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Nuclei Formed in Fission: Decay Characteristics, Fission Yields, and Chain Relationships

ISSUED BY THE PLUTONIUM PROJECT¹

Introduction

In the year that elapsed between the announcement of the discovery of fission by Hahn and Strassmann (H2) and the publication of the first review article by Turner (T4) about 50 radioactive fission products had been discovered and partly identified. Continued interest in the fission products is shown by the large number of entries on fission product nuclei in the most recent edition of Seaborg's Table of Isotopes (S19).

The achievement of self-sustaining fission chain-reactors and the operation of these at an industrial level (S150) have increased greatly the scientific significance of exact information on fission products, and given unique technological importance to this class of radioactive nuclei. It is obvious that a great deal of work on the identification, decay energies, chain relationships, fission yields, and mass assignments was required of research groups associated with the Plutonium Project. Studies have been made directly or indirectly on nearly all of the 160 radioactive fission products now recognized, and much of this work represents new contribution to scientific knowledge. This article presents in tabular form the results of a comprehensive survey of Project reports and scientific journals available as of June 1, 1946.

(1) This survey was prepared by J. M. Siegel, based partly on previous ones circulated on the Plutonium Project prepared by Coryell (C115), Coryell and Brady (C116), Brady and Turkevich (S120), Winsberg and Sugarman (W121), Glendenin, Siegel, and Coryell (G146), and Seaborg and Kohman (S149) based on the unclassified general tables of Seaborg (S19). Certain references (G120, T101) have been made available through courtesy of the National Research Council of Canada. Reprints of this survey may be obtained by writing: Plutonium Project File, The American Chemical Society, 1155 16th St., Washington 6, D. C.

Publication of Project Information

The scientific contributions of the workers on the Plutonium Project to this and other fields of scientific knowledge are to be published in a series of volumes, many of which will be unrestricted in circulation, to be known as the Plutonium Project Record (PPR) of the Manhattan Project Technical Series (MPTS). In particular, detailed surveys of the nuclear properties of the fission isotopes, the techniques of radiochemistry, and the special chemistry of the fission elements are to be given by various Project specialists in Volume 9A of the Plutonium Project Record, *Radiochemistry and the Fission Products*. The detailed experimental work is to be given in the associated Volume 9B, *Collected Papers on Radiochemistry and the Fission Products*, based on material now available only in the manifold secret reports of various sections of the Project.

The preparation of these two volumes for publication is a tremendous task since it includes extensive compilation, rewriting, and cross-comparison with other PPR volumes. Since this work can hardly be completed before the spring of 1947, it has been deemed advisable to make the key information on the fission product nuclei available in advance of the main body of information.

A fair distribution of credit to workers of the Project presents a problem for this type of publication since a large number of people in different subdivisions of the Project have made direct contributions of data for the table. Many more have contributed indirectly in physical and chemical studies that made the work significant or even

possible. It is not feasible, however, in this limited framework to indicate the indirect contributions to the extent that will occur in the PPR. In giving references, it seems advisable to follow the pattern of a normal survey article, *i. e.*, to list all results that present a contribution to the body of information, citing the names of those who carried out this work and the Project report in which it is described most completely. In addition to giving references to Project reports, some references to the PPR papers are included.

Description of Table I, Characteristics

In preparing the present survey an attempt was made to evaluate critically the results of various investigators published in the open literature and in the Plutonium Project reports. The values given in Table I (pp. 2416-36) are listed in order of preference. Column one gives the atomic number and mass number of the nucleus. Parentheses around the mass number indicate the mass assignment is uncertain, and an asterisk (*) denotes that the nucleus is in a metastable excited state, decaying by isomeric transition.

The half-life is listed in column two with the following abbreviations: "s" for seconds, "m" for minutes, "h" for hours, "d" for days, and "y" for years. In some cases an upper or lower limit to the half-life has been established for a nucleus whose radiations have not been directly observed. Half-life values were selected on the basis of initial purity of the activity and the number of half-lives over which the intensity was measured, taking into consideration the estimated precision of individual measurements.

Column three gives the mode of decay and the type of radiations emitted. The following symbols are used: β^- for negative electrons emitted from the nucleus, γ for gamma rays, e^- for internal-conversion electrons, n for neutrons, and "I.T." for isomeric transition. In the cases in which it has been established that the nucleus emits little or no gamma radiation, this fact is stated explicitly in column eight.

Column four refers to the investigators who first isolated and identified the nucleus as a fission product. As it was not always possible to establish absolute priority, the references serve mainly as a guide for the approximate date of discovery of each fission product nucleus.

The "class" of a nucleus, given in column five, refers to the degree of certainty in the atomic number and mass assignment. The classes are to be interpreted as follows:

- A = element certain, isotope certain;
- B = element certain, isotope probable;
- C = element certain, isotope uncertain;
- D = insufficient evidence.

Parentheses around the class rating signify that the corresponding nucleus has not been observed in the fission of uranium, although it is very probably formed in the process.

The value of the fission yield of the nucleus in percentage for U^{235} is given in column six. It is defined as the percentage of the fissions leading to the nucleus in question by direct formation and decay of precursors. Most of the values were determined relative to the value of 6.1% for ^{138}Ba based on direct fission counting (F108). Older fission yield values have been normalized to this value for ^{138}Ba . The majority of the fission yield determinations were made on natural uranium irradiated with pile neutrons. In a few cases, designated by the symbol (t), irradiations were made in a column containing neutrons in thermal equilibrium at room temperature; such irradiations gave essentially the same values. A fission yield is given only for the nucleus for which it has been determined; in most cases the fission yield will not be appreciably greater for succeeding members of the decay chain (G147).

The fission yields of the delayed neutron emitters $\text{Kr}^{(87)}$, $\text{Xe}^{(137)}$, and the last four nuclei listed in Table I have not been determined directly. The values in column six represent therefore the percentage of the fission neutrons emitted by the nucleus in question, as indicated in the table. These data can be transformed to the percentage fission yield of the neutron-decay process by multiplication by the value for ν , the number of neutrons per fission. The value of ν is given as 1-3 in the Smyth report (S150).

The energy values of both nuclear beta spectra and conversion electrons are listed in column seven. Only the maximum energy of a nuclear beta spectrum is given, and in cases where only Kono-pinski-Uhlenbeck extrapolated values (K8) are reported they are designated "(K.U.)". In each case the value is followed by a description of the method employed in its determination using the following abbreviations:

- Spect. = magnetic spectrometer or spectrograph studies,
- Abs.Al, P. = absorption of the particles in aluminum (range evaluated according to the method of Feather (F4,F5,F6)),
- Abs.Al = absorption of the particles in aluminum (range estimated visually or from the half-thickness),
- Abs.Al, colnc. = absorption in aluminum of β - γ coincidences,
- Cl.Ch. = cloud chamber studies.

The selection of values for the maximum energy of a beta spectrum or the energy of conversion electrons is based primarily on the method used in their determination. The various methods employed are given preference as to their reliability in the order listed above. In all cases where the range in aluminum is given for a nuclear beta component, the corresponding maximum energy has been recalculated using a revised range-energy relationship (G145).

Gamma ray energies are listed in column eight. Each value is followed by a description of the method employed in its determination and the following abbreviations are used:

- Spect. = magnetic spectrometer or spectrograph studies of secondary electrons,
 Spect. conv. = magnetic spectrometer or spectrograph studies of conversion electrons,
 Abs. Pb = absorption of radiations in lead (when elements other than lead were used they are designated by their chemical symbols),
 Abs. Al conv. = absorption in aluminum of conversion electrons,
 Abs. Al, coinc. = absorption in aluminum of secondary electron coincidences.

Only the first three methods listed above have been used extensively for the determination of gamma ray energies. Of these, spectrometric determinations are considered to be more reliable than absorption measurements.

Column nine contains three related items, a list of the nuclear reactions by which the nucleus has been produced, its genetic relationships, and its mass assignment.

The nuclear reactions are given in the conventional manner with target element listed first, followed by the projectile and ejected particle in parentheses. Conventional symbols are used for the various particles.

The genetic relationships are included in the item designated as fission, "fiss.," and only references which contribute to the establishment of the relationship are cited. The abbreviation "prec." signifies precursor of, "desc." signifies descendant of, and "hyp." signifies hypothetical for nuclei not directly observed.

In most cases the mass assignment follows directly from the reactions by which the nucleus was produced and, for a limited number of nuclei, by direct measurement with the mass spectrograph, designated "mass spect." In a few instances the fission yield of a nucleus was used as an index of its mass number, on the assumption that the fission yield is a smooth function of mass number (see Figure 1). This method is adaptable only in regions of the mass spectrum where the fission yield is changing rapidly with the mass number. Mass assignments made on this basis are designated as "fiss. yld." The term "ener." designates cases in which semi-quantitative use of the Bohr-Wheeler equation for decay energy (B10) has been made in arriving at the probable mass-assignment.

Column ten entitled "Other references" lists general references and those of lesser significance which may be useful to an investigator making a closer study.

Description of Table II, Chains and Yields

In Table II (pp. 2438-41) there is presented a graphic summary of the chain relations of the fission products, their mass assignments, and fission yields. The fission product chains are divided into a light group and a heavy group. The former contains fission products with mass numbers of 117 or less, and the latter contains those with mass numbers greater than 117. Parentheses

around the mass number indicate that the mass assignment is uncertain.

Genetic relationships of the fission products are shown by arrows. A broken arrow indicates the relationship has not been definitely established. Parentheses around the half-life of a nucleus mean the nucleus is probably formed in fission but has not yet been identified as a fission product.

The fission yield values listed opposite the mass numbers were generally determined for nuclei appearing late in the fission product chain. In a few cases, however, the values apply to isomers in an excited state or to nuclei that can only be formed directly in fission and not by beta decay. In these cases, the fission yield value is only a fraction of the chain yield (G147).

Description of Figure 1, Yield-Mass Curve

In Fig. 1 (p. 2437) there is plotted on logarithmic scale the total yields of the fission product chains, formed in U^{235} fission, as a function of their mass numbers on linear scale. Forty-two chains are shown in the figure.² The curve was drawn first with the heavy group reflected upon the light group at a plane of symmetry between the two groups. This was done to permit the averaging of the experimental data of both the light and heavy groups. The curve was then unfolded to its present form for greater graphical clarity. A circle is used for the fission yield of a nucleus when its mass number is certain, and a square when its mass number is uncertain. The smooth line drawn through the points corresponds to a total area of 197% which agrees very well with the possible 200% resulting from two large fragments per fission.

Description of the List of References

A list of the references is given on pp. 2414-15, 2436, and 2441-42. References are segregated alphabetically by the initial of the last name of the first author. A number below 100 signifies that the reference is to open scientific literature. A number above 100 signifies that the reference is to a Project report or other Project publication. Some of these, such as the well-known Smyth Report (S150), have already been declassified and given open printing; many others are in the process of being declassified and will eventually be available through the Office of Technical Services, Department of Commerce, Washington, D. C., when listed in its weekly Bibliography of Scientific and Industrial Reports. Many of the references are to papers written for the collected papers volume, *Radiochemistry and the Fission Products*, PPR Vol. 9B, the manuscript of which is not at present available but is in the process of being edited and declassified for open publication in the spring of 1947. The volumes of the Manhattan Project Technical Series will be well ad-

(2) Ed. Note: Grummitt and Wilkinson of the National Research Council of Canada have recently published a similar yield-mass curve for about 20 chains (*Nature*, 166, 163 (Aug. 3, 1946)).

vertised in advance of publication. Queries about this article may be addressed to the District Engineer, P. O. Box E, Oak Ridge, Tenn., attention Information Branch.

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List of References

- (A1) Abelson, P. H., *Phys. Rev.*, **55**, 670 (1939); (A2) *ibid.*, **55**, 1 (1939).
 (A3) Amaldi, E., O. D'Agostino, E. Fermi, B. Pontecorvo, F. Rasetti and E. Segrè, *Proc. Roy. Soc. (London)*, **A-149**, 522 (1935).
 (A4) Anderson, H. L., E. Fermi and A. V. Grosse, *Phys. Rev.*, **59**, 52 (1941).
 (A5) Aten, A. H. W., Jr., C. J. Bakker and F. A. Heys, *Nature*, **143**, 516 (1939); (A6) *ibid.*, 679 (1939).
 (A7) Alvarez, L. W., A. C. Helmholtz and E. Nelson, *Phys. Rev.*, **87**, 660 (1940).
 (A8) Abelson, P. H., *Phys. Rev.*, **55**, 418 (1939).
 (A101) Adams, R. M., H. Finston and W. Rubinson, CC-3146, Sept. 1945.
 (A103) Adams, R. M., and L. O. Stang, Jr., CN-2799, p. 7, Mar. 1945.
 (B1) Barnes, S. W., and P. W. Aradine, *Phys. Rev.*, **55**, 50 (1930).
 (B2) Born, H. J., and W. Seelmann-Eggebert, *Naturwissenschaften*, **31**, 86 (1943); (B3) *ibid.*, 201 (1943); (B4) *ibid.*, 420 (1943).
 (B5) Bothe, W., and A. Flammersfeld, *ibid.*, **29**, 194 (1941).
 (B6) Bothe, W., and W. Gentner, *ibid.*, **35**, 191 (1937); (B7) *Z. Physik*, **112**, 45 (1939).
 (B8) Bjerger, T., and C. H. Westcott, *Nature*, **134**, 177 (1934).
 (B9) Buck, J. H., *Phys. Rev.*, **54**, 1025 (1938).
 (B10) Bohr, N., and J. A. Wheeler, *Phys. Rev.*, **86**, 426 (1939).
 (B11) Booth, E. T., J. R. Dunning and F. G. Slack, *ibid.*, **55**, 575 (1939).
 (B12) Boström, K. J., J. Koch and T. Lauritsen, *Nature*, **144**, 830 (1939).
 (B101) Ballou, N. E., CC-298-D, pp. 3-4, Oct. 1942; (B102) CC-389-B, pp. 11-13, Dec. 1942; PPR Vol. 9B, 7.49.4 (1940); (B103) CC-465-B, pp. 19-22, Feb. 1943; (B104) pp. 22-23, Feb. 1943; (B105) CC-529, pp. 39-43, Mar. 1943; (B106) p. 55, Mar. 1943; (B107) pp. 57-59, Mar. 1943; (B108) pp. 59-65, Mar. 1943; PPR Vol. 9B, 7.48.1 (1946); (B109) CC-579, p. 15, Apr. 1943; (B110) CC-680, p. 22, May 1943; (B111) M-CN-2034, p. 13, Sept. 1944; (B112) CC-3418, Feb. 1946; PPR Vol. 9B, 7.54.1 (1946); (B113) MonC-76, Feb. 1946; PPR Vol. 9B, 7.13 (1946).
 (B114) Ballou, N. E., and W. H. Burgus, CC-529, pp. 66-69, Mar. 1943; CC-680, pp. 13-21, May 1943; PPR Vol. 9B, 7.49.3 (1946).
 (B115) Ballou, N. E., W. H. Burgus, J. B. Dial, L. E. Glendenin, H. Finston, M. F. Ravelly, B. Schloss and N. Sugarman, CC-920, p. 24, Sept. 1943.
 (B116) Brady, E. L., CC-529, p. 43, Mar. 1943; (B117) CC-920, p. 49, Sept. 1943.
 (B118) Brady, E. L., W. H. Burgus, D. W. Engelkemeir, L. E. Glendenin, T. B. Novey and N. Sugarman, CC-465-B, pp. 14-18, Feb. 1943; PPR Vol. 9B, 7.5.2 (1946).
 (B119) Brady, E. L., and E. Creutz, CC-529, pp. 28-30, Mar. 1943.
 (B120) Brady, E. L., and A. Turkevich, MUC-NS-#220, Aug. 1944; CL-607, III D, 2, Nov. 1944.
 (B121) Brady, E. L., D. W. Engelkemeir and E. P. Steinberg; PPR Vol. 9B, 7.15.2 (1946).
 (B122) Burgus, W. H., CC-465-B, pp. 13-25, Feb. 1943; (B124) CC-2310, pp. 210-211, Jan. 1945.
 (B125) Burgus, M. J., E. O. Wolfan, L. A. Pardue and H. B. Willard, private communication; June 1946.
 (C1) Clancy, E. P., *Phys. Rev.*, **58**, 58 (1940); (C2) *ibid.*, **60**, 87 (1941); **59**, 656 (1941).
 (C3) Collins, G. B., B. Waldman, E. M. Stubblefield and M. Goldhaber, *ibid.*, **58**, 507 (1939).
 (C4) Cork, J. M., and J. L. Lawson, *ibid.*, **56**, 291 (1939).
 (C5) Curtis, B. R., and J. M. Cork, *ibid.*, **58**, 681 (1938).
 (C6) Campbell, N. R., and H. W. Wood, *Proc. Camb. Phil. Soc.*, **24**, 15 (1906); Campbell, N. R., *ibid.*, 211 (1907); 557 (1908).
 (C101) Camac, M., CC-2409, Oct. 1944.
 (C102) Campbell, G. W., CC-529, p. 48, Mar. 1943; (C103) CC-724, p. 10, June 1943.
 (C104) Coryell, C. D., CC-1112, p. 15, Dec. 1943; (C105) CC-1204, pp. 12-15, Jan. 1944.
 (C106) Coryell, C. D., and N. E. Ballou, CC-529, pp. 70-73, Mar. 1943.
 (C107) Coryell, C. D., and co-workers, CC-235-D, pp. 2-3, Aug. 1942; (C108) CC-258-D, p. 5, Sept. 1942; (C109) CC-298-D, pp. 1-2, Oct. 1942; (C110) CC-359-B, pp. 1-4, Dec. 1942.
 (C112) Coryell, C. D., and K. Way, CC-1204, p. 23, Jan. 1944.
 (C115) Coryell, C. D., MUC-CDC-#10, Mar. 1943.
 (C116) Coryell, C. D., and E. L. Brady, MUC-CDC-#80, Sept. 1943.
 (D1) Deutch, M., *Phys. Rev.*, **59**, 940 (1941).
 (D2) DeVries, H., and J. Veldkamp, *Physica*, **8**, 249 (1938).
 (D3) Dodson, R. W., and R. D. Fowler, *Phys. Rev.*, **56**, 880 (1939); (D4) *ibid.*, **57**, 966 (1940).
 (D5) Doran and Henderson, private communication to K. Lark-Horovitz, cited by G. T. Seaborg, CL-697, III C, 3.1, Dec. 1944.
 (D6) Downing, J. R., M. Deutch and A. Roberts, *Phys. Rev.*, **61**, 389, 686 (1942).
 (D7) Dods, M., and B. Pontecorvo, *Compt. rend.*, **207**, 237 (1938).
 (D8) Downing, J. R., and A. Roberts, *Phys. Rev.*, **59**, 940 (1941).
 (D9) Deutch, M., *ibid.*, **61**, 672 (1942).
 (D10) Deutch, M., and A. Roberts, *ibid.*, **60**, 362 (1941).
 (D101) Davies, T. IL, M-CN-1424, p. 12, Apr. 1944.
 (D102) Deutch, M., LAMS-142, Oct. 1944.
 (D103) Dillard, C., R. M. Adams, H. Finston and A. Turkevich, CC-1142, p. 23, Dec. 1943; CC-1805, July 1944; PPR Vol. 9B, 7.5.3 (1946); (D104) CC-2310, p. 35, Jan. 1945; PPR Vol. 9B, 7.12 (1946); (D107) Dillard, C., H. Finston, R. M. Adams and A. Turkevich, CC-2310, p. 198, Jan. 1945; PPR Vol. 9B, 7.44.2 (1946); (D108) MUC-NS-#280, Jan. 1945; (D109) Dillard, C., R. M. Adams, H. Finston and A. Turkevich, CC-2310, pp. 53-62, 167-169, Jan. 1945; PPR Vol. 9B, 7.5.5 (1946).
 (E101) Edwards, R. R., and H. Gest, CN-2809, p. 8, Apr. 1945; (E102) MonN-2, p. 7, July 1945.
 (E103) Elliott, N., CC-342, p. 6, Nov. 1942; CC-465-B, p. 13, Feb. 1943; PPR Vol. 9B, 7.38.1 (1946).
 (E104) Engelkemeir, D. W., CC-389-B, pp. 1-4, 6, Dec. 1942; (E105) CN-1911, pp. 7-8, July 1944; PPR Vol. 9B, 7.15.6 (1946); (E106) CC-1959, Aug. 1944; PPR Vol. 9B, 7.45.2 (1946); (E107) CC-2310, p. 195, Jan. 1945; CC-2485, p. 3, Dec. 1944; PPR Vol. 9B, 7.40.2 (1946).
 (E108) Engelkemeir, D. W., and E. L. Brady, CC-418-B, pp. 9-13, Jan. 1943; PPR Vol. 9B, 7.15.9 (1946).
 (E109) Engelkemeir, D. W., M. S. Freedman, J. A. Sellar, E. P. Steinberg and L. Winsberg, CN-2929, p. 2, Apr. 1945.
 (E110) Engelkemeir, D. W., T. B. Novey and D. S. Schover, CC-793, pp. 6-16, July 1943.
 (E111) Engelkemeir, D. W., J. A. Sellar, E. P. Steinberg and L. Winsberg, PPR Vol. 9B, 7.57.18 (1946).
 (E112) Engelkemeir, D. W., and N. Sugarman, CC-2310, pp. 170-184, Jan. 1945; PPR Vol. 9B, 7.38.2 (1946); (E113) CC-298-D, p. 5, Oct. 1942.
 (E114) Evans, H. B., CN-2799, p. 3, Mar. 1945; reported in PPR Vol. 9B, 7.41 (1946).
 (E115) Edwards, R. R., H. Gest and T. H. Davies, CC-3300, June 1946.
 (E116) Engelkemeir, D. W., M. S. Freedman and L. E. Glendenin, reported in PPR Vol. 9B, 7.45.1 (1946).
 (E117) Engelkemeir, D. W., E. L. Brady and E. P. Steinberg, PPR Vol. 9B, 7.15.5 (1946).
 (F1) Feather, N., and J. V. Dunworth, *Proc. Roy. Soc. (London)*, **A-168**, 566 (1938).
 (F2) Feldmeier, J. R., and G. B. Collins, *Phys. Rev.*, **59**, 937 (1941).
 (F3) Flammersfeld, A., *Naturwissenschaften*, **22**, 36 (1944).
 (F4) Feather, N., *Phys. Rev.*, **58**, 1559 (1930); (F5) *Proc. Camb. Phil. Soc.*, **27**, 430 (1931); (F6) *ibid.*, **24**, 599 (1938).

- (F102) Finkle, B., E. Hoagland, S. Katcoff, R. P. Metcalf, E. P. Steinberg, N. Sugarman and L. Winsberg, CN-1998, p. 6, Aug. 1944.
- (F103) Finkle, B., E. Hoagland, S. Katcoff and N. Sugarman, CN-1958, Aug. 1944; PPR Vol. 9B, 7.57.17 (1946); (F104) CN-2126, pp. 8-9, Sept. 1944.
- (F105) Finkle, B., and N. Sugarman, CC-2310, pp. 74-84, Jan. 1945; PPR Vol. 9B, 7.9.1 (1946); (F106) CC-2310, pp. 193-194, Jan. 1945; CC-2379, p. 9, Nov. 1944; PPR Vol. 9B, 7.40.1 (1946); (F107) CN-2799, p. 4, Mar. 1945.
- (F108) Freedman, M. S., and D. W. Engelke, CC-1331, pp. 4-9, Feb. 1944.
- (F110) Fulbright, H. W., CP-1811, p. 36, July 1944.
- (F111) Finkle, B., D. W. Engelke and N. Sugarman, PPR Vol. 9B, 7.42.1 (1946).
- (F112) Feldman, M. H., L. E. Glendenin and R. R. Edwards, MonC-137, Aug. 1946; PPR Vol. 9B, 7.3.7 (1946).
- (F113) Feldman, M. H., and L. E. Glendenin, MonC-138, Aug. 1946; PPR Vol. 9B, 7.7 (1946).
- (G1) Glasoe, G. N., and J. Steigman, *Phys. Rev.*, **67**, 568 (1940); (G2) *ibid.*, **68**, 1 (1940).
- (G3) Goldhaber, M., R. D. Hill and L. Szilard, *ibid.*, **68**, 47 (1939).
- (G4) Götze, H., *Naturwissenschaften*, **29**, 449 (1940); (G5) *ibid.*, **30**, 108 (1942); (G6) *ibid.*, **29**, 496 (1941); (G7) private communication to O. Hahn and F. Strassmann; *ibid.*, **31**, 499 (1943).
- (G8) Grosse, A. V., and E. T. Booth, *Phys. Rev.*, **67**, 664 (1940).
- (G101) Gest, H., W. H. Burgus and O. K. Neville, CN-2559-B, p. 4, Jan. 1945.
- (G103) Gest, H., and R. R. Edwards, CN-2809, April 1945; PPR Vol. 9B, 7.46 (1946).
- (G104) Glendenin, L. E., CC-298, p. 2, Oct. 1942; CC-529, pp. 52-54, Mar. 1943; (G107) CC-579, pp. 11-15, Apr. 1943; (G108) CC-920, pp. 35-42, Sept. 1943; (G110) CC-1050, p. 9, Nov. 1943; (G112) M-CN-1634, p. 9, June 1944; (G113) M-CN-1844, p. 13, Aug. 1944; (G115) CC-2596, pp. 10-11, Mar. 1945; (G116) M-CN-2184, p. 11, Sept. 1944; PPR Vol. 9B, 7.18.4 (1946); (G117) CN-2839, p. 10, June 1945; MonN-15, pp. 12-13, Sept. 1945; PPR Vol. 9B, 7.3.1 (1946); (G118) MonN-6, p. 9, August 1945; (G119) PPR Vol. 9B, 7.22.2 (1946); (G120) private communication.
- (G121) Glendenin, L. E., and E. L. Brady, reported in MUC-CDC-#80, Sept. 1943.
- (G122) Glendenin, L. E., PPR Vol. 9B, 7.3.6 (1946).
- (G123) Glendenin, L. E., and R. P. Metcalf, CC-2219, Feb. 1945; PPR Vol. 9B, 7.33.2 (1946).
- (G126) Goldring, L. S., M-CN-1404, p. 14, March 1944.
- (G127) Glendenin, L. E., and E. P. Steinberg, CC-579, p. 11, Apr. 1943; CC-680, p. 9, May 1943; CC-920, p. 43, Sept. 1943; PPR Vol. 9B, 7.18.2 (1946).
- (G128) Goldschmidt, B. L., and I. Perlman, CC-295, Sept. 1942; PPR Vol. 9B, 7.15.1 (1946); (G129) CC-295, Sept. 1942; PPR Vol. 9B, 7.18.1 (1946).
- (G130) Goldschmidt, B. L., and F. Morgan, MC-11, Aug. 1943.
- (G131) Goldschmidt, B. L., and I. Perlman, CC-295, Sept. 1942.
- (G132) Goldstein, A., CN-2799, p. 4, Mar. 1945; PPR Vol. 9B, 7.43 (1946).
- (G133) Goldstein, A., R. P. Schuman and W. Rubinson, CN-2929, pp. 3-4, Apr. 1945; PPR Vol. 9B, 7.50.2 (1946).
- (G134) Glendenin, L. E., and C. D. Coryell, CC-529, pp. 31-38, Mar. 1943; CC-1112, p. 15, Dec. 1943; PPR Vol. 9B, 7.11.2 (1946).
- (G135) Glendenin, L. E., PPR Vol. 9B, 7.30.2 (1946).
- (G136) Glendenin, L. E., and R. P. Metcalf, PPR Vol. 9B, 7.39.1 (1946).
- (G137) Glendenin, L. E., PPR Vol. 9B, 7.42.3 (1946); (G138) reported in PPR Vol. 9B, 7.10 (1946).
- (G139) Glendenin, L. E., and R. P. Metcalf, CC-2219, Feb. 1945; reported in PPR Vol. 9B, 7.41 (1946); (G140) reported in PPR Vol. 9B, 7.39.2 (1946).
- (G141) Glendenin, L. E., PPR Vol. 9B, 7.24.3 (1946); (G142) PPR Vol. 9B, 7.35 (1946); (G143) PPR Vol. 9B, 7.18.3 (1946); (G144) PPR Vol. 9B, 7.17.1 (1946).
- (G145) Glendenin, L. E., and C. D. Coryell, CL-CDC-#10, Feb. 1946.
- (G146) Glendenin, L. E., J. M. Siegel and C. D. Coryell, CL-CDC-#8, July 1945.
- (G147) Glendenin, L. E., C. D. Coryell and R. R. Edwards, CL-LEG-#1, July, 1946.
- (H1) Haggstrom, E., *Phys. Rev.*, **68**, 144 (1942).
- (H2) Hahn, O., and F. Strassmann, *Naturwissenschaften*, **27**, 11 (1939); (H3) *ibid.*, 451 (1939); (H4) *ibid.*, 529 (1939); (H5) *ibid.*, 29, 54 (1940); (H6) *ibid.*, 61 (1940); (H7) *ibid.*, 455 (1940); (H8) *ibid.*, 543 (1940); (H9) *ibid.*, 29, 285 (1941); (H10) *ibid.*, 269 (1941); (H11) *Z. Physik*, **117**, 789 (1941); (H12); *Naturwissenschaften*, **30**, 324 (1942); (H13) *ibid.*, 31, 249 (1943); (H14) *ibid.*, 499 (1943); (H15) *Z. Physik*, **151**, 729 (1943).
- (H16) Hahn, O., F. Strassmann and H. Götte, *Abhandl. Preuss. Akad. Wiss., Math.-naturw. Klasse*, No. 3 (1942).
- (H17) Helmholtz, A. C., *Phys. Rev.*, **60**, 415 (1941); (H18) private communication to G. T. Seaborg in (S19).
- (H19) Hevesy, G. V., and H. Levi, *Nature*, **137**, 185 (1936); (H20) *Kgl. Danske Videnskab. Selskab. Math. fys. Medd.*, **14**, No. 5 (1936).
- (H21) Heyn, F. A., *Nature*, **139**, 842 (1937).
- (H22) Heyn, F. A., A. H. W. Aten, Jr., and C. J. Bakker, *ibid.*, **143**, 516 (1939).
- (H23) Huber, O., O. Leinhard and H. Wäfler, *Helv. Phys. Acta*, **17**, 195 (1944).
- (H24) Hahn, O., F. Strassmann and S. Flügge, *Naturwissenschaften*, **27**, 544 (1939).
- (H25) Helmholtz, A. C., *Phys. Rev.*, **60**, 160 (1941).
- (H26) Helmholtz, A. C., C. Fecher and P. R. Stou, *ibid.*, **59**, 902 (1941).
- (H27) Hamilton, J. O., private communication to G. T. Seaborg in (S19).
- (H101) Hayden, R. J., CP-3344, p. 5, Nov. 1945; (H102) CP-3383, p. 4, Dec. 1945.
- (H103) Hoagland, E. J., and S. Katcoff, CC-2310, p. 88, Jan. 1945; PPR Vol. 9B, 7.8.2 (1946).
- (H104) Hoagland, E. J., and N. Sugarman, CC-2310, pp. 63-69, Jan. 1945; (H105) CC-2310, pp. 185-192, Jan. 1945; PPR Vol. 9B, 7.37.2 (1946); (H106) CC-2379, p. 8, Nov. 1944; (H108) CN-2799, p. 5, Mar. 1945; CC-2891, Apr. 1945; PPR Vol. 9B, 7.7 (1946); (H109) CC-3007, Apr. 1946; PPR Vol. 9B, 7.37.3 (1946); (H110) PPR Vol. 9B, 7.6 (1946).
- (H111) Hughes, D. J., J. Dabbs and O. Cohn, CP-3094, July 1945.
- (H112) Hughes, D. J., and D. Hall, CP-3209, pp. 12-16, July 1945.
- (H113) Hayden, R. J., and M. G. Inghram, CP-3509, May 1946.
- (J101) Jacobson, L., and R. Overstreet, CC-2345, Dec. 1944; PPR Vol. 9B, 7.15.8 (1946).
- (J102) Jurney, E. T., and E. O. Wollan, CP-1576, p. 13, Apr. 1944.
- (K1) Kalbfell, D. C., *Phys. Rev.*, **54**, 543 (1938).
- (K2) Kalbfell, D. C., and R. A. Cooley, *ibid.*, **58**, 91 (1940).
- (K3) Klemperer, O., *Proc. Roy. Soc. (London)*, **A-148**, 638 (1935).
- (K4) Kraus, J. D., and J. M. Cork, *Phys. Rev.*, **52**, 763 (1937).
- (K5) Kurbatov, J. D., D. C. MacDonald, M. L. Pool and L. L. Quill; *ibid.*, **61**, 106 (1942).
- (K6) Kurbatov, J. D., and M. L. Pool, *Phys. Rev.*, **63**, 463 (1943).
- (K7) Kurchatov, B. V., I. Kurchatov, L. Muisovskii and L. Rusinov, *Compt. rend.*, **200**, 1201 (1935).
- (K8) Koroninski, K. J., and G. E. Uhlenbeck, *Phys. Rev.*, **68**, 7 (1935).
- (K101) Katcoff, S., CC-2310, p. 52, Jan. 1945; PPR Vol. 9B, 7.3.2 (1946); (K102) CC-2310, pp. 70-74, Jan. 1945; PPR Vol. 9B, 7.9.1 (1946); (K103) CC-2310, p. 102, Jan. 1945; PPR Vol. 9B, 7.16.1 (1946); (K104) CC-2310, p. 156, Jan. 1945; PPR Vol. 9B, 7.31 (1946); (K105) CC-2310, p. 206, Jan. 1945; PPR Vol. 9B, 7.47 (1946); (K106) CC-2310, pp. 224-226, Jan. 1945; PPR Vol. 9B, 7.48.2 (1946).
- (K108) Katcoff, S., C. Dillard, H. Finston, B. Finkle, J. A. Sailer and N. Sugarman, CN-2379, p. 8, Nov. 1944; CC-2310, p. 157, Jan. 1945; PPR Vol. 9B, 7.33.3 (1946).
- (K109) Katcoff, S., and B. Finkle, CC-2310, pp. 90-94, Jan. 1945; PPR Vol. 9B, 7.14.2 (1946).
- (K110) Katcoff, S., B. Finkle, C. Dillard and H. Finston, CC-2485, p. 5, Dec. 1944.
- (K111) Katcoff, S., B. Finkle and E. J. Hoagland, CN-2126, p. 5, Sept. 1944.
- (K112) Katcoff, S., B. Finkle, E. J. Hoagland and N. Sugarman, CC-1546, p. 5, Apr. 1944.
- (K113) Katcoff, S., B. Finkle and N. Sugarman, CC-1331, p. 10, Feb. 1944; PPR Vol. 9B, 7.44.1 (1946); (K114) CC-1331, pp. 10-15, 21, Feb. 1944; PPR Vol. 9B, 7.49.2 (1946); (K115) CC-1331, p. 14, Feb. 1944; PPR Vol. 9B, 7.3.3 (1946); (K116) CC-1331, p. 18, Feb. 1944.

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TABLE I

TABLE OF FISSION PRODUCTS: CHARACTERISTICS

Nucleus Z A	Half-life	Decay	Discovery in fission	Class	Fission yield, %	Energy of radiations in Mev Particles	Gamma radiations	Produced by and mass assignment	Other references
30 Zn ⁷²	49h (S121)	β^- , γ	(S120)	A	1.5×10^{-3} (S121)	0.3 (~95%), ~1.6 (~5%) (S121) abs. Al, F.	γ (S121)	fiss., prec. 14.25h Ga ⁷² (S121)	.....
Zn ⁷²	<2m (S121)	β^-	.....	(B)	.....	.....	.....	hyp. prec. 5h Ga ⁷² (S121)	.....
31 Ga ⁷¹	stable								
Ga ⁷²	14.25h (S121) 14.1h (S1)	β^- , γ	(S120)	A	.....	0.8 (~65%), ~3.1 (~35%) (S121) abs. Al, F. 1.71(S3) cl. ch. (K.U.)	0.64 (~10%), 0.84 (~45%), 2.25 (~45%) (M114) spect. 1.17, 2.65(M2) spect. 2.1(S121) abs. Pb	Ga(d,p) (L11) Ga(n, γ) (S1, S121) Ge(n,p) (S10, S121) fiss., desc. 49h Zn ⁷² (S121)	.....
Ga ⁷³	5h (S121)	β^-	(S118), (S121)	B	1.0×10^{-4} (S121)	1.4(S121) abs. Al, F.	no γ (S121)	Ge(n,p) (S121) fiss., desc. <2m Zn ⁷² (S121) 73(S121) fiss. yld.-ener.	.....
32 Ge ⁷²	stable								
Ge ⁷³	stable								
Ge ⁷⁴	stable								
Ge ⁷⁶	89m (S11)	β^- , γ	.....	(A)	.....	1.2 (S11) abs. Al 1.1(S3, S10) cl. ch. (K.U.)	γ (S11)	Ge(d,p) (S1, S10, S11) Ge(n, γ) (S1, S10) Ge(n,2n) (S10, S11) As(n,p) (S10, S11) Se(n, α) (S10, S11) Ge(γ ,n) (H23)	.....
Ge ⁷⁸	stable								
Ge ⁷⁷	12h (S11) 11h (S134)	β^- , γ	(S133)	A	0.0037(S134)	2.0(S133, S134) abs. Al 1.9(S3, S10) cl. ch. (K.U.)	γ (S134)	Ge(d,p) (S1, S10, S11) Ge(n, γ) (S1, S10) Se(n, α) (S11) fiss., prec. 40h As ⁷⁷ (S134) 77 (S1, S11) not prod. As(n,p)	.....
Ge ⁽⁷⁸⁾	2.1h (S134)	β^- , γ	(S133)	C	0.020(S134)	~0.9(S134) abs. Al	γ (S134)	fiss., prec. 90m As ⁽⁷⁸⁾ (S134)	.....
33 As ⁷⁵	stable								
As ⁷⁷	40h (S134)		(S133)	B	0.0091(S151)	0.7(S134) abs. Al	.....	fiss. (S151) desc. 12h Ge ⁷⁷ (S134)	.....
As ⁷⁸	80m (C5) 65m (S6, S22)	β^- , γ	.....	(A)	.....	1.4(S6) cl. ch. (K.U.)	0.27(S6) abs. Pb	Se(n,p) (S6) Br(n, α) (S22, C5, S6)	.....
As ⁽⁷⁸⁾	90m (S134)	β^-	(S133)	C	0.020(S134)	1.4(70%), 4.1(30%) (S134) abs. Al, F.	.....	fiss., desc. 2.1h Ge ⁽⁷⁸⁾ (S133, S134)	.....
As ⁸³	<10m (G117)	β^-	.....	B	.....	.....	.....	hyp. prec. 17m Se ⁸¹ (G117)	.....

34	Sc ⁷⁷	stable										
	Sc ⁷⁸	stable										
	Sc ⁷⁹	<10m or >7 × 10 ⁶ y (G122)	β ⁻	B	.....	.....	.....	.....	79(G117) not mass 81	(W109)	
	Sc ⁸⁰	stable										
	Sc ⁸¹	59m (G117) 57m (S22, L2)	I.T., γ, e ⁻	(G118)	B	0.008(G117)	e ⁻ : 0.0868(80%), 0.0964(20%) (H17) spect. e ⁻ : 0.085(L2) spect.	0.099(H17) spect. conv. 0.098(L2) spect. conv.; abs.		Se(n,γ) (S22, H21) Se(d,p) (S22, L2) Se(γ,n) (B7) Br(n,p) (L2) fiss., prec. 17m Se ⁸¹ (L2, G117)	.....
	Sc ⁸²	17m (G117) 19m (L2)	β ⁻	(G108)	B	0.125(G117)	1.5(G117, L2) abs. Al, F.	no γ (G117)		Se(n,γ) (S22, H21) Se(d,p) (S22, L2) Se(γ,n) (B7) Br(n,p) (L2) fiss., 59m Se ⁸¹ I.T. (L2, G117) 81(G117) fiss. yld.-ener.	.....
	Sc ⁸³	stable										
	Sc ⁸⁴	25m (G117) 30m (L2)	β ⁻ , γ	(G108)	A	0.21(G117)	1.5(G117) abs. Al, F.	0.17, 0.37, 1.1(G117) abs. Pb		Se(n,γ) (S22, L2) Se(d,p) (L2) fiss., prec. 2.4h Br ⁸³ (S22, L2)	.....
	Sc ⁸⁵	~2m (G117, E115)	β ⁻	(G117, E115)	A	.....	.....	.....		fiss., prec. 30m Br ⁸⁴ (G117, E115)	.....
25	Br ⁷⁹	stable										
	Br ⁸⁰	stable										
	Br ⁸²	34h (S22)	β ⁻ , γ	(F112)	A	2.8 × 10 ⁻⁶ (F112)	0.465(R3) spect.	0.547, 0.787, 1.35 (R3, D10) spect. 1.0(R3) abs. Pb		Br(d,p) (S22) Br(n,γ) (K7, S22) Se(p,n) (B9, R4) Se(d,2n) (S22) Rb(n,α) (S22, P7) fiss., (F112)	(D8, D4)	
	Br ⁸³	2.4h (K115, G117) 2.45h (S22) 2.33h (L2)	β ⁻	(L2, S25)	A	0.40 (G117) 0.30(K115)	0.9(G117) abs. Al, F. 1.0(L2) abs. Al, F. 1.3 (S22) abs. Al.	no γ (S22, G117)		Se(d,n) (S22) Se(d,p) desc. 25m Se ⁸³ (L2) Se(n,γ) desc. 25m Se ⁸³ (S22, L2) fiss., desc. 25m Se ⁸³ (L2, G117, S22); prec. 113m Kr ⁸¹ (L2, E102)	(M10, S143, G108)	
	Br ⁸⁴	30m (S25) 33m (K101)	β ⁻ , γ	(D3)	A	0.65(K116)	5.3(K101) abs. Al, F. 4.5(B3) abs. Al	γ (K101)		Rb(n,α) (B2) fiss., desc. ~2m Se ⁸⁴ (D3)	.....

Z	Nucleus A	Half-life	Decay	Discovery in fission	Class	Fission yield, %	Energy of radiations in Mev Particles	Gamma radiations	Produced by and mass assignment	Other references
	Br ⁸²	3.0m (S25)	β^-	(S25)	A	.....	.....	.....	fiss. prec. 4.5h Kr ⁸² (S18, B2).....	
	Br ^{82m}	50s (S25)	β^-	(S25)	A	.....	.....	.....	fiss., prec. 75m Kr ⁸² (S18, B2).....	
	Br ^{80m}	55.6s (H111) 56s (L105)	β^- (n)	(B11, L105)	C	.....	.....	.....	fiss., prec. Kr ^{80m} , inst. (S154, S126) n emitter (L105)	
36	Kr ⁸²	stable		.....		low (G147)				
	Kr ^{81m}	113m (L2)	I.T., e^-	(L2)	A	.....	e^- : 0.032, 0.045, 0.028 (H17) spect. e^- : 0.035 (L2) abs. air	X-ray (E102)	Sc(α, n) (C1, C2) Kr(d, p)? (C1, C2) Kr(d, d)? (C1, C2) desc. Sc(n, γ), (d, p) (L2) fiss., desc. 2.4h Br ⁸¹ (L2, E102)	
	Kr ⁸³	stable	.....	(T101)	A	.....	.....	.....	fiss. (T101) mass spect. desc. 2.4h Br ⁸³	
	Kr ⁸⁴	stable	.....	(T101)	A	.....	.....	.....	fiss. (T101) mass spect. desc. 30m Br ⁸⁴	
	Kr ⁸⁶	4.5h (H108, S22) 4.6h (S18) 4.0h (C2)	β^-, γ	(S18)	A	.....	0.94(H108) abs. Al, F. 0.85(B3) abs. Al	0.17, 0.37(H108) abs. Pb	Kr(d, p) (S22, C1, C2) Sr(n, α) (B2) Rb(n, p) (B2) fiss., desc. 3.0m Br ⁸⁶ (S18, B2)	
	Kr ⁸⁸	~10y (H110)	β^-	(H104)	A	~0.24 (H110)	0.74(H110) abs. Al, F.	no γ (H110)	Kr(n, γ) (H108) fiss. (H104) 85(T101) mass spect.	
	Kr ⁸⁹	stable	.....	(T101)	A	.....	.....	.....	fiss. (T101) mass spect.	
	Kr ⁹⁰	75m (S18) 74m (S22)	β^-	(S18)	A	.....	~4(B3) abs. Al	.....	Kr(d, p) (S22) Rb(n, p) (B2) 87(B2) not prod. Sr(n, α) fiss., desc. 50s Br ⁹⁰ (S18, B2)	
	Kr ^{90m}	instantaneous	n (L105)	(L105)	C	0.026% of fission neutrons (H111)	n: 0.30(B125) cl. ch. 0.25 (H111) abs. paraffin	.....	fiss., desc. 55.6s Br ^{90m} (S25, S126, L105) B2, R101, S18)	
	Kr ⁹²	3h (L1) 2.8h (G2)	β^-	(L1)	A	.....	2.5(W2) cl. ch. (K.U.)	.....	fiss., prec. 17.8m Rb ⁹² (H5) (L1, A6, G1, G2, H7, H22)	
	Kr ⁹³	2.6m (D109) 2.5-3m (S14) 2-5m (G2)	β^-	(G1, S14)	A	.....	.....	.....	fiss., prec. 15.4m Rb ⁹³ (D103, G1, G2, S14, H7); D108) prec. 53d Sr ⁹³ (G1, G2, O102, D109)	

Kr ⁸⁰	~33s (K119)	β^-	(D103)	A	.....	.....	.....	fiss., prec. 25y Sr ⁸⁰ (D103, K119)	.....
Kr ⁸¹	9.8s (D109) 5.7s (O102)	β^-	(H8)	A	.....	.....	.....	fiss., prec. 9.7h Sr ⁸¹ (D108) (D109); prec. 57d Y ⁸¹ (H8, B118, O102, D103)	.....
Kr ⁸²	3s (D109)	β^-	(H5)	C	.....	.....	.....	fiss., prec. 3.5h Y ⁸² (D108) (H5, H6, H8, H15, B118, D109)	.....
Kr ⁸³	2.0s (D109)	β^-	(H16, B118)	C	.....	.....	.....	fiss., prec. 10h Y ⁸³ (H15, D108, (H16, H13, B118, D103, D109)	O102)
Kr ⁸⁴	1.4s (D109)	β^-	(H15)	C	.....	.....	.....	fiss., prec. 20m Y ⁸⁴ (H15, D109)	.....
Kr ⁸⁶	short (A101)	β^-	(A101)	A	.....	.....	.....	fiss., prec. 17h Zr ⁸⁶ (A101, D109)	.....
37 Rb ⁸⁵	stable								
Rb ⁸⁵	19.5d (H26)	β^-, γ	(F113)	A	$\sim 1.6 \times 10^{-4}$ (F113)	1.60(H1) spect. 1.56(H26) aba.	γ (H27)	Rb(n, γ) (S22, S15) Sr(d, α) (H26) Rb(γ, n) (H23) fiss. (F113)	.....
Rb ⁸⁷	6.3×10^4 y (S26)	β^-, γ, α	.....	(A)	.....	0.132(L8) spect. 0.13(O1) spect. 0.25(K3) spect.	0.034, 0.053, 0.082, 0.102, 0.129 (O1) spect. conv.	87(N1) mass spect.	(T3, C6)
Rb ⁸⁸	17.8m (G2) 18m (H7) 17.5m (W2)	β^-	(H4, H22)	A	.....	4.6(G2) aba. 5.1(W2) cl. ch.	.....	Rb(n, γ) (P7, S22) fiss., desc. 3h Kr ⁸⁸ (L1, A6, H22, G1, G2, H7)	(H5)
Rb ⁸⁹	15.4m (G2) 15.5m (H7)	β^-	(G1, S14)	A	.....	3.8(G2) aba.	.....	fiss., desc. 2.6m Kr ⁸⁹ (G1, G2, S14, H7); prec. 53d Sr ⁸⁹ (G2)	(H13)
Rb ⁹⁰	short (D103)	β^-	(D103)	A	.....	.....	.....	fiss., desc. ~33s Kr ⁹⁰ prec. 25y Sr ⁹⁰ (D103)	.....
Rb ⁹¹	short (H8, B118, O101, D103, D109)	β^-	(H8)	A	.....	.....	.....	fiss., desc. 9.8s Kr ⁹¹ prec. 9.7h Sr ⁹¹ (D109); prec. 57d Y ⁹¹ (H8, B118, O102, D103)	.....
Rb ⁹²	short (H15, B118, D109)	β^-	(H5)	C	.....	.....	.....	fiss., desc. 3s Kr ⁹² ; prec. 3.5h Y ⁹² (H5, H6, H8, H15, B118, D109)	.....

Z	Nucleus A	Half-life	Decay	Discovery in fission	Class	Fission yield, %	Energy of radiations in Mev		Produced by and mass assignment	Other references
							Particles	Gamma radiations		
	Rb ⁹³	short (H16, H13, B118, D103, D109)	β^-	(H16, B118)	C	.....	.....	.....	fiss., desc. 2.0s Kr ⁹³ prec. 10h Y ⁹³ (H16, H13, H15, B118, D103, D109)	.....
	Rb ⁹⁴	short (H15, D109)	β^-	(H15)	C	.....	.....	.....	fiss., desc. 1.4s Kr ⁹⁴ prec. 20m Y ⁹⁴ (H15, D109)	.....
	Rb ⁹⁷	short (A101)	β^-	(A101)	A	.....	.....	.....	fiss., desc. short Kr ⁹⁷ prec. 17h Zr ⁹⁷ (A101, D109)	.....
	Rb	80s (H5)	β^-	(H5)	C	.....	.....	.....	fiss. (H5)	
38	Sr ⁸⁸	stable		.....		low (G147)				
	Sr ⁸⁹	stable								
	Sr ⁹⁰	stable								
	Sr ⁹⁰	55d (G138) 54d (L9) 55d (S23, S24)	β^-	(L9)	A	4.6(N112)	1.50(W104) spect. 1.52(N101) spect. 1.5(G131, B3) abs. Al; (S24) cl. ch.	no γ (G138, S23, S24)	Sr(n, γ) (S23, S24) Y(n, p) (S4) fiss., desc. 15.4m Rb ⁹⁰ (G2) 89 (L108) mass spect.	(H5, H7, H1, P104)
	Sr ⁹⁰	25y (N110, G134)	β^-	(H16, N108, G130)	A	.....	0.6(G134) abs. Al, F.	no γ (G134, G130)	fiss., desc. short Rb ⁹⁰ (D103); prec. 65h Y ⁹⁰ (H16, H13, N108, G130) 90 (H101) mass. spect.	(M113)
	Sr ⁹¹	9.7h (K102) 10h (H15) 8.5h (G6)	β^-, γ	(G6)	A	5.0(F103)	1.3(40%), 3.2(60%) (K102) abs. Al, F.	~ 1.3 (K102) abs. Pb	Zr(n, α) (S17) fiss., desc. short Rb ⁹¹ (D109); prec. 51m Y ^{91*} ($\sim 40\%$), 57d Y ⁹¹ ($\sim 60\%$) (G6, F105)	(B115)
	Sr ⁹²	2.7h (G6)	β^-	(G6)	C	5.1(H103)	.....	.....	fiss., desc. short Rb (H5); prec. 3.5h Y ⁹² (G6)	(H13, H15, B118, P102)
	Sr ⁹³	7m (L9)	β^-	(L9)	C	.....	.....	.....	fiss., desc. short Kr ⁹³ (L9, H16, H13, H15, B118, D109); prec. 10h Y ⁹³ (H16, H13, H15)	(H5)
	Sr ⁹⁴	~ 2 m (H15)	β^-	(H15)	C	.....	.....	.....	fiss., desc. 1.4s Kr ⁹⁴ (H15, D109); prec. 20m Y ⁹⁴ (H13, H15)	.....
	Sr ⁹⁷	short (A101)	β^-	(A101)	A	.....	.....	.....	fiss., desc. short Kr ⁹⁷ prec. 17h Zr ⁹⁷ (A101, D109)	.....

39	Y^{90}	stable										
	Y^{91}	65h (N110) 62h (G130) 60h (S23, G134)	β^-	(H16, N108, A G130)	.....	2.2(N101) spect. 2.45(G134) abs. Al, F. 2.55(N108) abs. Al 2.6(S23) cl. ch. (K.U.)	no γ (G134, G130)	$Y(n, \gamma)$ (S23, S4) $Y(d, p)$ (S23) $Cb(n, \alpha)$ (S5, S7, N104) $Zr(n, p)$ (S9, G126) $Zr(d, \alpha)$ (S9) fiss., desc. 25y Sr^{90} (H16, H13, G130, N110) 90(H101) mass spect.	.....		
	Y^{92}	51m (F105) 50m (G6)	I.T., γ, e^-	(G6)	A	.....	e^- : ~ 0.5 (F105) abs. Al	0.61(F105) abs. Pb ($\sim 10\%$ con- verted)	$Zr(n, p)$ (S17) fiss., desc. 9.7h Sr^{91} ($\sim 40\%$) (G6, F105); prec. 57d Y^{91} (F105)	.....	
	Y^{93}	57d (H8, G6)	β^-	(H8)	A	5.9(N112)	1.53(L113) spect. 1.6(B3) abs. Al 1.7(M113) abs. Al, F.	no γ (B101, M101)	$Zr(n, p)$ (S17) (G131, P103) fiss., desc. 9.7h Sr^{91} ($\sim 60\%$) (G6, F105); desc. 51m Y^{91} ($\sim 40\%$) (F105) 91(L108) massspect.			
	Y^{94}	3.5h (L9, H15)	β^-, γ	(L9)	C	.....	3.4(G6) abs. Al; (H103) abs. Al, F. 3.6(B3) abs. Al	0.6(G6) abs. Pb 0.7-1.1(K111) abs. Pb	$Zr(n, p)$ (S9, S17) (B115) fiss., desc. 2.7h Sr^{93} (G6, H103)			
	Y^{95}	10h (B113) 11.5h (H15)	β^-, γ	(H16, B101)	C	.....	3.1(B113) abs. Al, F.	0.7(B113) abs. Pb	fiss., desc. 7m Sr^{93} (B115) (H16, H13, H15); not mass 95 (S114)			
	Y^{96}	20m (H15, D104)	β^-, γ	(H15)	C	~ 5 (D104)	.....	γ (H15)	$Zr(n, p)$ (S17) fiss., desc. ~ 2 m Sr^{94} (H15, H13)	.....	
	Y^{97}	<3h (S114)	β^-	.....	A	.....	.....	.....	hyp. prec. 65d Zr^{96} (S114)			
	Y^{98}	short (A101)	β^-	(A101)	A	.....	.....	.....	fiss., desc. short Sr^{97} prec. 17h Zr^{97} (A101, D109)			
40	Zr^{90}	stable										
	Zr^{91}	stable										
	Zr^{92}	stable										
	Zr^{93}	2.5m (N104)	β^- (?)	.....	(D)	.....	.....	.....	$Cb(n, p)$ (?) (N104)	.....	
	Zr^{94}	stable										

Nucleus Z A	Half-life	Decay	Discovery in fission	Class	Fission ykld. %	Energy of radiations in Mev		Produced by and mass assignment	Other references
						Particles	Gamma radiations		
Zr ⁹⁰	65d (B117) 65.5d (P8) 63d (S9)	β^- , γ	(G128)	A	~6.4(S128, W101)	0.394(98%), 1.0(2%) (N103) spect. ~0.35(98%), 1.0(2%) (M113) abs. Al, F.; (E108) abs. Al e^- : 0.71, 0.90 (?) (N103) spect.	0.73, 0.92(?) (N103) spect. conv. 0.80(E108) abs. Pb 0.88(M113) abs. Pb	Zr(n, γ) (S9) Zr(d, p) (S9, J101) Mo(n, α) (S9) fiss., desc. <3h Y ^m (S114); prec. 90h Cb ^{m*} (~2%), 35d Cb ^m (~98%) (E108, S131, J101) 95 (L107, N103) 35d Cb ^m β^- emitter 95 (H102) mass spect.	(B121, N104) H13, G101)
Zr ⁹⁰	stable								
Zr ⁹¹	17.0h (G8, K109)	β^- , γ	(G8)	A	.....	2.1(K109) abs. Al, F.	~0.8(K109) abs. Pb	Zr(n, γ) (S9) Mo(n, α) (S9) fiss., desc. short Sr ^m (A101); prec. 75m Cb ^m (G8, H9, S9) 95, 97 (J101) not prod. by Cb(n, p) (N104) 97(S9) not prod. by Zr($n, 2n$)	(P105)
41 Cb ⁹⁴	stable								
Cb ^{94m*}	90h (S131) 80h (E108)	I. T., e^- , X-ray	(E104)	A	e^- : 0.22 <suba< sub="">, 0.23<subb< sub="">(L104) spect.; 0.22 (S131) abs. Al</subb<></suba<>	γ highly conv. (?) (S131) X-ray: ~0.016(S131) abs. Al	fiss., desc. 65d Zr ^m (~2%) (S131, E108); prec. 35d Cb ^m (S131, L104)
Cb ⁹⁵	35d (E108) 36.5d (J101)	β^- , γ	(G128)	A	0.15 <suba< sub="">(N106) spect. 0.15(G128, E108, M113) abs. Al e^-: 0.75, 0.77(N106) spect.</suba<>	0.75(W104) spect. 0.77 <suba< sub="">(N106) spect. conv. 0.79(J102) spect. 0.75(E108) abs. Pb ~0.7(G128) abs. Pb</suba<>	Mo(d, α) (J101) Zr(d, p) desc. 65d Zr ^m (J101) fiss., desc. 65d Zr ^m (~98%) (J101, G128, E108); 90h Cb ^{m*} I. T. (~2%) (S131, L104) 95(L107, N106) 35d Cb ^m β^- emitter 95(H102) mass spect.	(F110, N104, E117, E105, N101)
Cb ⁹⁶	75m (G8)	β^- , γ	(G8)	A	.....	1.4(K109) abs. Al, F	0.78(K109) abs. Pb	Mo(n, p) (S9) fiss., desc. 17h Zr ^m (G8, S9, H9)	(P105)
42 Mo ⁹²	stable								
Mo ⁹⁴	stable								
Mo ⁹⁶	stable								

	Mo ⁹⁹	67h (S13, K103)	β^- , γ	(H3)	A	6.2(F103, S153)	1.2(K103) abs. Al, F. 1.4(S13) abs. Al	0.24, 0.75(M114) spect. 0.4(S13) abs. Cu, Pb	Mo(d,p) (S13) Mo(n, γ) (S4, S13) Mo(n,2n) (S9) Zr(α ,n) (D5) fiss., prec. 5.9h 43 ⁹⁹ (~10%) (S13, S21); prec. 4 x 10 ⁶ y 43 ⁹⁹ (~90%) (S13, M107)	(H24, B115)
	Mo ¹⁰⁰	stable								
	Mo ¹⁰¹	14.6m (M6) 14m (H11)	β^- , γ	(H10)	A	.....	1.0, 2.2(M6) abs. Al 1.9(S9) abs. 1.8(S8) cl. ch. (K.U.)	0.3, 0.9(M6) abs. Pb	Mo(n, γ) (S8, S9, M5, M6) fiss., prec. 14.0m 43 ¹⁰¹ (M5, M6, H10, H11, S8) 101(S9, M6) not prod. by Mo(n,2n)	.....
	Mo ⁽¹⁰²⁾	12m (H11)	β^-	(H10)	C	.....	.....	.....	fiss., prec. <1m 43 ⁽¹⁰²⁾ (H10, H11)	.....
	Mo ¹⁰³	short (B4)	β^-	(B4)	A	.....	.....	.....	fiss., prec. 4.5h Ru ¹⁰³ (B4)	.....
43	43 ⁹⁹	5.9h (G144) 6.6h (S13)	I.T., γ , ϵ^- , X-ray	(S21)	A	.....	σ^- : 0.116(S13) spect. 0.12(S13) abs. Al	0.136(S13) spect. conv. 0.129(K1) spect. conv. ~0.18(S13) abs. Cu, Pb X-ray (S13)	Mo(n, γ) desc. 67h Mo ⁹⁹ (S13, S9) Mo(d,p) desc. 67h Mo ⁹⁹ (S13) fiss., desc. 67h Mo ⁹⁹ (S13, S21, G107); prec. 4 x 10 ⁶ y 43 ⁹⁹ (S13, M107)	(G110)
	43 ¹⁰⁰	4 x 10 ⁶ y (M107) ~10 ⁶ y (L111) ~3 x 10 ⁶ y (S104) >3000y (G110) >40y (S13)	β^-	(L111, S104)	A	.....	0.3(L111, S104, M107) abs. Al	.....	Mo(n, γ) desc. 67h Mo ¹⁰⁰ (M107) fiss., desc. 67h Mo ¹⁰⁰ ~(90%) (S13); 5.9h 43 ¹⁰⁰ I.T. (~10%) (S13, H10)	.....
	43 ¹⁰¹	14.0m (M6, H11)	β^- , γ	(H10)	A	.....	1.3(M6) abs. Al 1.2(M5, S9) abs. Al 1.1(S8) cl. ch. (K.U.)	0.30(M6) abs. Pb	Mo(n, γ) desc. 14.6m Mo ¹⁰¹ (S8, S9) fiss., desc. 14.6m Mo ¹⁰¹ (M5, M6, H10, H11, S8)	.....
	43 ⁽¹⁰²⁾	<1m (H10, H11)	β^-	.....	C	.....	.....	.....	fiss., desc. 12m Mo ⁽¹⁰²⁾ (H10, H11)	.....
	43 ¹⁰³	short (B4)	β^-	(B4)	A	.....	.....	.....	fiss., desc. short Mo ¹⁰³ ; prec. 4.5h Ru ¹⁰³ (B4)	.....
	43 ⁽¹⁰⁴⁾	<1.5m (B4)	β^-	.....	C	.....	.....	.....	hyp. prec. 4m Ru ⁽¹⁰⁴⁾ (B4)	.....
44	Ru ⁹⁸	stable								
	Ru ¹⁰¹	stable								
	Ru ¹⁰²	stable								

Z	Nucleus A	Half-life	Decay	Discovery in fission	Class	Fission yield, %	Energy of radiations in Mev		Produced by and mass assignment	Other references
							Particles	Gamma radiations		
	Ru ¹⁰²	42d (S145, G143) 45d (N2)	β^- , γ	(N2, G129)	A	3.7(S132)	0.2(95%), 0.80(5%) (S145) abs. Al, F. 0.2(97%), 0.8(3%) (G143) abs. Al, F.	0.56(G127) abs. Pb 0.54(S145) abs. Pb	Ru(<i>d,p</i>) (L10, S145) Ru(<i>n,γ</i>) (S145) fiss., prec. 56m Rh ^{102*} (G143, G127)	(N6, B115, G115)
	Ru ¹⁰⁴	stable								
	Ru ¹⁰⁶	4.5h (S145) 4h (L10, D2, N6)	β^- , γ	(S20)	A	~0.9(S145)	1.35(S145) abs. Al, F. 1.5(B4) abs. Al	0.76(S145) abs. Pb	Ru(<i>d,p</i>) (L10, S145) Ru(<i>n,γ</i>) (D2, S145) fiss., desc. short 43 ¹⁰⁶ (B4); prec. 36.5h Rh ¹⁰⁶ (N6, S145, S122)	.....
	Ru ¹⁰⁸	1.0y (G143)	β^-	(G129)	A	0.48(S132) 0.53(G121)	~0.03(?) (G143) abs. Al	no γ (G143)	fiss., prec. 30s Rh ¹⁰⁸ (G127, G143) 106(H102) massspect.	(C105, S123)
	Ru ⁽¹⁰⁷⁾	4m (B4, G116)	β^-	(B4)	C	.....	~4(B4) abs. Al	.....	fiss., desc. <1.5m 43 ⁽¹⁰⁷⁾ (B4); prec. 24m Rh ⁽¹⁰⁷⁾ (B4, G116)	.....
45	Rh ^{103*}	56m (G127) 48m (F3) 45m (W6)	I.T., ϵ^- , X-ray	(G127)	A	.....	ϵ^- : ~0.03(G143) abs. Al	X-ray: 0.020(G143) abs. Al	Rh(<i>γ,γ</i>) (W6) Rh(<i>n,n</i>) (F3) fiss., desc. 42d Ru ¹⁰³ ($\geq 97\%$) (G143)	(S123, S145, G115)
	Rh ¹⁰⁵	stable								
	Rh ¹⁰⁶	36.5h (S145) 34h (N5)	β^- , γ	(N5)	A	.....	0.60(S145) abs. Al, F. ϵ^- : ~0.3(S145) abs. Al	0.33(S145) abs. Pb	Ru(<i>d,n</i> ?) (S145) Ru(<i>d,p</i>), Ru(<i>n,γ</i>), desc. 4.5h Ru ¹⁰⁶ (S145) fiss., desc. 4.5h Ru ¹⁰⁶ (N6, S122, S145)	.....
	Rh ¹⁰⁸	30s (G127)	β^- , γ	(G127)	A	.....	~2.8(20%), 3.9(80%) (G143) abs. Al coinc. ~4.5(S123) abs. Al	0.3, 0.8(G143) abs. Pb (low intensity)	fiss., desc. 1.0y Ru ¹⁰⁸ (G127, G143)	.....
	Rh ⁽¹⁰⁷⁾	24m (B4) 26m (G116)	β^- , γ (?)	(B4)	C	.....	1.2(B4) abs. Al	γ (?) (G116)	fiss., desc. 4m Ru ⁽¹⁰⁷⁾ (B4, G116) 107(G116) fiss. yld.-ener.	.....
	Rh ¹⁰⁹	<1h (S107)	β^-	.....	A	.....	.....	.....	hyp. prec. 13.4h Pd ¹⁰⁹ (S107)	.....
	Rh	9h (B111)	β^- , γ	(B111)	D	.....	~1.3(B111) abs. Al	0.8(B111) abs. Pb	fiss. (B111)	.....
46	Pd ¹⁰⁶	stable								
	Pd ¹⁰⁸	stable								
	Pd ¹⁰⁷	very short or >3 \times 10 ² y (G119) >8.6 \times 10 ² y (L115)	β^-	.....	A	.....	.....	.....	.....	(C112)

Pd ¹⁰⁰	stable		(S109)	A	0.028(t) (E111)	1.1(S107) abs. Al, F. 1.03(K4) cl. ch.	no γ (S107)	Pd(<i>d,p</i>) (K4) Pd(<i>n,γ</i>) (A3, K4) Ag(<i>n,p</i>) (F1) fiss., prec. 40s Ag ^{100*} (S20) 109(R103)mass spect.
Pd ¹⁰⁰	13.4h (S138) 13.2h (L103) 13h (K4)	β^-						
Pd ¹¹⁰	stable		(N4)	A	.....	3.5(B4) abs.	.....	Pd(<i>d,p</i>) (K4) Pd(<i>n,γ</i>) (A3, K4) fiss., prec. 7.6 Ag ¹¹¹ (K4, S20)
Pd ¹¹¹	26m (S20)	β^-						
Pd ¹¹²	21h (S107)	β^-	(N4)	A	0.011(S107)	0.2(S107) abs. Al	no γ (S107)	fiss., prec. 3.2h Ag ¹¹² (N4, S107)
47 Ag ¹⁰⁷	stable		.....	(A)	.....	ϵ^- : 0.0664, 0.0896, 0.0915 (V1, H17), spect.	0.0426(V1, H17) spect. conv. 0.092(H25) spect. conv. 0.09(A7, H17) abs.	Ag(<i>d,2n</i>) 5.7h Cd ¹⁰⁹ K-capt. (A7, H25) Ag(<i>d,2n</i>) 158d Cd ¹⁰⁹ K-capt. (H25) Pd(<i>n,γ</i>) desc. 13.4h Pd ¹⁰⁹ (S20) Ag(<i>n,n</i>) (A7, B8) Ag(<i>e,e</i>) (W5) Ag(<i>γ,γ</i>) (F3, W5)
Ag ^{108*}	40.4s (W5) 40s (A7)	I.T., ϵ^- , γ , X-ray						
Ag ¹⁰⁹	stable		(N4)	A	0.018(t) (E111)	\sim 0.24(?), 1.0(S129) abs. Al, F. \sim 0.8(K4) cl. ch. (B3) abs.	no γ (?) (K4, P5) γ (low intensity) (S129)	Pd(<i>d,n</i>) (K4, P5) (N3) Pd(<i>α,p</i>), Cd(<i>n,p</i>) (P5) fiss., desc. 26m Pd ¹¹¹ (K4, S20)
Ag ¹¹¹	7.6d (S129) 7.5d (K4, P5)	β^- , γ (?)						
Ag ¹¹²	3.2h (P5, S107)	β^- , γ	(N4)	A	.....	3.6(S107) abs. Al, F. 2.2(P5) cl. ch.	0.86(S107) abs. Pb	Cd(<i>n,p</i>), In (<i>n,α</i>) (P5) (S105) fiss., desc. 21h Pd ¹¹² (N3, N4, S107)
48 Cd ¹¹¹	stable		(N4)	A	0.011(M111)	\sim 0.6, 1.13(L7) spect. 1.11(C4) spect. 0.56(60%), 1.20(40%) (M111) abs. Al, F.	0.65(M3) spc .. 0.55(L7) cl. ch.	Cd(<i>d,p</i>) (C4) Cd(<i>n,γ</i>) (M8, G3) Cd(<i>n,2n</i>) (G3) In(<i>n,p</i>) (S116) fiss., prec. 4.5h In ^{115*} (C4, G3, N3, N4)
Cd ¹¹²	stable							
Cd ¹¹³	stable							
Cd ¹¹⁴	stable							
Cd ¹¹⁵	2.33d (C4, M111) 2.5d (G3)	β^- , γ						

Z	Nucleus A	Half-life	Decay	Discovery in fission	Class	Fission yield, %	Energy of radiations in Mev		Produced by and mass assignment	Other references
							Particles	Gamma radiations		
	Cd ¹¹⁴	44d (G141) 43d (S116, M118, S117) 40d (C4)	β^- , γ (?)	(M109, G113)	A	0.0008 (M118)	1.7(G141) abs. Al 1.8(M118) abs. Al, F. 1.5(S116, S117) abs. Al	~ 0.5 (?) (S117) abs. Pb	Cd(d,p) (C4) Cd(n, γ) (S115, S116) In(n,p) (S116) fiss., (M109, G113) 115(C4) 44d Cd ¹¹⁴ β^- emitter	.....
	Cd ¹¹⁶	stable								
	Cd ¹¹⁷	2.83h (L7) 2.72h (M112)	β^-	(N4)	A	0.01(M112)	1.3-1.7(L7) spect.	.....	Cd(d,p) (C4) Cd(n, γ) (M8, G3) fiss., prec. 1.95h In ¹¹⁷ (G3, C4, L7, N3, N4) 117(C4), 1.95h In ¹¹⁷ β^- emitter	.....
	Cd*	48.7m (W10) 50m (D7)	I.T., e^-	(N4)	C	.....	e^- : 0.17 (W10) abs. Al	.....	Cd(n,n) (D7) Cd(e,e) (W10) Cd(γ , γ) (F2, W10) fiss. (N3, N4)	.....
49	In ^{115*}	4.53h (L6) 4.5h (L5, C4) 4.1h (G3, B1)	I.T., γ , e^-	(N4)	A	.....	e^- : 0.308, 0.332 (L5) spect. 0.43(G3) abs. Al	0.338(L7) spect. conv. ~ 0.4 (L7) abs. Pb	In(n,n) (G3) In(p,p) (B1) In(α , α) (L3) In(e , e) (W1) In(X-ray) (P4, C3, W1) Cd(d,p) desc. 2.33d Cd ¹¹⁵ (C4, L7) fiss., desc. 2.33d Cd ¹¹⁵ (G3, C4, N3, N4)	(M111)
	In ¹¹⁶	stable								
	In ¹¹⁷	1.95h (L6, L7) 1.9h (M112)	β^-	(N4)	A	.....	1.73(C4) spect. 1.90(M112) abs. Al, F.	no γ (L6, L7)	Cd(d,n) (L7) Cd(d,p) desc. 2.83h Cd ¹¹⁷ (C4, L7) fiss., desc. 2.83h Cd ¹¹⁷ (G3, C4, N3, N4, L7)	.....
50	Su ¹¹⁷	stable								
	Su ¹¹⁸	stable								
	Su ¹¹⁹	stable								
	Su ¹²⁰	stable								
	Su ⁽¹²¹⁾	62h (S108) 60h (N2) ~ 80 h (H14)	β^-	(N2)	C	0.014(S108)	0.76(S108) abs. Al, F.	no γ (S109)	fiss. (N2, H14, S108)	.....
	Su ^(121,122)	130d (L101)	β^-	(L101)	C	0.0012 (L101)	1.44-1.53(L101) abs. Al, F.	no γ (L101)	fiss., no active daughter (L101)	.....

	Sn^{122}	stable										
	$\text{Sn}^{(122)}$	10d (S108) 11d (H14)	β^-, γ	(H14)	C	0.0044 (S108)	2.6(S108) abs. Al, F.	γ (S108)		$\text{Sn}(d,p)$ (L13) $\text{Sn}(n,\gamma)$ (L13) fiss. (H14, S108)	.....
	Sn^{124}	stable										
	Sn^{126}	9m (L13)	β^-	.....	(B)	.....	.....	.....		$\text{Sn}(d,p)$ (L13) $\text{Sn}(n,\gamma)$ (L13) 125(L13) not prod. by $\text{Sn}(n,2n)$	.....
	Sn	$\sim 20\text{m}$ (H14)	β^-	(H14)	C	.....	.....	.....		fiss. (H14)	.....
	$\text{Sn}^{(126)}$	70m (N2, H14)	$\beta^-, \gamma(?)$	(N2)	C	0.1(S108)	(70m $\text{Sn}^{(126)}$ + $\sim 60\text{m}$ $\text{Sb}^{(126)}$): 0.7(60%), 2.7(40%) (S108) abs. Al, F.	(70m $\text{Sn}^{(126)}$ + $\sim 60\text{m}$ $\text{Sb}^{(126)}$): 1.2(S108) abs. Pb		fiss., prec. $\sim 60\text{m}$ $\text{Sb}^{(126)}$ (N2, H14)	(S109)	
51	Sb^{121}	stable										
	Sb^{123}	stable										
	Sb^{125}	$\sim 2.7\text{y}$ (L102)	$\beta^-, \gamma, \text{X-ray}$	(C102, S124)	B	0.023(S127) 0.018(L102)	0.3($\sim 65\%$), 0.7 ($\sim 35\%$)(S127) abs. Al, F. ~ 0.6 (C102, L102) abs. Al	0.6(S127) abs. Pb 0.56(L102) abs. Pb X-ray: 0.027(S127, L102) abs. Al		desc. $\text{Sn}(n,\gamma)$ (S127) fiss. (C102, S124, S127, L102)	.....
	$\text{Sb}^{(126)}$	$\sim 60\text{m}$ (N2)	$\beta^-, \gamma(?)$	(N2)	C	.....	see 70m $\text{Sn}^{(126)}$	see 70m $\text{Sn}^{(126)}$		fiss., desc. 70m $\text{Sn}^{(126)}$ (N2)	.....
	Sb^{127}	93h (S124) 80h (A2)	β^-, γ	(A2)	A	.....	1.15(S124) abs. Al	0.72(S125) abs. Pb		fiss., prec. 9.3h Te^{127} (A2, C103)	.....
	Sb^{129}	4.2h (A2)	β^-	(A2)	A	.....	.....	.....		fiss., prec. 70m Te^{129} (A2)	.....
	$\text{Sb}^{(129)}$	$\sim 5\text{m}$ (A2)	β^-	(A1)	C	.....	.....	.....		fiss., prec. 77h $\text{Te}^{(129)}$ (A2)	.....
	Sb^{131}	$< 10\text{m}$ (A2)	β^-	.....	A	.....	.....	.....		hyp. prec. 60m Te^{131} (A2)	.....
	$\text{Sb}^{(131)}$	$< 10\text{m}$ (A2)	β^-	.....	C	.....	.....	.....		hyp. prec. 43m $\text{Te}^{(131)}$ (A2)	.....
52	Te^{128}	stable										
	Te^{130}	stable										
	Te^{132}	90d (S12, G135)	I. T., σ^- , X-ray	(G112)	A	0.033 (G135)	σ^- : 0.055, 0.082, 0.085 (H17) spect.	X-ray: 0.028(G135) abs. Al		$\text{Te}(d,p)$, $\text{Te}(n,\gamma)$ (S12) I(n,p) (S12) fiss., prec. 9.3h Te^{132} (S12, G135)	.....
	Te^{137}	9.3h (S12, C103, G135)	β^-	(A2)	A	.....	0.70(S12, C103, G135) abs. Al, F.	no γ (C103, S125, G135)		$\text{Te}(d,p)$ (T2, S12) $\text{Te}(n,\gamma)$ (S12) $\text{Te}(n,2n)$ (T2) I(n,p) (S12) fiss., desc. 93h Sb^{137} (A2, C103); 90d Te^{132} I. T. (S12, G135)	.....

Nucleus Z A	Half-life	Decay	Discovery in fission	Class	Fission yield, %	Energy of radiations in Mev Particles	Gamma radiations	Produced by and mass assignment	Other references
Te ¹²⁸	stable								
Te ¹²⁹	32d (S12, G135)	I. T., e ⁻	(N111)	A	0.19(B119)	e ⁻ : 0.070, 0.10(H17) spect.	X-ray (G135)	Te(d,p) (S12) Te(n,γ) (S12) Te(n,2n) (T2) fiss., prec. 70m Te ¹²⁹ (S12, G135)	.....
Te ¹³⁰	70m (A2, G135) 72m (S12)	β ⁻ , γ, X-ray	(A2)	A	.....	1.8(W104) spect. 1.75(M113) abs. Al, F. 1.7(G135) abs. Al, F. 1.6(N111) abs. Al, F.	0.3, 0.8(G135) abs. Pb 0.3, 0.7(M113) abs. Pb X-ray: ~0.030 (G135) abs. Al	Te(d,p) (T2, S12) Te(n,γ) (S12) Te(n,2n) (H12, T2) Te(γ,n) (B7) fiss., desc. 4.2h Sb ¹³⁰ (A2); 32d Te ¹³⁰ I. T. (S12, G135); prec. very long I ¹³⁰ (S12, L112)	.....
Te ¹³¹	stable								
Te ^{131m}	30h (A2) 29h (L12)	I. T., e ⁻	(A2)	A	~0.5(K104)	e ⁻ : 0.147, 0.175(H17) spect.	.....	Te(d,p) (S12) Te(n,γ) (S12) fiss., prec. 25m Te ¹³¹ (S12); prec. 8.0d I ¹³¹ (A2, H4, S12)	.....
Te ¹³²	25m (S12) 20m (A2)	β ⁻	(A2)	A	.....	.....	.....	Te(d,p) (S12) Te(n,γ) (S12) fiss., desc. 30h Te ¹³² I. T. (S12); prec. 8.0d I ¹³² (A2, S12)	.....
Te ⁽¹³²⁾	77h (A2) 66h (H3)	β ⁻ , γ, e ⁻ , X-ray	(A8)	C	3.6(E110)	0.28(N115) abs. Al, F. ~0.3(B3) abs. Al e ⁻ (N115)	0.22(N115) abs. Pb X-ray (A2) abs.	fiss., desc. ~5m Sb ⁽¹³²⁾ (A2); prec. 2.4h I ⁽¹³²⁾ (A8, A2, H3, H4, N115)	.....
Te ¹³³	60m (A2, W9)	β ⁻	(A2)	A	.....	.....	.....	fiss., desc. <10m Sb ¹³³ (A2); prec. 22h I ¹³³ (A2, H4, W9)	.....
Te ⁽¹³⁴⁾	43m (A2)	β ⁻	(A2)	C	.....	.....	.....	fiss., desc. <10m Sb ⁽¹³⁴⁾ (A2); prec. 54m I ⁽¹³⁴⁾ (A2, H4)	.....
Te ¹³⁵	<2m (D4, G123, K108)	β ⁻	A	.....	.....	.....	hyp. prec. 6.7h I ¹³⁵ (S21, D4, G123, K108, W9)	(W7)
Te	~1m (H14)	β ⁻	(H14)	D	.....	.....	.....	fiss. (H14)	.....

53	I^{127}	stable																		
	I^{128}	very long (L112)	β^-		A															
	I^{129}	8.0d (L12, G142) 7.9d (A2)	β^-, γ, e^-	(A2)	A	2.8(t) (E111)	0.595(D1, D6) spect. 0.60(M113)abs. Al, F.	0.367(D6) spect., spect. conv.; 0.080 (D6) spect. conv., abs. Pt, Hg, coinc. 0.36(S144, M113) abs. Pb 0.4(L12) abs. Pb												
	I^{130}	2.4h (A2) 2.3h (H3)	β^-, γ	(A8)	C		1.0(~50%), 2.1 (~50%) (N115) abs. Al, F. 1.3(B3) abs. Al	0.6(~50%), 1.4 (~50%) (N115) abs. Pb 0.85(B3) abs. Pb												
	I^{131}	22h (A2, S21, K108, W9) 18.5h (H4)	β^-, γ	(A2)	A	~4.5(K108)	1.3(S144) abs. Al 1.1(P1) cl. ch.	0.55(S144) abs. Pb												
	I^{132}	54m (A2)	β^-, γ	(A2)	C	~5.7(K112)		> 1(G123) abs. Pb												
	I^{133}	6.7h (G123, K108) 6.6h (S21, D4, W9)	β^-, γ	(S21, D4)	A	5.6(G123, K108)	1.35(K108) abs. Al, F. 1.5(S144) abs. Al	1.6(K108) abs. Pb 1.3(S144) abs. Pb												
	I^{134}	1.8m (S25)	β^-	(S25)	C															
	I^{135}	30s (S25)	β^-	(S25)	B															
	I^{136}	22.0s (H111) 23s (L105, R101)	β^-, γ, e^-	(B11, L105)	C															
54	Xe^{128}	stable																		
	Xe^{129}	stable		(T101)	A															
	Xe^{130}	stable		(T101)	A															
	Xe^{131}	5.3d (E112) 5.4d (C2)	β^-, γ, e^- , X-ray	(L1)	A		0.35(E112) abs. Al, F. 0.33(E103) abs. Al 0.32(B3, S16) 0.26(W9) e^- : 0.049(H18) spect.	0.085(E112) abs. Cu, Pb 0.083(B3) abs. X-ray: 0.031(F'12) abs. Al; 0.04 (E103) abs. Al												
	Xe^{134}	stable		(T101)	A															

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NUCLEI FORMED IN FISSION

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Z	Nucleus A	Half-life	Decay	Discovery in fission	Class	Fission yield, %	Energy of radiations in Mev		Produced by and mass assignment	Other references
							Particles	Gamma radiations		
	Xe ^{136*}	13m (N116) 15.6m (R1, S16) 10m (W9)	I.T., γ , e^-	(G4)	A	.....	e^- : 0.50(N116) abs. Al; 0.6(S16) abs. Al	0.54(N116) abs. Al, conv. \sim 0.5(W9) abs. Pb 0.6(S16) abs. Al, conv.	Xe(n, γ) (R1, S16) fiss., desc. 6.7h I ¹³⁶ (\sim 10%) (G4, S16); prec. 9.2h Xe ¹³⁶ (G4, W9)	.....
	Xe ¹³⁸	9.2h (H105) 9.4h (S21, W7) 9.5h (D4)	β^- , γ	(S21, D4)	A	5.9(H109)	0.94(H105) abs. Al, F. 0.96(W9) abs. Al 0.92(B3) abs. Al 0.90-1.0(S144) abs. Al	0.25(W9) abs. Pb 0.26(S144) abs. Pb	Xe(d, p) (C2) Ba(n, α) (W7, S16, W9) fiss., desc. 6.7h I ¹³⁸ (\sim 90%) (S21, D4, S16, W9); 13m Xe ^{138*} I.T. (W9); prec. >2.5 $\times 10^4$ y Cs ¹³⁸ (E107)	.....
	Xe ¹³⁸	stable	.....	(T101)	A	.....	.....	.....	fiss. (T101) mass spect.	.....
	Xe ¹³⁷	3.4m (R1, S16) 3.8m (S18)	β^-	(S18)	B	.....	\sim1(S18, B3) abs. Al	.....	Xe(n, γ) (R1, S16) fiss., desc. 30s I ¹³⁷ (S18); prec. 33y Cs ¹³⁷ (G123, T102)	(B2)
	Xe ⁽¹³⁷⁾	instantaneous (L105)	n (L105)	(L105)	C	0.17% of fiss. neutrons (H111)	n : 0.67(B125) cl. ch. 0.56(H111) abs. paraffin	.....	fiss., desc. 22.0s I ⁽¹³⁷⁾ (L105)	.....
	Xe ¹³⁶	17m (G2) 16-18m (S14)	β^-	(H4)	B	.....	.....	.....	fiss., prec. 32m Cs ¹³⁶ (H4, G1, G2, S14)	(S16, H5)
	Xe ¹³⁶	41s (D109) \sim 30s (H22)	β^-	(H4, H22)	A	.....	.....	.....	fiss., prec. 7m Cs ¹³⁶ (H22, H4, H5) prec. 85m Ba ¹³⁶ (D109, H5, H22)	.....
	Xe ¹³⁶	16s (D109) 9.8s (O102)	β^-	(H5)	A	.....	.....	.....	fiss., prec. 12.8d Ba ¹³⁶ (H5, B118, O102, D103, D109)	(D108)
	Xe ¹⁴¹	3s (D109) 1.7s (K119, O102)	β^-	(B118)	A	.....	.....	.....	fiss., prec. 3.5h La ¹⁴¹ (B118); prec. 28d Ce ¹⁴¹ (O102, D109)	.....
	Xe ¹⁴³	1s (D109)	β^-	(B118)	A	.....	.....	.....	fiss., prec. 33h Ce ¹⁴³ (B118, D109); prec. 13.8d Pr ¹⁴³ (O102)	.....
	Xe ¹⁴⁴	short (D103)	β^-	(D103)	A	.....	.....	.....	fiss., prec. 275d Ce ¹⁴⁴ (D103) (O102)	.....
	Xe ⁽¹⁴⁰⁾	0.8s (D109)	β^-	(A103)	C	.....	.....	.....	fiss., prec. 1.8h Ce ⁽¹⁴⁰⁾ (D109)	.....
	Xe	68m (C2)	I. T. (?) (S16)	.....	(C)	.....	.....	.....	Xe(d, p) (?) (C2) Xe(n, n) (?) (S16)	.....
55	Cs ¹³³	stable	.....	.....	.....	.....	.....	.....	.....	.....

Cs^{132}	$>2.5 \times 10^4y$ (E107) β^- $>2 \times 10^4y$ (G123, F106)		.....	A	.....	.....	.....	hyp. desc. 6.7h I^{132} (G123, F106, E107)	.....
Cs^{134}	13d (F111, G137) β^-, γ	(F107)		C	0.008(F111) 0.011(G137)	~ 0.28 (F111) abs. Al coinc.	1.2(F111) abs. Pb coinc.	fiss. (F111, G137)	.....
Cs^{137}	33y (G140) β^-, γ	(S27)		A	.....	0.5(50%), 0.8(50%) (G136) abs. Al, F. ~ 0.4 (50%), 0.8(50%) (M113) abs. Al, F.	0.75(G136) abs. Pb 0.7(M113) abs. Pb	desc. Xe(n, γ) (T102) (G104) 137 (F106) not 135 fiss., desc. 3.4m Xe^{137} (T102, G123) 137 (L110) mass spect.	
Cs^{138}	32m (G2, G139) β^-, γ 33m (A6, H4, E114)	(H4, H22)		B	.....	2.6(G2) abs. Al	1.2(G139) abs. Pb	Ba(n, p) (S16) (H5, P109) fiss., desc. 17m Xe^{138} (H4, G1, G2, S14)	
Cs^{139}	7m (H5) β^- 10m (H22)	(H4, H22)		A	.....	.....	.....	fiss., desc., 41s Xe^{139} (H6, A6) (H4, H22, H5); prec. 85m Ba^{139} (H4, H22)	
Cs^{140}	40s (H5) β^-	(H5)		C	.....	.....	.....	fiss. (H5)	.....
Cs^{140}	short (H5, B118, O102, D103, D109) β^-	(H5)		A	.....	.....	.....	fiss., desc. 16s Xe^{140} prec. 12.8d Ba^{140} (H5, H12, D118, O102, D109, D103)	
Cs^{141}	short (B118, O102, D109) β^-	(B118)		A	.....	.....	.....	fiss., desc. 3s Xe^{141} prec. 3.7h La^{141} (B118); prec. 28d Ce^{141} (O102, D109)	
Cs^{142}	$\sim 1-2m$ (H12) β^-	(H12)		D	.....	.....	.....	fiss., prec. 6m Ba^{142} (H12).....	
Cs^{143}	short (B118, O102, D109) β^-	(B118)		A	.....	.....	.....	fiss., desc. 1s Xe^{143} (A103) prec. 33h Ce^{143} (B118, D109); prec. 13.8d Pr^{143} (O102)	
Cs^{144}	short (D103) β^-	(D103)		A	.....	.....	.....	fiss., desc. short Xe^{144} prec. 275d Ce^{144} (D103)	
Cs^{146}	short (D106) β^-	(A103)		C	.....	.....	.....	fiss., desc. 0.8s Xe^{146} prec. 1.8h Ce^{146} (D109)	
56 Ba^{130}	stable								
Ba^{132}	stable				.....	low (G147)			
Ba^{134}	stable								
Ba^{136}	stable								
Ba^{138}	85m (D107) β^-, γ 86m (P6, H6, H2) 87m (H22)	(H2)		A	6.3(K113)	2.2(B3, K113) abs. Al	0.6(K2) abs. Pb, Cu	Ba(d, p) (P6, K2) (H5, H6) Ba(n, γ) (A3, P7) La(n, p) (P6, P10) Ce(n, α) (W3) fiss., desc. 7m Cs^{138} (H4, H22)	

Nucleus Z A	Half-life	Decay	Discovery in fission	Class	Fission yield, %	Energy of radiations in MeV		Produced by and mass assignment	Other references
						Particles	Gamma radiations		
Ba ¹⁴⁰	12.8d (E116) ~12.5d (H2)	β^- , γ , e^-	(H2)	A	6.1(F108) . 5.8(E110)	1.05(W105) spect. ~0.4(25%), 1.0(75%) (E106) abs. Al 1.0(C109) abs. Al; (M113) abs. Al, F. e^- : 0.50 (W105) spect.	0.542(W105) spect. 0.529(N101) spect. 0.5(E106) abs. Pb	fiss., desc. short Cs ¹⁴⁰ (H5, H12, B118, O102, D103, D109) prec. 40h La ¹⁴⁰ (H2, C107, C109, M117)	(P110, L106 W103)
Ba ¹⁴²	18m (H12, G132)	β^- , γ	(H12)	B	4.6(G132)	.....	γ (G132)	fiss., desc. short Cs ¹⁴² (B118, O102, D109) prec. 3.7h La ¹⁴² (H12)	.....
Ba ¹⁴³	6m (H12)	β^-	(H12)	C	.....	.....	.....	fiss., desc. 1-2m Cs ¹⁴³ prec. 74m La ¹⁴³ (H12)	.....
Ba ¹⁴⁴	<0.5m (H12)	β^-	(H2)	A	.....	.....	.....	fiss., desc. short Cs ¹⁴⁴ (B118, D109, O102); prec. 19m La ¹⁴⁴ (H2, H12)	.....
Ba ¹⁴⁴	short (D103)	β^-	(D103)	A	.....	.....	.....	fiss. desc, short Cs ¹⁴⁴ prec. 275d Ce ¹⁴⁴ (D103)	.....
Ba ¹⁴⁶	short (D109)	β^-	(A103)	C	.....	.....	.....	fiss., desc. short Cs ¹⁴⁶ prec. 1.8h Ce ¹⁴⁶ (D109)	.....
La ¹³⁹	stable								
La ¹⁴⁰	40.0h (M9, W4) 40.2h (B106)	β^- , γ	(H2)	A	.....	0.90(20%), 1.4(70%), 2.12(10%)(O2) spect. 1.45, ~2.2 (low in- tensity) (W106, W103) spect. 1.41(W4) abs. Al, spect. 1.5(C107, C109, G131) abs. Al 1.75(M113, B106) abs. Al, F.	0.335(1%), 0.49 (7%), 0.83(14%), 1.63(74%), 2.3 (4%) (M115) spect. 0.335(2%), 0.49 (5%), 0.87(10%), 1.65(77%), 2.3 (6%) (W106) spect. 0.333, 0.505, 0.832, 1.61, 2.52, (O2) spect. 1.69(>97%), 2.5 (<3%) (D102) abs. Al, coinc. 2.0(W4, M9) ab- Pb; (M1, M2) spect. 2.1(C107, C109) abs. Pb	La(n, γ) (M4, P10, M9, G5, W4) La(d, p) (P6, P10, M9, W4) Ce(n, p) (W4) fiss., desc. 12.8d Ba ¹⁴⁰ (H2, G2, C107, C109, M117) 140(L110) mass spect.	(P111, L106, H12, W107, S140)
La ¹⁴¹	3.7h (K105) 3.5h (H12)	β^- , γ (?)	(H12, B107)	B	.....	2.8(K105) abs. Al, F.	γ (?) (K105)	fiss., desc. 18m Ba ¹⁴¹ (H12); prec. 28d Ce ¹⁴¹ (B107, B109)	.....

$\text{La}^{(143)}$	74m (H12) 77m (K105)	β^-, γ	(H12)	C	.....	.....	γ (K105)	fiss., desc. 6m $\text{Ba}^{(143)}$ (H12)	.....
La^{144}	19m (G103) 20m (H12) ~15m (H14)	β^-	(H12, G103)	A	> 4.3(S152)	.....	.....	fiss., desc. <0.5m Ba^{144} (H12, H14, G103, B118, A103); prec. 33h Ce^{144} (G103)	.....
La^{144}	short (D103)	β^-	(D103)	A	.....	.....	.....	fiss., desc. short Ba^{144} (O102) prec. 275d Ce^{144} (D103)	.....
$\text{La}^{(146)}$	short (D109)	β^-	(A103)	C	.....	.....	.....	fiss., desc. short $\text{Ba}^{(146)}$ prec. 1.8h $\text{Ce}^{(146)}$ (D109)	.....
58 Ce^{140}	stable								
Ce^{141}	28d (B122) 30d (P9)	β^-, γ	(H8)	A	5.7(S102)	0.55(B114, M113) abs. Al, F. 0.65(P9) abs. Al	0.21(B114) abs. Pb 0.22(M113) abs. Pb 0.2(P9) abs. Pb	$\text{Ce}(d,p)$ (P9, B122) (G131, $\text{Ce}(n,\gamma)$ (P9, B114) P114) $\text{Ce}(n,2n)$ (P9, B114) $\text{Ba}(\alpha,n)$ (P9) $\text{Pr}(n,p)$ (P9) fiss., desc. 3.7h La^{141} (B107, B109) 141(L110) mass spect.	
Ce^{142}	stable								
Ce^{143}	33h (B114) 32h (E113) 36h (P9)	β^-, γ	(S139)	A	5.4(K114)	1.35(B114) abs. Al, F.; (E113) abs. Al	0.5(B114) abs. Pb	$\text{Ce}(d,p)$ (P9) (B122, (B107, B114) P112) $\text{Ce}(n,\gamma)$ (P9, B114) fiss., desc. 19m La^{143} (G103); prec. 13.8d Pr^{143} (P9, B122, B114) 143(B114) not prod. by $\text{Ce}(n,2n)$ 143(L110) mass spect.	
Ce^{144}	275d (B124) 300d (H14, B3)	β^-	(H8)	A	5.3(R102)	0.348(N105) spect. ~0.3(W112) abs. Al, F.; (N107) abs. Al	no γ (S111)	fiss., desc. short La^{144} (P115) (D103, A101); prec. 17.5m Pr^{144} (N107, B122, H14, S111, L110, G130) 144(L110) mass spect.	
$\text{Ce}^{(146)}$	1.8h (B108)	β^-	(B108, B104)	C	.....	.....	.....	fiss., desc. short $\text{La}^{(146)}$ (B104) (B109, D109); prec. 4.5h $\text{Pr}^{(146)}$ (B108, K106)	
$\text{Ce}^{(148)}$	14.6m (S103) ~15m (G7)	β^-	(G7)	C	.....	.....	.....	fiss., prec. 24.6m $\text{Pr}^{(148)}$ (G7, H14, S103)	

Z	Nucleus A	Half-life	Decay	Discovery in fission	Class	Fission yield, %	Energy of radiations in Mev Particles	Gamma radiations	Produced by and mass assignment	Other references
59	Pr ¹⁴¹	stable								
	Pr ¹⁴²	13.8d (M104) 14d (B102) 14.2d (O101) 13.5d (P9, C106)	β^-	(B101, B102)	A	.....	1.0(M104, B114) abs. Al, F. 0.95(P9)	no γ (B114, M104)	fiss., desc. 33h Ce ¹⁴² (P9, B122, B114) 143 (L110) mass spect.	(H14, B103, P113)
	Pr ¹⁴⁴	17.5m (N107, S111) 18m (G130) 17m (H14)	β^-, γ, e^-	(N107, H14, G130)	A	.....	3.07(N105) spect. 3.0(W112) abs. Al, F.; (G130) abs. Al 3.1(B3, H14) abs. Al 3.2(M113) abs. Al, F. 2.8(N107, B122) e^- : 0.091, 0.128, 0.103(?) (N105) spect.	0.135, 0.145(?) (N105) spect. conv. 0.22, 1.25 (low inten- sity) (S111) abs. Pb	fiss., desc. 275d Ce ¹⁴⁴ (N107, B122, H14, G130, S111, L110) 144 (L110) mass spect.	.....
	Pr ⁽¹⁴⁶⁾	4.5h (K106) 4.7h (B108)	β^-	(B101, B108)	C	.....	3.1(K106) abs. Al, F.	no γ (K106)	fiss., desc. 1.8h Ce ⁽¹⁴⁶⁾ (B108, K106)	.....
	Pr ⁽¹⁴⁶⁾	24.6m (S101) 25m (G7)	β^-, γ	(G7)	C	.....	\sim3(S101) abs. Al	1.4(S101) abs. Pb	fiss., desc. 14.6m Ce ⁽¹⁴⁶⁾ (G7, S103)	.....
60	Nd ¹⁴²	stable								
	Nd ¹⁴⁴	stable								
	Nd ¹⁴⁶	stable								
	Nd ¹⁴⁸	stable								
	Nd ¹⁵⁰	11.0d (M119)	β^-, γ, e^- , X-ray	(D101, M103)	A	2.6(M119)	\sim 0.4(40%), 0.90 (60%) (M119) abs. Al, F. e^- : 0.03(M119) abs. Al	0.58(M119)abs. Pb X-ray: \sim 0.040 (M119) abs. Al	Nd(n, γ) (M122, M103) fiss., prec. 3.7y 61 ¹⁵⁰ (M120, M108) 147(M119, M103) fiss. yld. 147 (L110) mass spect.	(S110)
	Nd ¹⁵²	stable								
	Nd ⁽¹⁵²⁾	1.7h (M122) 2.0h (P10)	β^-, γ or X-ray	.....	(C)	.....	1.5(M122) abs. Al, F.	γ or X-ray (M122)	Nd(d, p) (P10) Nd(n, γ) (P10, M122) Nd($n, 2n$) (P10)	(M102)
	Nd ¹⁵⁰	stable								
	Nd ⁽¹⁵¹⁾	short (M122)	β^-	.....	(D)	.....	.....	.....	Nd(n, γ) prec. 12m 61 ⁽¹⁵¹⁾ (M122)	.....
61	61 ¹⁴⁷	3.7y (S113) 4y (B112) 2.2y (S113)	β^-	(B110, G130, M103)	A	.....	0.20(M120, S112)abs. Al, F.; (G130, B110, B112) abs. Al	no γ (M120, S112)	Nd(n, γ) desc. 11d Nd ¹⁴⁷ (M120) fiss., desc. 11d Nd ¹⁴⁷ (M120, M108) 147(L110, H102) mass spect.	.....

61 ¹⁴⁰	47h (M121)	β^- , γ , X-ray(?)	(M105)	B	1.4(M121)	1.1(M121) abs. Al, F.	0.25 (low intensity) (M121) abs. Pb X-ray(?) (M121)	Nd(n, γ) desc. Nd ⁽¹⁴⁰⁾ (M122, M106, M102) fiss., desc. 1.7h Nd ⁽¹⁴⁰⁾ (?) (M122) 149(M102, M105) fiss. yld.	(M108)
61 ⁽¹⁴¹⁾	12m (M122)	β^-	.....	(D)	.....	.....	.....	Nd(n, γ) desc. short Nd ⁽¹⁴¹⁾ (M122)	.....
61 ¹⁴²	<5m (W118)	β^-	.....	A	.....	.....	.....	hyp. prec. 47h Sm ¹⁴² (W118)	.....
61 ¹⁴³	<5m (W118)	β^-	.....	B	.....	.....	.....	hyp. prec. ~10h Sm ¹⁴³ (W118)	.....
62	Sm ¹⁴⁴	stable	.....	.....	.....	.....	.....	.....	.....
	Sm ¹⁴⁶	stable	.....	.....	.....	.....	.....	.....	.....
	Sm ⁽¹⁴⁷⁾	long (L110)	.....	(L109)	.....	.....	.....	fiss. (L110) mass spect.	.....
	Sm ¹⁴⁸	stable	.....	.....	.....	.....	.....	.....	.....
	Sm ¹⁴⁹	47h (W116, L4, K5, M102)	β^- , γ I. T.(?)(W8)	(W115)	A	0.15(t) (E111)	0.73(W116) abs. Al, F. 0.7(M102) abs. Al, F. 0.11, ~0.6(M114) spect. X-ray(?) (W8)	Sm(d, p) (L4, K5) Sm(n, γ) (H19, H20, P10, L4, W8, M102) Sm($n, 2n$) (P10, K5) Sm(γ, n) (L4); Nd(α, n) (K5) fiss., desc. <5m 61 ¹⁴⁹ (W118) 153 (W116) fiss. yld. 153(H113) mass spect.	.....
	Sm ¹⁵⁰	stable	.....	.....	.....	.....	.....	.....	.....
	Sm ¹⁵²	25m (W118) 21m (P10)	β^- , γ	(W118)	B	0.031(W118)	1.9(W118) abs. Al, F. 1.8(K5) abs. Al	~0.3(W118) abs. Pb Sm(d, p) (L4, K5) Sm(n, γ) (A3, M4, H19, P10, L4) Sm($n, 2n$) (?) (P10, K5) Sm(γ, n) (L4); Nd(α, n) (K5) fiss., prec. 2y Eu ¹⁵² (?) (W118) 155 (W118) fiss. yld.-ener.	.....
	Sm ¹⁵⁴	~10h (W116)	β^-	(W113)	B	~0.016(W119)	~0.8(W119) abs. Al	fiss., hyp. prec. 15.4d Eu ¹⁵⁴ (W113, W116) hyp. desc. <5m 61 ¹⁵⁴ (W118) 156 (W119) fiss. yld.	.....
63	Eu ¹⁵¹	stable	.....	.....	.....	.....	.....	.....	.....
	Eu ¹⁵³	stable	.....	.....	.....	.....	.....	.....	.....
	Eu ¹⁵⁴	2y (W117)	β^- , γ	(W110)	A	~0.03 (W113)	~0.23(W110) abs. Al 0.0844(W110) criti- cal abs. in P ^u , Hg, Tl, Pb	Sm(d, n) (?) (K6) fiss. (W110) 155(W113) fiss. yld. 155 (L110) mass spect.	.....
	Eu ¹⁵⁶	15.4d (W110)	β^- , γ	(W108)	B	0.013(W113)	~0.5 (60%), 2.4 (40%)(W110) abs. Al, F.	2.0(W110) abs. Pb fiss., desc. ~10h Sm ¹⁵⁶ (W113, W116) 156(W113) fiss. yld.-ener.	.....

Z	Nucleus	Half-life	Decay	Discovery in fission	Class	Fission yield, %	Energy of radiations in Mev	Gamma radiations	Produced by and mass assignment	Other references	
	Eu^{152}	15.4h (W113)	β^- , γ	(W111)	B	0.0074 (W113)	$\sim 1.0(75\%)$, $\sim 1.7(25\%)$ (W113) abs. Al, F.	0.2, 0.6(W113) abs. Pb	fiss. (W113) 157(W113) fiss. y/d.-ener.		
64	Gd^{148}	60m (W113)	β^-	(W111)	C	0.002(W113)	~ 2.6 (W113) abs. Al, F.		fiss. (W113)		
	Gd^{146}	stable									
	Gd^{144}	stable									
	Gd^{142}	stable									
	Gd^{140}	stable									
	Unidentified fission product nuclei with daughters emitting neutrons instantaneously										
(1)	$4.51s$ (H111)	β^- (π)	(B12)		...	0.21(H111)	π : 0.430(H111) abs. paraffin		fiss. (B12, H111)		
	$4.5s$ (L114)										
	$3s$ (B12)										
(2)	$1.52s$ (H111)	β^- (π)	(L114)		...	0.24(H111)	π : 0.620(H111) abs. paraffin		fiss. (L114, H111)		
	$1.8s$ (L114)										
(3)	$0.43s$ (H111)	β^- (π)	(L114)		...	0.084(H111)	π : 0.420(H111) abs. paraffin		fiss. (L114, H111)	(B12)	
	$0.4s$ (L114)										
(4)	$0.05s$ (H112)	β^- (π)	(H112)		...	~ 0.029 (H112)			fiss. (H112)		

(K118) Kohman, T. P., and A. Turkevich, CN-1044, pp. 4-8, Nov. 1943.

(K119) Katcoff, S., and co-workers, LA-548, private communication from N. Sugarman.

(L1) Langsdorf, A., Jr., *Phys. Rev.*, **56**, 205 (1939).

(L2) Langsdorf, A., Jr., and E. Segré, *ibid.*, **57**, 105 (1940).

(L3) Lark-Horovitz, K., J. R. Risser and R. N. Smith, *ibid.*, **58**, 878 (1939).

(L4) Law, H. B., M. L. Pool, J. D. Kurbatov and L. L. Quill, *ibid.*, **59**, 936 (1941).

(L5) Lawson, J. I., *ibid.*, **56**, 131 (1939).

(L6) Lawson, J. I., and J. M. Cork, *ibid.*, **57**, 356 (1940); (L7) *ibid.*, 982 (1940).

(L8) Libby, W. F., and D. D. Lee, *ibid.*, **58**, 245 (1939).

(L9) Lieber, C., *Naturwissenschaften*, **27**, 421 (1939).

(L10) Livingood, J. J., *Phys. Rev.*, **50**, 425 (1936).

(L11) Livingood, J. J., and G. T. Seaborg, *ibid.*, **54**, 51 (1938); (L12) *ibid.*, 775 (1938); (L13) *ibid.*, **58**, 667 (1939).

(L101) Leader, G. R., (H)-CN-3454, Jan. 1945; PPR Vol. 9B, 7.26.2 (1946).

(L102) Leader, G. R., and W. H. Sullivan, (H)-CN-3465, Jan. 1946; PPR Vol. 9B, 7.28.2 (1946).

(L103) Leslie, W. B., private communication, Mar. 1946.

(L104) Levinger, J. S., CC-2775, Mar. 1945; PPR Vol. 9B, 7.15.11 (1946).

(L105) Levinger, J. S., E. P. Meiners, M. B. Sampson, A. H. Snell and R. Wilkinson, CP-1967, July 1944; PPR Vol. 9B, 7.4 (1946).

(L106) Lévy, H. A., and L. G. Stang, Jr., CC-1204, p. 9, Jan. 1944.

(L107) Levy, P. W., CP-1811, p. 15, June 1944.

(L108) Lewis, L. O., and R. J. Hayden, CP-2928, Apr. 1945; (L109) CP-3221, pp. 3-4, Sept. 1945; (L110) CP-3295, Oct. 1945.

(L111) Lincoln, D. C., and W. H. Sullivan, (H)-CN-3449, Jan. 1946; PPR Vol. 9B, 7.17.2 (1946).

(L112) Leader, G. R., and W. H. Sullivan, (H)-CN-3466, Jan. 1946; PPR Vol. 9B, 7.36 (1946).

(L113) Levy, P. W., MonP-104, p. 13, Apr. 1946.

(L114) Levinger, J. S., M. B. Sampson and A. H. Snell, CP-1014, Oct. 1943; CP-1954, July 1944.

(L115) Leader, G. R., and W. H. Sullivan, (H)-CN-3463, Jan. 1946; PPR Vol. 9B, 7.22.3 (1946).

(M1) Mandeville, C. E., *Phys. Rev.*, **63**, 387 (1943); (M2) *ibid.*, **64**, 147 (1943).

(M3) Mandeville, C. E., and H. W. Fulbright, *ibid.*, **64**, 265 (1943).

(M4) Marsh, J. K., and S. Sugden, *Nature*, **136**, 102 (1935).

(M5) Maurer, W., and W. Ramm, *Naturwissenschaften*, **29**, 368 (1941); (M6) *Z. Physik*, **119**, 334 (1942).

(M7) Meitner, L., *Archiv. Mat. Astron. Fysik*, **27A**, No. 17, 18 (1940).

(M8) Mitchell, A. C. G., *Phys. Rev.*, **51**, 905 (1937).

(M9) Mounce, W. D., M. L. Pool and J. D. Kurbatov, *ibid.*, **61**, 380 (1942).

(M10) Mousse, A., and L. Goldstein, *ibid.*, **60**, 534 (1941).

(M101) Marinsky, J. A., reported in PPR Vol. 9B, 7.9.2 (1946).

(M102) Marinsky, J. A., and L. E. Glendenin, CN-2809, p. 9, Apr. 1945; (M103) CC-2829, June 1945; (M104) CC-2829, pp. 7-8, 12, June 1945; (M105) CN-2839, p. 10, June 1945; (M106) MonN-2, p. 7, July 1945.

(M107) Motta, E. E., and G. E. Boyd, MonC-99, Aug. 1946.

(M108) Marinsky, J. A., and L. E. Glendenin, MonN-15, pp. 12-13, Sept. 1945.

(M109) Metcalf, R. P., CN-1911, p. 3, July 1944; (M111) CC-2310, pp. 131-139, Jan. 1945; PPR Vol. 9B, 7.24.4 (1946); (M112) CC-2310, pp. 140-144, Jan. 1945; PPR Vol. 9B, 7.25 (1946).

(M113) Metcalf, R. P., W. Rubinson, J. A. Sellar, E. P. Steinberg and L. Winsberg, MUC-NS-#230, Sept. 1944.

(M114) Miller, L. C., and L. F. Curtis, CP-3102, June 1945; (M115) CP-3102, June 1945; PPR Vol. 9B, 7.45.6 (1946).

(M116) Mitchell, A. C. G., and L. J. Brown, CC-826, p. 2, July 1942.

(M117) Mitchell, A. C. G., L. M. Langer and L. J. Brown, CP-318, Oct. 1942.

(M118) Metcalf, R. P., CC-2310, pp. 126-130, Jan. 1945; PPR Vol. 9B, 7.24.2 (1946).

(M119) Marinsky, J. A., and L. E. Glendenin, PPR Vol. 9B, 7.54.3 (1946); (M120) PPR Vol. 9B, 7.54.4 (1946); (M121) PPR Vol. 9B, 7.54.5 (1946); (M122) MonN-6, p. 9, Aug. 1945; PPR Vol. 9B, 7.54.6 (1946).

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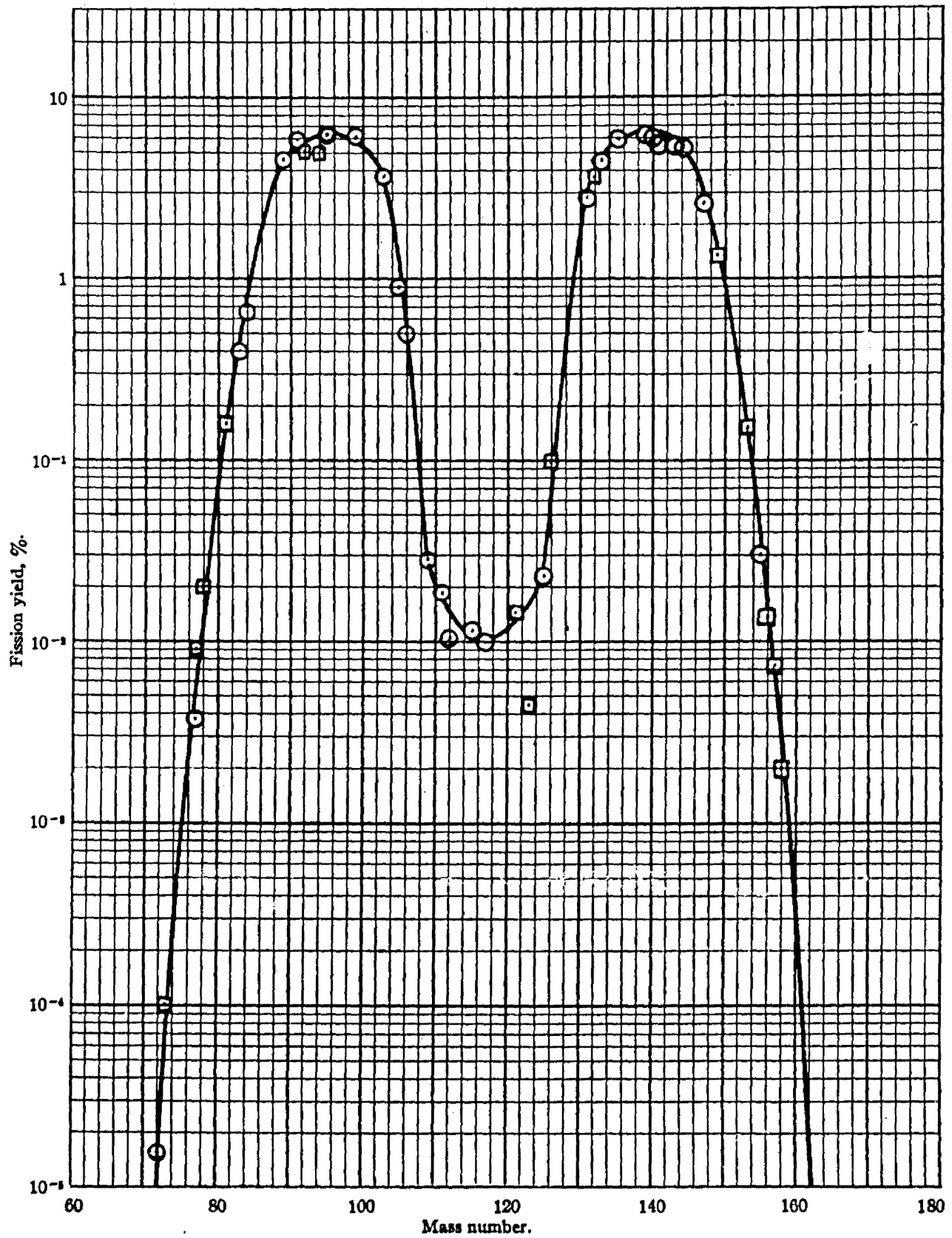


Fig. 1.—Yields of U²³⁵ fission product chains as a function of mass: ○, certain mass assignment; □, uncertain mass assignment (mass 153 is now certain (H113)).

Mass No.	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	Fission yield, %			
(93)	•	•	•	•	•	•	2.0s	→short	→7m	→10h	→	→stable	•	•	•	•	•	•	•	•	•	•	~5		
(94)	•	•	•	•	•	•	1.4s	→short	→~2m	→20m	→stable	•	•	•	•	•	•	•	•	•	•	•	•	~6.4	
95	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	~6.4
96	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
97	•	•	•	•	•	•	short	→short	→short	→short	→17.0h	→75m	→stable	•	•	•	•	•	•	•	•	•	•	•	•
98	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
99	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
100	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
101	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
(102)	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
103	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
104	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
105	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
106	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
107	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
108	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
109	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
110	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
111	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
112	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
113	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
114	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
115	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
116	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
117	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
...	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
	Zn	Ga	Ge	As	Se	Br	Kr	Rb	Sr	Y	Zr	Nb	Mo	43	Ru	Rh	Pd	Ag	Cd	In	Sn				

* Yield of ^{34}Br formed directly in fission; not representative of total chain yield. ^b Yield of $^{19.5\text{d}}\text{Rb}$ formed directly in fission; not representative of total chain yield. ^c Delayed neutron yield based on fission neutrons rather than on fissions. ^d Instantaneous, *via* delayed neutrons.

Mass No.	Element	60 Nd	61 Sm	62 Sm	63 Eu	64 Gd	Fission yield, %
147	Pr	11.0d → 3.7y → stable	•	•	•	•	2.6
148	Ce	stable	•	•	•	•	
149	La	(1.7h) → 47h → stable	•	•	•	•	1.4
150	Ba	stable	•	•	•	•	
(151)	La	(short) → 12m → long → stable	•	•	•	•	
152	Ba	stable	•	•	•	•	
153	La	•	•	•	•	•	0.15
154	Ce	•	•	•	•	•	
155	Pr	•	•	•	•	•	
156	Ce	•	•	•	•	•	~0.03
157	La	•	•	•	•	•	0.013
158	Ba	•	•	•	•	•	0.0074
(159)	La	•	•	•	•	•	0.002

• Yield of ¹³⁴Cs formed directly in fission; not representative of total chain yield. • Delayed neutron yield based on fission neutrons rather than on fissions. • Instantaneous, via delayed neutrons.

(N1) Nier, A. O., *Phys. Rev.*, **60**, 1041 (1936).
 (N2) Nishina, Y., K. Kimura, T. Yasaki and M. Ikawa, *Z. Physik*, **119**, 195 (1942).
 (N3) Nishina, Y., T. Yasaki, H. Ezoe, K. Kimura and M. Ikawa, *Nature*, **146**, 24 (1940).
 (N4) Nishina, Y., T. Yasaki, K. Kimura and M. Ikawa, *Phys. Rev.*, **60**, 660 (1940); (N5) *ibid.*, **69**, 323 (1941); (N6) *ibid.*, 677 (1941).
 (N101) Nedzel, V. A., CC-2283, Oct. 1944.
 (N102) Nedzel, V. A., and E. C. Barker, CP-1728, May 1944; CP-1811, June 1944.
 (N103) Nedzel, V. A., CC-2283, Oct. 1944; PPR Vol. 9B, 7.15.4 (1946).
 (N104) Nedzel, V. A., L. J. Brown and E. P. Meiners, CC-2299, Oct. 1944.
 (N105) Nedzel, V. A., CC-2283, Oct. 1944; PPR Vol. 9B, 7.52.4 (1946); (N106) CC-2283, Oct. 1944; PPR Vol. 9B, 7.15.7 (1946).
 (N107) Newton, A. S., A. Kant and R. E. Hein, CC-418-C, pp. 7-11, Jan. 1943; PPR Vol. 9B, 7.52.2 (1946).
 (N108) Nottorf, R. W., CC-521, p. 2, March 1943. (N110) CC-725, p. 5, June 1943; PPR Vol. 9B, 7.11.1 (1946).
 (N111) Novey, T. B., CC-680, p. 22, May 1943; PPR Vol. 9B, 7.30.1 (1946).
 (N112) Novey, T. B., D. W. Engelkemeir and E. L. Brady, CC-920, pp. 4-8, Sept. 1943; (N113) CC-1331, Feb. 1944.
 (N115) Novey, T. B., W. H. Sullivan, C. D. Coryell, A. S. Newton, N. Slight and O. Johnson, CC-763, May 1943; PPR Vol. 9B, 7.29 (1946).
 (N116) Novey, T. B., PPR Vol. 9B, 7.37.4 (1946).
 (O1) Ollano, Z., *Nuovo cimento*, **18**, 11 (1941).
 (O2) Osborne, R. K., and W. C. Peacock, *Phys. Rev.*, **69**, 670 (1946).
 (O101) Overstreet, R., and L. Jacobson, CH-1460, Sect. A, Feb. 1944; (O102) CH-1460, p. 77, Feb. 1944; PPR Vol. 9B, 7.5.4 (1946).
 (P1) Perflov, N. A., *Compt. rend. acad. sci. U.R.S.S.*, **33**, 485 (1941).
 (P2) Polesitskii, A. E., and N. Nemerovskii, *ibid.*, **28**, 217 (1940).
 (P3) Polesitskii, A. E., and M. Orbelli, *ibid.*, **28**, 215 (1940).
 (P4) Pontecorvo, B., and A. Lazard, *Compt. rend.*, **208**, 999 (1938).
 (P5) Pool, M. L., *Phys. Rev.*, **53**, 116 (1938).
 (P6) Pool, M. L., and J. M. Cork, *ibid.*, **51**, 1010 (1937).
 (P7) Pool, M. L., J. M. Cork and R. L. Thornton, *ibid.*, **52**, 239 (1937).
 (P8) Pool, M. L., and J. E. Edwards, *ibid.*, **67**, 60 (1945); *Bull. A.P.S.*, **19**, No. 5, 7 (1944).
 (P9) Pool, M. L., and J. D. Kurbatov, *Bull. A.P.S.*, **18**, No. 2, 9 (1943); *Phys. Rev.*, **63**, 463 (1943).
 (P10) Pool, M. L., and L. L. Quill, *ibid.*, **53**, 437 (1938).
 (P101) Peacock, W. C., Ph.D. thesis, M.I.T. (Quoted by M. Deutsch in LAMS-142, Oct. 1944).
 (P102) PPR, Vol. 6B, 7.8.1; (P103) *ibid.*, 7.9.2; (P104) *ibid.*, 7.10; (P105) *ibid.*, 7.14.1; (P106) *ibid.*, 7.32; (P107) *ibid.*, 7.34; (P108) *ibid.*, 7.35; (P109) *ibid.*, 7.41; (P110) *ibid.*, 7.45.1; (P111) *ibid.*, 7.45.3; (P112) *ibid.*, 7.49.1; (P113) *ibid.*, 7.49.5; (P114) *ibid.*, 7.50.1; (P115) *ibid.*, 7.52.1, all 1946 compilations.
 (R1) Riezler, W., *Naturwissenschaften*, **31**, 326 (1943).
 (R2) Roberts, J., and J. W. Irvine, *Phys. Rev.*, **69**, 936 (1941).
 (R3) Roberts, A., J. R. Downing and M. Deutsch, *ibid.*, **60**, 544 (1941).
 (R4) Rotblat, J., *Nature*, **148**, 371 (1941).
 (R5) Roberts, R. B., L. R. Hafstad, R. C. Meyer and P. Wang, *Phys. Rev.*, **58**, 510, 664 (1939).
 (R101) Redman, C., and D. Saxon, CP-1965, July 1944.
 (R102) Rubinson, W., reported by J. H. Goldstein, PPR, Vol. 9B, 7.52.1 (1946).
 (R103) Rall, W., CP-3462, p. 3, Mar. 1940.
 (S1) Sagane, R., *Phys. Rev.*, **66**, 31 (1939); (S2) *ibid.*, **64**, 147 (1943).
 (S3) Sagane, R., S. Kojima and O. Miyamoto, *Proc. Phys. Math. Soc. Japan*, **21**, 728 (1939).
 (S4) Sagane, R., S. Kojima, G. Miyamoto and M. Ikawa, *Phys. Rev.*, **54**, 543 (1938); (S5) *ibid.*, 670 (1938); (S6) *Proc. Phys. Math. Soc. Japan*, **21**, 600 (1939); (S7) *ibid.*, **22**, 174 (1940); (S8) *Phys. Rev.*, **67**, 750 (1940); (S9) *ibid.*, 1180 (1940).
 (S10) Sagane, R., G. Miyamoto and M. Ikawa, *ibid.*, **69**, 904 (1941).

- (S11) Seaborg, G. T., J. J. Livingood and G. Friedlander, *ibid.*, **69**, 320 (1941).
- (S12) Seaborg, G. T., J. J. Livingood and J. W. Kennedy, *ibid.*, **67**, 363 (1940).
- (S13) Seaborg, G. T., and E. Segré, *ibid.*, **58**, 808 (1939).
- (S14) Seelmann-Eggebert, W., *Naturwissenschaften*, **28**, 451 (1940).
- (S15) Scheichenberger, H., *Ans. Akad. Wiss. Wien, Math. naturw. Klass.*, **75**, 108 (1938).
- (S16) Seelmann-Eggebert, W., *Naturwissenschaften*, **31**, 491 (1943); (S17) *ibid.*, 510 (1943).
- (S18) Seelmann-Eggebert, W., and H. J. Born, *ibid.*, **59** (1943).
- (S19) Seaborg, G. T., *Rev. Mod. Phys.*, **16**, 1 (1944).
- (S20) Segré, E., and G. T. Seaborg, *Phys. Rev.*, **59**, 212 (1941).
- (S21) Segré, E., and C. S. Wu, *ibid.*, **67**, 552 (1940).
- (S22) Snell, A. H., *ibid.*, **62**, 1007 (1937).
- (S23) Stewart, D. W., J. L. Lawson and J. M. Cork, *ibid.*, **68**, 901 (1937); (S24) *ibid.*, **66**, 629 (1939).
- (S25) Strassmann, F., and O. Hahn, *Naturwissenschaften*, **28**, 817 (1940).
- (S26) Strassmann, F., and E. Walling, *Ber. Deutsch. Chem. Ges.*, **71**, 1 (1938).
- (S27) Seaborg, G. T., and M. Melhase, private communication to C. D. Coryell (1941).
- (S101) Schuman, R. P., CN-2799, p. 4, Mar. 1945; (S102) CN-2920, p. 5, Apr. 1945; (S103) CN-2929, p. 6, Apr. 1945; (S104) CN-3434, Feb. 1946; PPR Vol. 9B, 7.17.3 (1946).
- (S107) Sells, J. A., CC-2310, pp. 110-124, Jan. 1945; PPR Vol. 9B, 7.21 (1946); (S108) CC-2310, pp. 145-154, Jan. 1945; PPR Vol. 9B, 7.20.1 (1946); (S109) CC-2379, pp. 3-4, Nov. 1944; (S110) CN-2929, p. 5, Apr. 1945.
- (S111) Sells, J. A., and L. Winsberg, CC-2310, pp. 213-223, Jan. 1945; PPR Vol. 9B, 7.52.3 (1946); (S112) CC-2310, pp. 227-230, Jan. 1945; PPR Vol. 9B, 7.54.2 (1946); (S113) PPR Vol. 9B, 7.54.2 (1946).
- (S114) Selikson, B., and J. M. Siegel, PPR Vol. 9B, 7.13.2 (1946).
- (S115) Seren, L., CP-964, Sept. 1943.
- (S116) Seren, L., D. W. Engelkemeir and W. Sturm, CP-1903, July 1944.
- (S117) Seren, L., H. N. Friedlander, and S. H. Turkel, CP-2161, Sept. 1944, Addendum CP-1903, July 1944.
- (S118) Siegel, J. M., and L. E. Glendenin, CN-2586, p. 7, Feb. 1945; (S120) CN-2809, p. 9, Apr. 1945; (S121) CC-2835, June 1945; PPR Vol. 9B, 7.1 (1946).
- (S122) Sleight, N. R., CC-664, May 1943; (S123) CC-1776, July 1944.
- (S124) Sleight, N. R., and W. H. Sullivan, CC-725, p. 6, June 1943; PPR Vol. 9B, 7.27 (1946).
- (S125) Sleight, N. R., W. H. Sullivan and E. M. Gladrow, CC-1244, p. 7, Jan. 1944.
- (S126) Snell, A. H., and co-workers, CP-1011, p. 4, Oct. 1943.
- (S127) Stanley, C. W., and L. E. Glendenin, MonN-63, Apr. 1946; PPR Vol. 9B, 7.28.3 (1946).
- (S128) Steinberg, E. P., CC-1142, p. 5, Dec. 1943; (S129) CC-1331, p. 23, Feb. 1944; Steinberg, E. P., and L. E. Glendenin, PPR Vol. 9B, 7.23 (1946).
- (S130) Steinberg, E. P., CN-1911, July 1944; (S131) CC-2310, pp. 95-101, Jan. 1945; PPR Vol. 9B, 7.15.10 (1946); (S132) CC-2310, p. 106, Jan. 1945.
- (S133) Steinberg, E. P., and D. W. Engelkemeir, CN-2126, p. 3, Sept. 1944; (S134) CC-2310, pp. 31-46, Jan. 1945; PPR Vol. 9B, 7.2.1 (1946).
- (S135) Steinberg, E. P., L. Winsberg, J. A. Sells and D. W. Engelkemeir, CC-2485, p. 4, Dec. 1944.
- (S136) Sugarman, N., CN-2126, p. 5, Sept. 1944; (S137) CC-2310, p. 201, Jan. 1945; (S138) private communication.
- (S139) Sugarman, N., and N. E. Ballou, CC-196-E, p. 2, July 1942.
- (S140) Sugarman, N., CC-2310, pp. 201-205, Jan. 1945; PPR Vol. 9B, 7.45.8 (1946).
- (S141) Sugarman, N., and co-workers, CC-2310, p. 10, Jan. 1945.
- (S142) Sugarman, N., B. Finkle, E. J. Hoagland and S. Katcoff, CK-1806, June 1944.
- (S143) Sugarman, N., M. F. Ravelly, L. E. Glendenin and H. Finston, CC-793, p. 17, July 1943.
- (S144) Sullivan, W. H., O. Johnson and R. W. Nuttorf, CC-465-C, pp. 4-8, Feb. 1943.
- (S145) Sullivan, W. H., N. R. Sleight and E. M. Gladrow, CC-1493, Mar. 1944.
- (S147) Steinberg, E. P., and M. S. Freedman, PPR Vol. 9B, 7.57.20 (1946).
- (S149) Seaborg, G. T., and T. P. Kohman, CL-697, III C, 3.1, Dec. 1944.
- (S150) Smyth, H. D., *A General Account of the Development of Methods of Using Atomic Energy for Military Purposes*, U. S. Government Printing Office, 1945; Princeton University Press 1945; *Rev. Mod. Phys.*, Oct. 1945.
- (S151) Steinberg, E. P., and D. W. Engelkemeir, PPR Vol. 9B, 7.2.1 (1946).
- (S152) Schuman, R. P., PPR Vol. 9B, 7.50.3 (1946).
- (S153) Steinberg, E. P., PPR Vol. 9B, 7.16.2 (1946).
- (S154) Snell, A. H., A. V. Nedzel and H. W. Ibsen, C-81, May 1942.
- (T1) Tape, G. F., *Phys. Rev.*, **66**, 965 (1939).
- (T2) Tape, G. F., and J. M. Cork, *ibid.*, **63**, 676 (1938).
- (T3) Thomson, J. J., *Phil. Mag.*, (6) **10**, 584 (1905).
- (T4) Turner, L. A., *Rev. Mod. Phys.*, **13**, 1 (1940).
- (T101) Thode, H. G., and R. L. Graham, MX-129, Apr. 1945.
- (T102) Turkevich, A., E. P. Steinberg, B. Finkle and N. Sugarman, CC-2310, p. 196, Jan. 1945; PPR Vol. 9B, 7.39.3 (1946).
- (V1) Valley, G. E., and R. L. McCreary, *Phys. Rev.*, **66**, 863 (1939).
- (W1) Waldman, B., and M. L. Wiedenbeck, *ibid.*, **63**, 60 (1943).
- (W2) Weil, G. L., *ibid.*, **63**, 229 (1942).
- (W3) Weimer, K. E., M. L. Pool and J. D. Kurbatov, *ibid.*, **63**, 59 (1943); (W4) *ibid.*, 67 (1943).
- (W5) Wiedenbeck, M. L., *ibid.*, **67**, 92 (1945).
- (W6) Wiedenbeck, M. L., *ibid.*, 267 (1945).
- (W7) Wu, C. S., *ibid.*, **66**, 928 (1940).
- (W8) Wu, C. S., and E. Segré, *ibid.*, **61**, 203 (1942); (W9) *ibid.*, 67, 142 (1945).
- (W10) Wiedenbeck, M. L., *ibid.*, **66**, 36 (1944); 67, 92 (1945).
- (W101) Waters, D. E., and D. N. Hume, CN-1312, pp. 21-22, May 1945; PPR Vol. 9B, 8.8.6 (1946).
- (W103) Wilkinson, R. G., and W. Rall, CP-1811, June 1944; (W104) CP-2590, Feb. 1945; (W105) CP-2590, Feb. 1945; PPR Vol. 9B, 7.45.5 (1946); (W106) CP-2590, Feb. 1945; PPR Vol. 9B, 7.45.6 (1946).
- (W107) Wilkinson, R. G., W. Rall, L. C. Miller and L. F. Curtiss, CP-2589, p. 4, Feb. 1945.
- (W108) Winsberg, L., CC-1331, pp. 26-29, Feb. 1944; (W109) PPR Vol. 9B, 7.3.5 (1946); (W110) CC-2000, Aug. 1944; (W111) CN-2126, p. 4, Sept. 1944; (W112) CC-2310, pp. 210-212, Jan. 1945; (W113) CC-2310, pp. 231-244, Jan. 1945; PPR Vol. 9B, 7.56.1, 7.56.2 (1946); (W115) CN-2799, Mar. 1945; (W116) CC-2966, April, 1945; PPR Vol. 9B, 7.55.1 (1946); (W117) PPR Vol. 9B, 7.56.4 (1946); (W118) PPR Vol. 9B, 7.55.2 (1946); (W119) PPR Vol. 9B, 7.56.3 (1946); (W120) CC-3508, May 1946.
- (W121) Winsberg, L., and N. Sugarman, CC-2310, pp. 7-10, Jan. 1945.

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