr^{212}$ 49H13 p $3^y Po^{208}$ 49H13

216 86 130	217 86 131	218 86 132
τ short 49M16	τ $\sim 10^{-3\,s}$ 49M16	τ 0.019^s 46S14 1.3 49W5
α 8.07 ic 49M16	α 7.74 ic 49M16	α 7.12 46S14
d $9.3^m U^{228}$ 49M16	d $58^m U^{229}$ 49M16	gaseous d $3.05^m Po^{218}$ (RaA) 49W5 d $38^s Ra^{222}$ 46S14

An 219 (86, 133)

τ 3.92^s 31IR

For levels in An see decay scheme of Ra^{223} (AcX)



0.198 γ very intense, suggesting another α obscured by AcC α 37S7

α_1	4%	6.224	s	36R5
α_2	12%			36R5
		6.434	s	34LB
α_3	15%			36R5
		6.558	s	34LB
α_4	69%			36R5
		6.824	s	38HL, 34LB
γ's			sc	37S7

γ values in agreement with 37S7 found by crystal spect 40F2

d 11.2^d Ra^{223} (AcX)
p 1.8x10$^{-3\,s}$ Po^{215} (AcA)

Tn 220 (86, 134)

τ 54.5^s 31IR

α 6.282 s 38HL

d 3.6^d Ra^{224} (ThX)
p 0.16^s Po^{216} (ThA)

221 (86, 135)

Rn 222 (86, 136)

τ 3.825^d 31IR

α 5.486 s 38HL

$\beta/\alpha < 10^{-6}$ 46K6

d 1622^y Ra^{226}
p 3.05^m Po^{218} (RaA)

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 $23^m Em^{212}$	49H13	
	p $7.5^h At^{211}$	49H13		p $1.7^h At^{208}$	49H13	

87 FRANCIUM Fr

218
87 131

τ	short		49M16
α	7.85	ic	49M16
	d 1.7^m Pa^{226} ?		49M16

219
87 132

τ	$\sim 0.02^s$		49M16
α	7.30	ic	49M16
	d 2^m Ac^{223}		48G5

220
87 133

τ	27.5^s		49M16
α	6.69	ic	49M16
	d 2.9^h Ac^{224}		48G5

221
87 134

τ	4.8^m		47H2
	5		47E3
α	6.30		47H2
	6.31		47E3
	d 10^d Ac^{225}		47H2, 47E3
	p 0.018^s At^{217}		47H2, 47E3

222
87 135

τ	14^m		49H13
β^-			49H13
Th-p	chem		49H13
	p 38^s Ra^{222}		49H13

AcK 223
87 136

τ	21^m		46P5
β^-	1.20	cc	46P5
γ	0.095	a	46P5
	0.090	a	44L9
	d 21.7^y Ac^{227}		39P1
	p 11.2^d Ra^{223} (AcX)		47G17

$^{220}_{88}$Ra (N = 132)

τ	short	49M16
α	7.49 ic	49M16
	d 9.3^{m}U^{228}	49M16

$^{221}_{88}$Ra (N = 133)

τ	31^s	49M16
α	6.71 ic	49M16
	d 58^{m}U^{229}	49M16

$^{222}_{88}$Ra (N = 134)

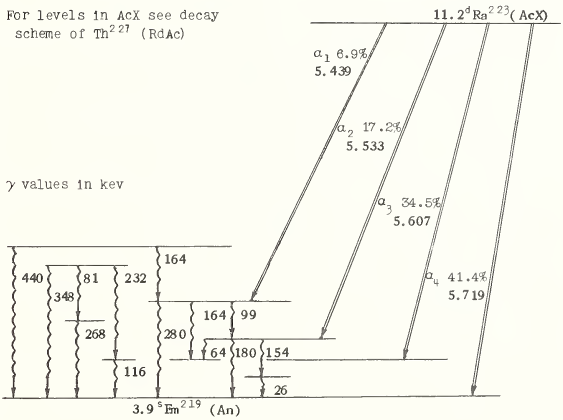
τ	38.0^s	46S14
α	6.51 ic	46S14
	d 31^{m}Th^{226}	46S14
	p 0.019^{s}Em^{218}	46S14

AcX $^{223}_{88}$Ra (N = 135)

τ 11.2^d 31IR

For levels in AcX see decay scheme of Th^{227} (RdAc)

γ values in kev



α_1	6.9%	5.439	36R5
α_2	17.2%		36R5
	9.1%	5.533	34LB
α_3	34.5%		36R5
	36.4%	5.607	34LB
α_4	41.4%		36R5
	54.5%	5.719	34LB

γ's (in kev in scheme) sc 37S7

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)

ThX $^{224}_{88}$ 136

τ		3.64^{d}	38L7
Levels		0.0833	Th^{228} (RdTh)
		0.0868	
α		5.681 s	36B5
		5.66 ic	45C3
	4.6%	5.448 s	49R9
	0.4%	5.194 s	49R9
γ		~0.250	15V1
No low energy e^-			28M2

d 1.9^{y} Th^{228} (RdTh)
d 2.9^{h} Ac^{224} 48G5
p 54.5^{s} Em^{220} (Tn)

225 88 137

τ	14.8^{d}	47H2
	14	47E3
β^-	~0.2	47H2
	<0.05	47E3
Levels	0.10 ?	Th^{229}
	0.20 ?	

d $7\times10^{3\,y}$ Th^{229} 47H2, 47E3
p 10^{d} Ac^{225} 47H2, 47E3

226 88 138

τ		1620^{y}	47K7
		1600	39G5
		1690	35G2(47K7)
		1600	34G3(47K7)
		1590	31IR
Levels		0.068	Th^{230} (Io)
		~0.190	
α	93.5%	4.795 s	49R8
		4.791 s	34LB
	6.9%	4.611 s	49R8
		4.610 s	34LB
γ		0.188	24H1
Probably no additional α fine structure			48W17

d $8.0\times10^{4\,y}$ Th^{230}(Io)
p 3.82^{d} Em^{222} (Rn)

227 88 139

β^-	47P9
Ra-n-γ	47P9

p 21^{y} Ac^{227} 47P9

$MsTh_1$ 228 88 140

τ		6.7^{y}	31IR
β^-		~0.0015 cc	49L2
		0.053	39L14
β^- or e^-	15%	0.0015-0.018	49L2

d $1.39\times10^{10\,y}$ Th^{232}
d 6.13^{h} Ac^{228} ($MsTh_2$)

222
89 133

τ	short	49M16
α	6.96 ic	49M16
	d $1.7^m Pa^{226}$?	49M16

223
89 134

τ	2.2^m	49M16
K 0.1%		49M16
α 99.9%	6.64 ic	49M16
	d $38^m Pa^{227}$	48G5
	p $2.2^m Bi^{211}$ (AcC)	48G5
	p $11^d Ra^{223}$ (AcX)	49M16

224
89 135

τ	2.9^h	49M16
K ~90%		49M16
α ~10%	6.17	48G5
	d $22^h Pa^{228}$	48G5
	p $3.6^d Ra^{224}$ (ThX)	48G5
	p $27.5^s Fr^{220}$	48G5

225
89 136

τ	10.0^d	47H2
	10	47E3
α	5.80 ic	47H2, 47E3
	d $1.5^d Ac^{229}$	
	d $7.8^m Th^{225}$	49M16
	d $14.8^d Ra^{225}$	47H2, 47E3
	p $4.8^m Fr^{221}$	47H2, 47E3

226
89 137

τ	22^h	48S9
β^-		48S9
U-α		48S9
	p $31^m Th^{226}$	48S9

227
89 138

τ	21.7^y	44C2
	13.5	31IR
β^- 99%	~0.02 cc	46P5
γ	0.037 a	46P5
	α large	43L3
L X-ray 40%		43L3
α 1.2%		46P5, 47P15
	4.94 ic	48G15
	4.92	48V3
	photographic plate	

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 $3.4x10^{4y} Pa^{231}$
p $18.6^d Th^{227}$ (RdAc)
p $21^m Fr^{223}$ (AcK)

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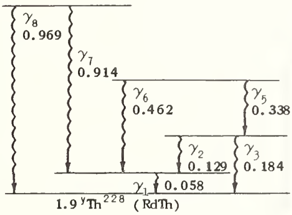
MsTh$_2$
228
89 139

τ		6.13^h	31IR

β^-	1.55	s	39L1
	~1.7	cc	38L7
	2.0	a	38F3
γ		sc	24B1



α ? 4.54 a 33G1

Two β groups observed in cloud chamber with ~ equal intensity with upper limits 0.060 and 1.5
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

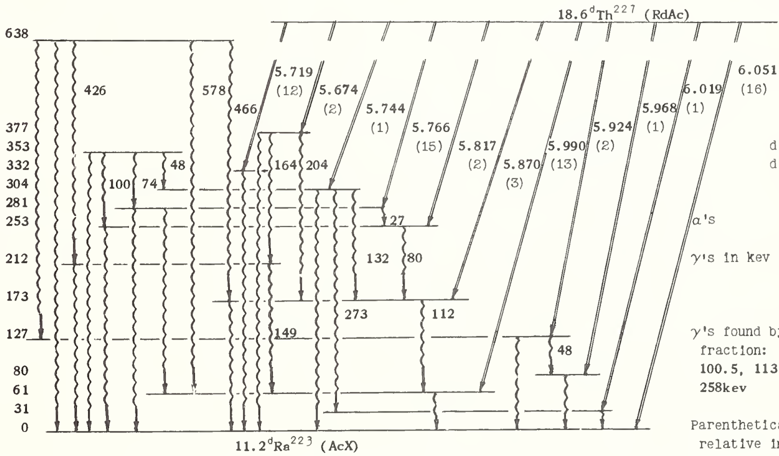
d $6.7^y Ra^{228}$ (MsTh$_1$)
p $1.9^y Th^{228}$ (RdTh)

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

RdAc
227
90 137

τ	18.6^{d}	47P14
	18.9	31IR

Level in Th^{227}
0.037 Ac^{227}



d $22^{y}Ac^{227}$
d $38^{m}Pa^{227}$ 48G5

α's s 34LB

γ's in kev sc 37S7

γ's found by crystal diffraction: 50.0, 57, 79.5, 100.5, 113, 129, 208, 204, 258kev 40F2

Parenthetical figures are relative intensities 36S5

RdTh 228 (Z = 90, N = 138)

τ		1.90^{y}	31IR
α	72%	5.423 s	49R2
		possibly double	49R2
	28%	5.338 s	49R2
	83%	5.418 s	34LB
	17%	5.333 s	34LB
Corroborating results			48C21
γ		0.0833	41S10
		0.0868	41S10
not K_{α} lines of Ra			41S10
		d $6.1^{h}Ac^{228}$ ($MsTh_2$)	48G5
		d $22^{h}Pa^{228}$	48G5
		p $3.6^{d}Ra^{224}$ (ThX)	48G5

229 (Z = 90, N = 139)

τ		$7{,}000^{y}$	47H2
		~10,000	47E3
Levels		0.040 ?	U^{233}
		0.080 ?	
		0.31 ?	
α		5.02	48J18
		4.94	48J18
		4.85	48J18
	~10%	5.05	46H20
	~20%	4.95	46H20
	~70%	4.85	46H20
		d $1.62\times10^{5\,y}U^{233}$	47H2, 47E3
		p $14.8^{d}Ra^{225}$	47H2, 47E3

Io 230 (Z = 90, N = 140)

τ		$8.0\times10^{4\,y}$	46H21
		8.3×10^{4}	31IR
Level		0.94 ?	Pa^{230}
α	~75%	4.682 s	48R5
	~25%	4.612 s	48R5
		4.509 ? s	48R5
		4.66	44C9
γ		0.068 a	39W6
		0.190 a	39W6
	~11%	0.068 a	48C20
		α = 14	48T12, 48C20
	~1%	0.15-0.20 a	48C20
		α = 5	48T12, 48C20
e^-/α = 0.1			48T12, 49A9
L X-rays/α = 0.1			49R10, 48C20
		d $17.7^{d}Pa^{230}$	
		d $2.67\times10^{5\,y}U^{234}$	
		p $1.62\times10^{3\,y}Ra^{226}$	

UY 231 (Z = 90, N = 141)

τ		25.65^{h}	48J17
		25.5	49K9
		24.6	31IR
β^-		0.21 a	49K9
		~0.2 a	37E1, 48J15
γ	>80%	0.035 a	49K9
		α = 4.5	49K9
		$\tau < 1^{\mu s}$	49K9
		0.035 a	48J15
		0.065 a	48J15
Level		0.16	U^{235}
		d $8.8\times10^{8\,y}U^{235}$	
		p $3.43\times10^{4\,y}Pa^{231}$	

232 (Z = 90, N = 142)

τ		$1.39\times10^{10\,y}$	38K1
α		3.98 ic	45C3
		4.20 ic	37S5
σ's			
(9Mev d,p) 23^{m}Th		6.3mb	42K7
		p $6.7^{y}Ra^{228}$ ($MsTh_1$)	

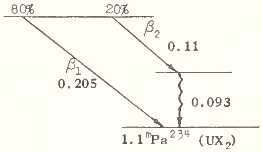
233 (Z = 90, N = 143)

τ	23.5^m		47S5
	23.0		41G3
β^-	1.2	a	42S6
No γ			42S6
Th-n-γ			38M4, 41S9, 41G3
Th-d-p			42G4
	chem, σ, f		42K7

p $27.4^d Pa^{233}$

UX_1 234 (Z = 90, N = 144)

τ		24.10^d		48K23
		24.1		39S11



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
		0.092	sc	46J1
γ	4.5%	0.180	a	46B12
		not assigned		

d $4.5 \times 10^{9\,y} U^{238}$

226 (Z = 91, N = 135)

τ		1.7^m	49M16
α		6.81 ic	49M16
Th-d-8n		chem	49M16

227 (Z = 91, N = 136)

τ		38^m	49M16
K	16%		49M16
α	84%	6.46 ic	49M16
Th-α-7n		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 $4.8^m Tl^{207}$ (AcC")	48G5

228 (Z = 91, N = 137)

τ		22^h	49M16
K	98%		48G5
α	2%	6.09 ic	49M16
Th-d-6n		chem	48G5
		p $61^m Bi^{212}$ (ThC)	48G5
		p $1.9^y Th^{228}$ (RdTh)	48G5

229 (Z = 91, N = 138)

τ		1.5^d	48H9
		1.4	46H11
K	99%		48M24
α	1%	5.69 ic	48M24
		5.66 ic	48H9
Th^{230}-d-3n		chem	46H11
		p $10^d Ac^{225}$	46H11

230 (Z = 91, N = 139)

τ		17.7^d	46O2
		17.0	46S14
K	90%		48S10
β^-		~1.1 a	46O2
γ		0.94 a	46O2
Th^{230}-d-2n		chem	46H11
Th-d-4n			46S14
Pa-d-p2n			46O2
Pa-α-αn			46O2
U^{233}-d-αn			46H9
		p $21^d U^{230}$	46S14

231 (Z = 91, N = 140)

τ		$34,300^y$		48V2
		32,000		30G1
I		3/2	S	34S4
Levels		0.035		Th^{231}
		0.065		
α	11%	5.042	s	49C25
	47%	5.002	s	49C25
	25%	4.938	s	49C25
	3%	4.838	s	49C25
	11%	4.720	s	49C25
	1-3%	4.660	s	49C25
	~85%	5.00	ic	46T2
	~15%	4.69 / 4.72	ic	46T2
γ		0.095	s	28M1, 42H1
		0.294	s	28M1, 42H1
		0.323	s	28M1, 42H1
e^-	24, 36, 46, 75kev			49T15
e^-	27			49S35
L X-ray				49S35
		d $25^h Th^{231}$ (UY)		
		p $21.7^y Ac^{227}$		

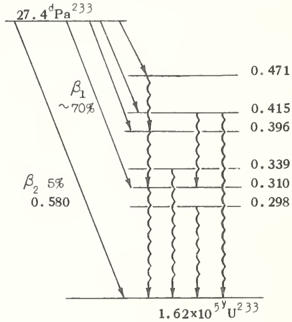
232
91 141

τ	1.32^d		48J10
	1.4		4602
β^-	0.28	a	48J16
γ	~0.23	a	48J16
	1.05	a	48J16
Th-d-2n	chem		42G4, 46S14
Th-α-p3n	chem		46S14
Pa-d-p			4602
	p $70^y U^{232}$		42G4

233
91 142

τ	27.4^d		41G3
β^-	0.23	s	42H1, 41H6
	~0.2	s	47L6
γ	0.084	sc	47L6
	0.298	sc	47L6
	0.309	sc	47L6
	0.337	sc	47L6
Th-d-n	chem		42G4, 46S14
Th-α-p2n	chem		46S14
	d $23.5^m Th^{233}$		38M4, 41S9, 41G3
	d $2.2\times10^{6y} Np^{237}$		47H2
	p $1.62\times10^{5y} U^{233}$		47S5

Proposed decay scheme 50E1



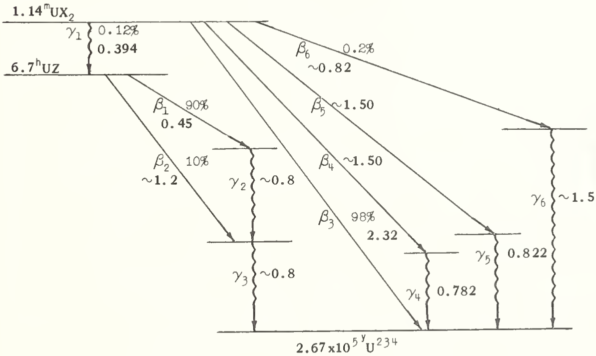
Possibly γ's of 0.396 and 0.471 coincidences shown by two spectrometers 50E1

234
91 143

UX_2

τ_1	1.14^m	31IR
	1.22	48H6

Proposed decay scheme 45B5, 47B17



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}

UZ

τ_2	6.7^h	31IR

$1.14^m UX_2$

β_3^-	98%	2.32	s	45B5
β_4^-, β_5^-	~2%	~1.50		47B17
β_6^-	0.2%	~0.82		47B17
γ_1	0.12%	0.394	s	45B5
		K/L < 0.3		45B5
		α_{L+M} ~1		45B5
	0.15%			38F2
γ_4, γ_5		0.782, 0.822	s	43B4
		α_K = 0.36, α_L = 0.10		43B4
γ_6		~1.5		47B17

$6.7^h UZ$

β_1^-	90%	0.45	s	45B5
$\beta\gamma$ coincidences				45B5
β_2^-	10%	~1.2	s	45B5
γ_2, γ_3		~0.8	a	45B5
		α small		45B5
γ/β = 1.8				45B5
No $\gamma\gamma$ angular correlation				45B5

228 (Z = 92, N = 136)

τ	9.3^m		49M16
K ~20%			49M16
α ~80%	6.72	ic	49M16
Th-α-8n			49M16
p Po^{212} (ThC')			49M16
p $22^h Pa^{228}$			49M16

229 (Z = 92, N = 137)

τ	58^m		49M16
K ~84%			49M16
α ~16%	6.42	ic	49M16
Th-α-7n			49M16
p Po^{213}			49M16
p $1.5^d Pa^{229}$			49M16

230 (Z = 92, N = 138)

τ	20.8^d		46S14
α	5.86	ic	46S14
	5.85	ic	48J4
Th-α-6n			46S14
p Po^{214} (RaC')			46S14
d $18^d Pa^{230}$		chem	46S14

231 (Z = 92, N = 139)

τ	4.2^d		4602
K			4602
K,L X-rays			49C6
No γ			49C6
α 0.05%			49C6
Pa-d-2n			4602
Pa-α-p3n			4602
p $18.6^d Th^{227}$ (RdAc)			49C6
p $3.43x10^{4y} Pa^{231}$			49C6

232 (Z = 92, N = 140)

τ	70^y		48J8
	~30		42G4
Levels	~0.23 ?		Pa^{232}
	1.05 ?		
α	5.31	a	48J19
	5.27		44K8
Th-α-4n			48N4
Pa-d-n			4602
Pa-α-p2n			4602
d $1.3^d Pa^{232}$			42G4, 4602
d $2.7^y Pu^{236}$			48J8
p $1.9^y Th^{228}$ (RdTh)			42G4

233 (Z = 92, N = 141)

τ	$1.62x10^{5y}$		46H10
	$1.63x10^5$		45L7
Levels	0.084	} ?	Pa^{233}
	0.298		
	0.309		
	0.337		
α	4.823	ic	48C12
	4.825	ic	47E3
	4.80	a	43C5
Complexity in α's not detected			47S19
γ	0.040	a	} 47S19
0.8%	0.080	a, α~8	
0.1%	0.31	a, α~3	
L X-ray			47S19
σ's			
(44Mev α,n) Pu^{236}	0.5mb		} 48P10
(44Mev α,3n) Pu^{234}	1mb		
(44Mev α,p2n) Np^{234}	0.2mb		
d $27.4^d Pa^{233}$			47S5, 47S19
p $7000^y Th^{229}$			47H2, 47E3

234 (Z 92, N 142)

	0.00580% (wt)		49G18
	0.00548 (wt)		49K26
	0.0050 (atom)		46C2
	0.0058 (atom)		39N3
τ	$2.67\times10^{5\,y}$		49G18
	2.52×10^{5}		49K26
	2.35×10^{5}		46C2
	2.69×10^{5}		39N3
	2.3×10^{5}		49B41
Levels	0.78		Pa^{234}
	0.82		Pa^{234}
	1.5		Pa^{234}
	~1.8		Np^{234}, Pa^{234}
α	4.763	ic	44C9
	4.76	ic	39S13
	4.78	ic	47A6
L X-ray 33%			47M30
L X-ray 25% attributed to highly converted γ			49S35

d $92^{y}Pu^{238}$
d $1.1^{m}Pa^{234}$ (UX_2)
d $6.7^{h}Pa^{234}$ (UZ)
p $8\times10^{4\,y}Th^{230}$ (Io)

235 (Z 92, N 143)

	0.71%		39N3
τ	$8.8\times10^{8\,y}$		49K26
	8.91×10^{8}		44C9
	7.07×10^{8}		39N3, 41K8
I	5/2 or 7/2	S	47A5, 45T5
Levels	0.2 ?		Pu^{239}
	0.4 ?		
α 20%	4.56	ic	44C9
80%	4.396	ic	44C9
	4.39	ic	49B41
γ ~100%	0.162	a	49M37
	0.187	a	46S20

p $26^{h}Th^{231}$ (UY)

236 (Z 92, N 144)

237 (Z 92, N 145)

τ	6.63^{d}		49M43
	6.8		50b16, 42W5
	6.9		50e10
β^- complex ?	~0.23	s	49M43
	0.17	a	44A1
	0.22	a	44A1
complex	~0.25	a	50e10
γ	0.057	s	49M43
	0.204	s	49M43
	0.260	s	49M43
	0.05	a	50e10
	0.22	a	50e10
	0.40	a	50e10
βe^-, $\gamma\gamma$, and $\beta\gamma$ coincidences			50e10
Np X-ray			50e10
U-n-2n			42W5, 44A1
U-α-αn			48J8

d $10^{y}Pu^{241}$ 48S5, 45K9
p $2.2\times10^{6\,y}Np^{237}$ 48W4

238 (Z 92, N 146)

	99.28%		39N3
τ	$4.498\times10^{9\,y}$		49K26, 44C9
	4.51×10^{9}		39N3, 41K8
τ for double β decay	$>6\times10^{18\,y}$		49L18
α	4.180	ic	44C9
	4.18	ic	47A6
	4.21	ic	39S13
σ's			
(9Mev d,p) $23.5^{m}U$	5.1mb		42K7

p $24^{d}Th^{234}$ (UX_1)

239 (Z 92, N 147)

τ	23.5^{m}		47F5
	23.2		42W6
	23.54		43M10

$23.5^{m}U^{239}$

β^-	1.12	s	48S14
	1.20	a	47F5
	1.2	a	42M7, 42W6
γ	0.073	s	47S27, 48S14
	α = 0.19		48S14
	0.076	a	47F5

$2.33^{d}Np^{239}$

β of 2.06 reported by 47S27 not confirmed 47F11
γ of 0.92 assumed to be in cascade with 0.073γ 47S27, 48S14
Second γ also found, but in only 10% of disintegrations 47F11

U-n-γ		37H5, 39I1, 42S4
U-d-p	chem, σ	42K7

p $2.33^{d}Np^{239}$

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231 93 138			
τ	53^m		48G12
K			48G12
α	6.2	ic	48G12
U^{235}-d-6n U^{233}-d-4n U-d-9n			48G12
	p $38^m Pa^{227}$		48G12

232 93 139			

233 93 140			
τ	35^m		49M39
K			49M39

234 93 141			
τ	4.40^d		46H9
	4.5		48J8
K			46H9, 48J8
γ	1.9	a	46H9
	1.8		48J8
X-ray			48J8
U^{233}-d-n			46H9
U^{235}-d-3n			48J8
U^{235}-α-p4n			48J8
U^{233}-α-p2n			46H9
U^{235}-p-2n			46G13

235 93 142			
τ	435^d		48J12
	400		48J8
K			48J8
No γ ?			48J8
α ~0.1%	5.06	ic	48J12
U^{235}-d-2n			48J8
U^{235}-α-p3n			48J8
U^{233}-α-pn			46H9

236 93 143			
τ	22^h		48J8
β^-	0.5	a	48M25
γ			48J8
U^{235}-d-n U^{238}-d-4n U^{235}-α-p2n			48J8
U^{233}-α-p			46H9
Np-d-t			48J9
Np-α-αn			48J9
	p $2.7^y Pu^{236}$		48J8

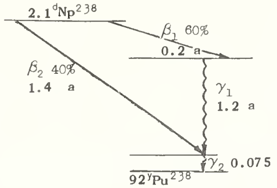
237 (Z = 93, N = 144)

τ	$2.2\times10^{6\,y}$		48M23, 48M16
	3×10^{6}		48W4
I	5/2	S	48T8
α	4.77	ic	48G13
	4.72	a	47L9
	d $6.6^{d}U^{237}$		48W4
	p $27^{d}Pa^{233}$		48SP

238 (Z = 93, N = 145)

τ	2.10^{d}	47J3
	2.0	42S7

Proposed decay scheme 47J3



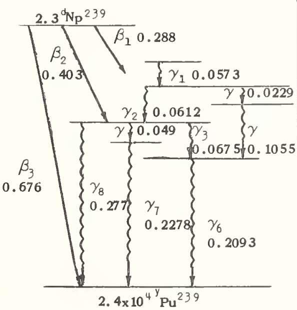
γ_1	1.2	47J3
	α = 0.018	
γ_2	0.075	47J3
	almost complete L conversion	
Coincidence measurements		47J3
Np-d-p		48J9
U^{235}-α-p		48J8
U^{238}-α-p3n		48J8
U-d-2n		46S3, 42K6
Np-n-γ		45J2
	d $400^{y}Am^{242}$	48S5
	p $92^{y}Pu^{238}$	46S4

239 (Z = 93, N = 146)

τ	2.33^{d}	42W6
	2.31	46P11
	2.3	40M2

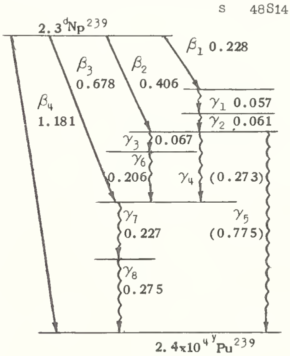
Proposed decay scheme 49K25

β and γ values s 44F11



U-d-n		48J8, 46S3
	d $23.5^{m}U^{239}$	40M2, 42S4
	p $2.4\times10^{4\,y}Pu^{239}$	46K2

Proposed decay scheme, β and γ values s 48S14



γ_1	0.057	α = 0.33	48S14
γ_2	0.061	α = 0.33	48S14
γ_3	0.067	α = 0.33	48S14
γ_6	0.206	α = 0.22	48S14
	0.208		46P11
	0.209		44F11
γ_7	0.227	α = 0.41	48S14
	0.226		46P11
	0.228		44F11
γ_8	0.275	α = 0.19	48S14
	0.276		46P11
	0.277		44F11
γ	0.5	a	48S14
γ_4 and γ_5 hypothetical			48S14
Other β values			46F6, 40M2, 45H12

232 94 138	233 94 139	234 94 140
τ 22^m 48J14		τ $\sim 8.5^h$ 48P10 8 46H9
		K $\sim$99% 48P10
α 6.6 ic 48J14		α < 1% 6.2 ic 48P10 6.0 ic 46H9
U^{235}-α-7n 48J14		U^{233}-α-3n 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 48G13 5.7 ic 48J8	
	U^{235}-α-3n 48J8 U^{233}-α-n 46H9, 48P10 Np-d-3n 48J9	U^{235}-α-2n 48J8 U^{238}-α-5n 48J8 Np-d-2n 48J8, 48J9 Np-p-n 46S26
	d $22^h Np^{236}$ 48J8 d $27^d Cm^{240}$ 48S4	

238 (94, 144)				239 (94, 145)				240 (94, 146)			
τ	92^{y}		48S4	τ	$2.41\times10^{4\,y}$		47S6	τ	$\sim6000^{y}$		48J8
	89		47J2		2.44×10^{4}		46W4				
	77		47J3								
γ < 2%			42F1	γ weak	0.2	a	45S16				
					0.42	a	45S16				
					0.05	a	44G3				
				weak	0.3	a	44G3				
α	5.493	ic	48J2	α	5.159	ic	48C12	α	5.1	ic	48J8
	5.51	a	47C3		5.140	ic	48J2				
	5.4	a	42F1		5.15	a	47C3				
U^{235}-α-n			48J8					U-α-2n			48J8
U^{238}-α-4n			48J8								
Np-d-n			48J9								
U^{238}-d-2n			42F1								
d $150^{d}Cm^{242}$			48S4	d $2.3^{d}Np^{239}$			46K2				
d $2^{d}Np^{238}$			46S4, 42K6								

241 (94, 147)			
τ	$\sim10^{y}$		48S5
β^{-}	0.01-0.02	a	48S5
α			45K2, 48S5
0.002%			47S18
ms			46B17
U-α-n			48S5, 48J8
p $490^{y}Am^{241}$			48S5
p $6.6^{d}U^{237}$			45K2, 48S5

238 (95, 143)			239 (95, 144)			240 (95, 145)		
τ	1.5^h	48J11	τ	12^h	48S5	τ	50^h	48S5
							53	48J11
K ?		48J11	K ~100%		48S5	K		48S5
			γ ~60%	0.285 a	48S5	γ ~100%	~1.3 a	48S5
				α~0.5	48S5		α~0.06	48S5
			Pu K,L X-rays		48S5	Pu K,L X-rays		48S5
			α ~0.1%	5.77	48J11			
Pu-d-3n		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	48C17	τ_1	$\sim 16^h$	48A6	τ_2	$\sim 400^y$	48T5
	470	49Y3		17	48S5		~600	48S5
	510	48C15						
			β^-	1.0	48A6	β^-	~0.5	48S5
				0.8	48S5			
α 100%	5.45 ic	48S5				α ~0.2%		48S5
	5.48 ic	48G13						
γ ~60%	0.062 a	48S5						
Np L X-ray		48S5						
X/α = 1		48S5						
			Am-n-γ		48A6, 48S5	Am-n-γ		48S5
	d $10^y Pu^{241}$	48S5					p $150^d Cm^{242}$	48S5
				p $150^d Cm^{242}$	48S4, 48A6		p $2^d Np^{238}$	48S5

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	48G13
						6.3	ic	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	48G13
				6.1		48S4
Pu-α-2n	chem	48S4	Pu-α-n	chem		48S4
				d 16^h and 400^y Am^{242},		48S4, 48A6
				p Pu^{238}		48S4

	$^{243}_{97}Bk_{146}$?	
	τ 4.6^h 50T1	
	K ~100% 50T1	
	α ~0.1% 6.72 30%; 6.55 53%; 6.20 17% 50T1	
	Am^{241}-α-2n 50T1	

	244 ? 98 146 ?	
	τ ~45^m 50T2 K 50T2 α 7.1 50T2 Cm^{242}-α-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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