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

ISSUED BY THE PLUTONIUM PROJECT[1]

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 (B120), 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 (G130, 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 12.8d Ba^{140} based on direct fission counting (F108). Older fission yield values have been normalized to this value for Ba^{140}. 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 $Kr^{(87)}$, $Xe^{(137)}$, 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 Konopinski–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, F.	= 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, coinc.	= 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 indentified 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*, **158**, 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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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^{-5} (S121)	0.3(~95%), ~1.6 (~5%) (S121) abs. Al, F.	γ (S121)	fiss., prec. 14.25h Ga^{72} (S121)	......
	Zn^{73}	<2m (S121)	β^-	....	(B)	....	....	....	hyp. prec. 5h Ga^{73} (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) $Ga(n,\gamma)$ (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^{73} (S121) 73(S121) fiss. yld.-ener.	......
32	Ge^{72}	stable								
	Ge^{73}	stable								
	Ge^{74}	stable								
	Ge^{75}	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) $Ge(n,\gamma)$ (S1, S10) $Ge(n,2n)$ (S10, S11) $As(n,p)$ (S10, S11) $Se(n,\alpha)$ (S10, S11) $Ge(\gamma,n)$ (H23)	......
	Ge^{76}	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) $Ge(n,\gamma)$ (S1, S10) $Se(n,\alpha)$ (S11) fiss., prec. 40h As^{77} (S134) 77 (S1, S11) not prod. $As(n,p)$	......
	$Ge^{(76)}$	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) $Br(n,\alpha)$ (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^{81}	<10m (G117)	β^-	....	B	....	....	....	hyp prec. 17m Se^{81} (G117)	......

34	Se^{77}	stable								
	Se^{78}	stable								
	Se^{79}	<10m or $>7 \times 10^6$y (G122)	β^-	....		....	....	....	79(G117) not mass 81	(W109)
	Se^{80}	stable								
	Se^{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)	......
	Se^{81}	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.	......
	Se^{82}	stable								
	Se^{83}	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)	......
	Se^{84}	~2m (G117, E115)	β^-	(G117, E115)	A	....	....	....	fiss., prec. 30m Br^{84} (G117, E115)	......
35	Br^{79}	stable								
	Br^{81}	stable								
	Br^{82}	34h (S22)	β^-, γ	(F112)	A	2.8×10^{-5} (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^{83*} (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	Energy of radiations in Mev: Gamma radiations	Produced by and mass assignment	Other references
	Br^{85}	3.0m (S25)	β^-	(S25)	A	....	....	....	fiss. prec. 4.5h Kr^{85} (S18, B2)	.....
	Br^{87}	50s (S25)	β^-	(S25)	A	....	....	....	fiss., prec. 75m Kr^{87} (S18, B2)	.....
	$Br^{(87)}$	55.6s (H111) 56s (L105)	β^- (n)	(B11, L105)	C	....	....	....	fiss., prec. $Kr^{(87)}$, inst. n emitter (L105)	(S154, S126)
36	Kr^{82}	stable		....		low (G147)				
	Kr^{83*}	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)	Se(α,n) (C1, C2) Kr(d,p)? (C1, C2) Kr(d,d)? (C1, C2) desc. Se(n,γ), (d,p) (L2) fiss., desc. 2.4h Br^{83} (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^{85}	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^{85} (S18, B2)	....
	Kr^{85}	~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^{86}	stable	....	(T101)	A	....	....	....	fiss. (T101) mass spect.	
	Kr^{87}	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^{87} (S18, B2)	....
	$Kr^{(87)}$	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 $Br^{(87)}$ (L105)	(S25, S126, B2, R101, S18)
	Kr^{88}	3h (L1) 2.8h (G2)	β^-	(L1)	A	....	2.5(W2) cl. ch. (K U.)	....	fiss., prec. 17.8m Rb^{88} (L1, A6, G1, G2, H7, H22)	(H5)
	Kr^{89}	2.6m (D109) 2.5–3m (S14) 2–5m (G2)	β^-	(G1, S14)	A	....	....	....	fiss., prec. 15.4m Rb^{89} (G1, G2, S14, H7); prec. 53d Sr^{89} (G1, G2, O102, D109)	(D103, D108)

	Kr^{90}	~33s (K119)	β^-	(D103)	A	....	....	....	fiss., prec. 25y Sr^{90} (D103, K119)	....
	Kr^{91}	9.8s (D109) 5.7s (O102)	β^-	(H8)	A	....	....	....	fiss., prec. 9.7h Sr^{91} (D109); prec. 57d Y^{91} (H8, B118, O102, D103)	(D108)
	$Kr^{(92)}$	3s (D109)	β^-	(H5)	C	....	....	....	fiss., prec. 3.5h $Y^{(92)}$ (H5, H6, H8, H15, B118, D109)	(D108)
	$Kr^{(93)}$	2.0s (D109)	β^-	(H16, B118)	C	....	....	....	fiss., prec. 10h $Y^{(93)}$ (H16, H13, B118, D103, D109)	(H15, D108, O102)
	$Kr^{(94)}$	1.4s (D109)	β^-	(H15)	C	....	....	....	fiss., prec. 20m $Y^{(94)}$ (H15, D109)	....
	Kr^{97}	short (A101)	β^-	(A101)	A	....	....	....	fiss., prec. 17h Zr^{97} (A101, D109)	....
37	Rb^{85}	stable								
	Rb^{86}	19.5d (H26)	β^-, γ	(F113)	A	$\sim 1.6 \times 10^{-4}$ (F113)	1.60(H1) spect. 1.56(H26) abs.	γ(H27)	Rb(n,γ) (S22, S15) Sr(d,α) (H26) Rb(γ,n) (H23) fiss. (F113)	....
	Rb^{87}	6.3×10^{10}y (S26)	β^-, γ, e^-	....	(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) abs. 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) abs.	....	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: Particles	Energy of radiations in Mev: Gamma radiations	Produced by and mass assignment	Other references
	$Rb^{(93)}$	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^{86}	stable		....		low (G147)				
	Sr^{87}	stable								
	Sr^{88}	stable								
	Sr^{89}	53d (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)	$Sr(n,\gamma)$ (S23, S24) $Y(n,p)$ (S4) fiss., desc. 15.4m Rb^{89} (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	$Zr(n,\alpha)$ (S17) fiss., desc. short Rb^{91} (D109); prec. 51m Y^{91*} (~40%), 57d Y^{91} (~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)
	$Sr^{(94)}$	~2m (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^{89}	stable								
	Y^{90}	65h (N110) 62h (G130) 60h (S23, G134)	β^-	(H16, N108, G130)	A	....	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^{91*}	51m (F105) 50m (G6)	I.T , γ, e^-	(G6)	A	....	e^-: ~0.5(F105) abs. Al	0.61(F105) abs. Pb (~10% converted)	$Zr(n,p)$ (S17) fiss., desc. 9.7h Sr^{91} (~40%) (G6, F105); prec. 57d Y^{91} (F105)	....
	Y^{91}	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) fiss., desc. 9.7h Sr^{91} (~60%) (G6, F105); desc. 51m Y^{91*} (~40%) (F105) 91(L108) massspect.	(G131, P103)
	$Y^{(92)}$	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) fiss., desc. 2.7h $Sr^{(92)}$ (G6, H103)	(B115)
	$Y^{(93)}$	10h (B113) 11.5h (H15)	β^-, γ	(H16, B101)	C	....	3.1(B113) abs. Al, F.	0.7(B113) abs. Pb	fiss., desc. 7m $Sr^{(93)}$ (H16, H13, H15); not mass 95 (S114)	(B115)
	$Y^{(94)}$	20m (H15, D104)	β^-, γ	(H15)	C	~5(D104)	....	γ (H15)	$Zr(n,p)$ (S17) fiss., desc. ~2m $Sr^{(94)}$ (H15, H13)	....
	Y^{95}	<3h (S114)	β^-	....	A	....	....	....	hyp. prec. 65d Zr^{95} (S114)	
	Y^{97}	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 yield, %	Energy of radiations in Mev: Particles	Gamma radiations	Produced by and mass assignment	Other references
	Zr^{95}	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	$Zr(n,\gamma)$ (S9) $Zr(d,p)$ (S9, J101) $Mo(n,\alpha)$ (S9) fiss., desc. <3h Y^{95} (S114); prec. 90h Cb^{95*} (~2%), 35d Cb^{95} (~98%) (E108, S131, J101) 95 (L107, N103) 35d Cb^{95} β^- emitter 95 (H102) mass spect.	(B121, N104 H13, G101)
	Zr^{96}	stable								
	Zr^{97}	17.0h (G8, K109)	β^-, γ	(G8)	A	....	2.1(K109) abs. Al, F.	~0.8(K109) abs. Pb	$Zr(n,\gamma)$ (S9) $Mo(n,\alpha)$ (S9) fiss., desc. short Sr^{97} (A101); prec. 75m Cb^{97} (G8, H9, S9) 95, 97 (J101) not prod. by $Cb(n,p)$ (N104) 97(S9) not prod. by $Zr(n,2n)$	(P105)
41	Cb^{93}	stable								
	Cb^{95*}	90h (S131) 80h (E108)	I. T., e^-, X-ray	(E104)	A	....	e^-: 0.22_8, 0.23_9(L104) spect.; 0.22 (S131) abs. Al	γ highly conv. (?) (S131) X-ray: ~0.016(S131) abs. Al	fiss., desc. 65d Zr^{95} (~2%) (S131, E108); prec. 35d Cb^{95} (S131, L104)	....
	Cb^{95}	35d (E108) 36.5d (J101)	β^-, γ	(G128)	A	....	0.15_4(N106) spect. 0.15(G128, E108, M113) abs. Al e^-: 0.75, 0.77(N106) spect.	0.75(W104) spect. 0.77_6(N106) spect. conv. 0.79(J102) spect. 0.75(E108) abs. Pb ~0.7(G128) abs. Pb	$Mo(d,\alpha)$ (J101) $Zr(d,p)$ desc. 65d Zr^{95} (J101) fiss., desc. 65d Zr^{95} (~98%) (J101, G128, E108); 90h Cb^{95*} I. T. (~2%) (S131, L104) 95(L107, N106) 35d Cb^{95} β^- emitter 95(H102) mass spect.	(F110, N104, E117, E105, N101)
	Cb^{97}	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^{97} (G8, S9, H9)	(P105)
42	Mo^{95}	stable								
	Mo^{97}	stable								
	Mo^{98}	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. 4×10^6y 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^{105}	short (B4)	β^-	(B4)	A	....	....	....	fiss., prec. 4.5h Ru^{105} (B4)	....
43	43^{99*}	5.9h (G144) 6.6h (S13)	I.T., γ, e^-, X-ray	(S21)	A	....	e^-: 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. 4×10^6y 43^{99} (S13, M107)	(G110)
	43^{99}	4×10^6y (M107) ~10^6y (L111) ~3×10^5y (S104) >3000y (G110) >40y (S13)	β^-	(L111, S104)	A	....	0.3(L111, S104, M107) abs. Al	....	Mo(n,γ) desc. 67h Mo^{99} (M107) fiss., desc. 67h Mo^{99} ~(90%)(S13); 5.9h 43^{99*} 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^{105}	short (B4)	β^-	(B4)	A	....	....	....	fiss., desc. short Mo^{105}; prec. 4.5h Ru^{105} (B4)	....
	$43^{(107)}$	<1.5m (B4)	β^-	....	C	....	....	....	hyp. prec. 4m $Ru^{(107)}$ (B4)	....
44	Ru^{99}	stable								
	Ru^{101}	stable								
	Ru^{102}	stable								

Z	Nucleus A	Half-life	Decay	Discovery in fission	Class	Fission yield, %	Energy of radiations in Mev: Particles	Energy of radiations in Mev: Gamma radiations	Produced by and mass assignment	Other references
	Ru^{103}	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(*d,p*) (L10, S145) Ru(*n*,γ) (S145) fiss., prec. 56m Rh^{103*} (G143, G127)	(N6, B115, G115)
	Ru^{104}	stable								
	Ru^{105}	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(*d,p*) (L10, S145) Ru(*n*,γ) (D2, S145) fiss., desc. short 43^{105} (B4); prec. 36.5h Rh^{105} (N6, S145, S122)	....
	Ru^{106}	1.0y (G143)	β^-	(G129)	A	0.48(S132) 0.53(G121)	~0.03(?)(G143) abs. Al	no γ (G143)	fiss., prec. 30s Rh^{106} (G127, G143) 106(H102) mass spect.	(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., e^-, X-ray	(G127)	A	....	e^-: ~0.03(G143) abs. Al	X-ray: 0.020(G143) abs. Al	Rh(γ,γ) (W6) Rh(*n,n*) (F3) fiss., desc. 42d Ru^{103} (≥97%) (G143)	(S123, S145, G115)
	Rh^{103}	stable								
	Rh^{105}	36.5h (S145) 34h (N5)	β^-, γ	(N5)	A	....	0.60(S145) abs. Al, F. e^-: ~0.3(S145) abs. Al	0.33(S145) abs. Pb	Ru(*d,n*)(?) (S145) Ru(*d,p*), Ru(*n*,γ), desc. 4.5h Ru^{105} (S145) fiss., desc. 4.5h Ru^{105} (N6, S122, S145)	....
	Rh^{106}	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^{106} (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^{105}	stable								
	Pd^{106}	stable								
	Pd^{107}	very short or $>3 \times 10^8$y (G119) $>8.6 \times 10^7$y (L115)	β^-	....	A	....	....	....	....	(C112)

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

Z	Nucleus A	Half-life	Decay	Discovery in fission	Class	Fission yield, %	Energy of radiations in Mev: Particles	Energy of radiations in Mev: Gamma radiations	Produced by and mass assignment	Other references
	Cd^{115}	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^{115} 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. 0.48(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^{115}	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	Sn^{117}	stable								
	Sn^{118}	stable								
	Sn^{119}	stable								
	Sn^{120}	stable								
	$Sn^{(121)}$	62h (S108) 60h (N2) ~80h (H14)	β^-	(N2)	C	0.014(S108)	0.76(S108) abs. Al, F.	no γ (S109)	fiss. (N2, H14, S108)	....
	$Sn^{(121,123)}$	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								
	Sn$^{(123)}$	10d (S108) 11d (H14)	β^-, γ	(H14)	C	0.0044 (S108)	2.6(S108) abs. Al, F.	γ (S108)	Sn(d,p) (L13) Sn(n,γ) (L13) fiss. (H14, S108)	....
	Sn^{124}	stable								
	Sn^{125}	9m (L13)	β^-	....	(B)	....	....	....	Sn(d,p) (L13) Sn(n,γ) (L13) 125(L13) not prod. by Sn($n,2n$)	....
	Sn	$\sim$20m (H14)	β^-	(H14)	C	....	....	....	fiss. (H14)	....
	Sn$^{(126)}$	70m (N2, H14)	β^-, γ(?)	(N2)	C	0.1(S108)	(70m Sn$^{(126)}$ +$\sim$60m Sb$^{(126)}$): 0.7(60%), 2.7(40%) (S108) abs. Al, F.	(70m Sn$^{(126)}$ + $\sim$60m Sb$^{(126)}$): 1.2(S108) abs. Pb	fiss., prec. $\sim$60m Sb$^{(126)}$ (N2, H14)	(S109)
51	Sb^{121}	stable								
	Sb^{123}	stable								
	Sb^{125}	$\sim$2.7y (L102)	β^-, γ, X-ray	(C102, S124)	B	0.023(S127) 0.018(L102)	0.3($\sim$65%), 0.7 ($\sim$35%)(S127) abs. Al, F. $\sim$0.6(C102, L102) abs. Al	0.6(S127) abs. Pb 0.56(L102) abs. Pb X-ray: 0.027(S127, L102) abs. Al	desc. Sn(n,γ) (S127) fiss. (C102, S124, S127, L102)	....
	Sb$^{(126)}$	$\sim$60m (N2)	β^-, γ(?)	(N2)	C	....	see 70m Sn$^{(126)}$	see 70m Sn$^{(126)}$	fiss., desc. 70m 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)	....
	Sb$^{(132)}$	$\sim$5m (A2)	β^-	(A1)	C	....	....	....	fiss., prec. 77h Te$^{(132)}$(A2)	....
	Sb^{133}	<10m (A2)	β^-	....	A	....	....	....	hyp. prec. 60m Te^{133}(A2)	....
	Sb$^{(134)}$	<10m (A2)	β^-	....	C	....	....	....	hyp. prec. 43m Te$^{(134)}$(A2)	....
52	Te^{125}	stable								
	Te^{126}	stable								
	Te^{127*}	90d (S12, G135)	I. T., e^-, X-ray	(G112)	A	0.033 (G135)	e^-: 0.055, 0.082, 0.085 (H17) spect.	X-ray: 0.028(G135) abs. Al	Te(d,p), Te(n,γ) (S12) I(n,p) (S12) fiss., prec. 9.3h Te^{127} (S12, G135)	....
	Te^{127}	9.3h (S12, C103, G135)	β^-	(A2)	A	....	0.70(S12, C103, G135) abs. Al, F.	no γ (C103, S125, G135)	Te(d,p) (T2, S12) Te(n,γ) (S12) Te(n, 2n) (T2) I(n,p) (S12) fiss., desc. 93h Sb^{127} (A2, C103); 90d Te^{127*} I. T. (S12,G135)	....

Nucleus Z A	Half-life	Decay	Discovery in fission	Class	Fission yield, %	Energy of radiations in Mev: Particles	Energy of radiations in Mev: 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^{129}	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^{129} (A2); 32d Te^{129*} I. T. (S12, G135); prec. very long I^{129} (S12, L112)	....
Te^{130}	stable								
Te^{131*}	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^{131}	25m (S12) 30m (A2)	β^-	(A2)	A	....	....	....	Te(d,p) (S12) Te(n,γ) (S12) fiss., desc. 30h Te^{131*} I. T. (S12); prec. 8.0d I^{131} (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^{129}	very long (L112)	β^-	....	A	....	....	....	hyp. desc. 70m Te^{129}(S12)	....
	I^{131}	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	Te(d,n) (L12, R2) fiss., desc. 25m Te^{131} (L12, A2, S12)	(P108, H4, T1)
	$I^{(132)}$	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	fiss., desc. 77h $Te^{(132)}$ (A8, A2, H3, N115, H4)	(M116)
	I^{133}	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	fiss., desc. 60m Te^{133} (A2, H4, W9); prec. 5.3d Xe^{133} (S21, D4, W9)	(W7, K113, P107)
	$I^{(134)}$	54m (A2)	β^-, γ	(A2)	C	~5.7(K112)	....	>1(G123) abs. Pb	fiss., desc. 43m $Te^{(134)}$ (A2, H4)	(P2, P13, P106)
	I^{135}	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	fiss., desc. <2m Te^{135} (D4, G123, K108, W9); prec. 9.2h Xe^{135} (~90%) (S21, D4, W9); prec. 13mXe^{135*}(~10%)(W9)	(W7, K110)
	$I^{(136)}$	1.8m (S25)	β^-	(S25)	C	....	....	....	fiss. (S25)	....
	I^{137}	30s (S25)	β^-	(S25)	B	....	....	....	fiss., prec. 3.4m Xe^{137}(S18)	....
	$I^{(137)}$	22.0s (H111) 23s (L105, R101)	β^-, (n)	(B11, L105)	C	....	....	....	fiss., prec. $Xe^{(137)}$ inst. n emitter (L105)	(R5, S154)
54	Xe^{129}	stable								
	Xe^{131}	stable	....	(T101)	A	....	....	....	fiss. (T101) mass spect.; desc. 8.0d I^{131}	
	Xe^{132}	stable	....	(T101)	A	....	....	....	fiss. (T101) mass spect.	
	Xe^{133}	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(E112) abs. Al; 0.040 (E103) abs. Al	Xe(d,p) (C2) Xe(n,γ) (R1)(?) Te(α,n) (C2) Ba(n,α) (W7, W9, C101) Cs(n,p) (W7, W9, C101) fiss., desc. 22h I^{133} (S21, D4, W9)	....
	Xe^{135}	stable	....	(T101)	A	....	....	....	fiss. (T101) mass spect.	

Z	Nucleus A	Half-life	Decay	Discovery in fission	Class	Fission yield, %	Energy of radiations in Mev: Particles	Energy of radiations in Mev: Gamma radiations	Produced by and mass assignment	Other references
	Xe^{135*}	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. ~0.5(W9) abs. Pb 0.6(S16) abs. Al, conv.	$Xe(n,\gamma)$ (R1, S16) fiss., desc. 6.7h I^{135} (~10%) (G4, S16); prec. 9.2h Xe^{135} (G4, W9)	....
	Xe^{135}	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) $Ba(n,\alpha)$ (W7, S16, W9) fiss., desc. 6.7h I^{135} (~90%) (S21, D4, S16, W9); 13m Xe^{135*} I.T. (W9); prec. >2.5 × 10^4y Cs^{135} (E107)	....
	Xe^{136}	stable	....	(T101)	A	....	....	....	fiss. (T101) mass spect.	
	Xe^{137}	3.4m (R1, S16) 3.8m (S18)	β^-	(S18)	B	....	~4(S18, B3) abs. Al	....	$Xe(n,\gamma)$ (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^{138}	17m (G2) 16–18m (S14)	β^-	(H4)	B	....	....	....	fiss., prec. 32m Cs^{138} (H4, G1, G2, S14)	(S16, H5)
	Xe^{139}	41s (D109) ~30s (H22)	β^-	(H4, H22)	A	....	....	....	fiss., prec. 7m Cs^{139} (H22, H4, H5) prec. 85m Ba^{139} (D109, H5, H22)	....
	Xe^{140}	16s (D109) 9.8s (O102)	β^-	(H5)	A	....	....	....	fiss., prec. 12.8d Ba^{140} (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)
	$Xe^{(145)}$	0.8s (D109)	β^-	(A103)	C	....	....	....	fiss., prec. 1.8h $Ce^{(145)}$(D109)	.....
	Xe	68m (C2)	I. T.(?) (S16)	....	(C)	....	....	....	$Xe(d,p)$(?) (C2) $Xe(n,n)$(?) (S16)	....
55	Cs^{133}	stable								

	Cs^{135}	$>2.5\times10^4$y (E107) $>2\times10^3$y (G123, F106)	β^-	....	A	....	....	....	hyp. desc. 6.7h I^{135} (G123, F106, E107)	....
	$Cs^{(136)}$	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) 137 (F106) not 135 fiss., desc. 3.4m Xe^{137} (T102, G123) 137 (L110) mass spect.	(G104)
	Cs^{138}	32m (G2, G139) 33m (A6, H4, E114)	β^-, γ	(H4, H22)	B	....	2.6(G2) abs. Al	1.2(G139) abs. Pb	Ba(n,p) (S16) fiss., desc. 17m Xe^{138} (H4, G1, G2, S14)	(H5, P109)
	Cs^{139}	7m (H5) 10m (H22)	β^-	(H4, H22)	A	....	....	....	fiss., desc., 41s Xe^{139} (H4, H22, H5); prec. 85m Ba^{139} (H4, H22)	(H6, A6)
	$Cs^{(140)}$	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)	....
	$Cs^{(142)}$	~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} prec. 33h Ce^{143} (B118, D109); prec. 13.8d Pr^{143} (O102)	(A103)
	Cs^{144}	short (D103)	β^-	(D103)	A	....	....	....	fiss., desc. short Xe^{144} prec. 275d Ce^{144} (D103)	....
	$Cs^{(145)}$	short (D109)	β^-	(A103)	C	....	....	....	fiss., desc. 0.8s $Xe^{(145)}$ prec. 1.8h $Ce^{(145)}$ (D109)	....
56	Ba^{135}	stable								
	Ba^{136}	stable		....		low (G147)				
	Ba^{137}	stable								
	Ba^{138}	stable								
	Ba^{139}	85m (D107) 86m (P6, H6, H2) 87m (H22)	β^-, γ	(H2)	A	6.3(K113)	2.2(B3, K113) abs. Al	0.6(K2) abs. Pb, Cu	Ba(d,p) (P6, K2) Ba(n,γ) (A3, P7) La(n,p) (P6, P10) Ce(n,α) (W3) fiss., desc. 7m Cs^{139} (H4, H22)	(H5, H6)

Z	Nucleus A	Half-life	Decay	Discovery in fission	Class	Fission yield, %	Energy of radiations in MEV: Particles	Energy of radiations in MEV: Gamma radiations	Produced by and mass assignment	Other references
	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^{141}	18m (H12, G132)	β^-, γ	(H12)	B	4.6(G133)	....	γ (G132)	fiss., desc. short Cs^{141} (B118, O102, D109) prec. 3.7h La^{141} (H12)	....
	$Ba^{(142)}$	6m (H12)	β^-	(H12)	C	....	....	....	fiss., desc. 1–2m $Cs^{(142)}$ prec. 74m $La^{(142)}$ (H12)	....
	Ba^{143}	<0.5m (H12)	β^-	(H2)	A	....	....	....	fiss., desc. short Cs^{143} (B118, D109, O102); prec. 19m La^{143} (H2, H12)	....
	Ba^{144}	short (D103)	β^-	(D103)	A	....	....	....	fiss. desc, short Cs^{144} prec. 275d Ce^{144} (D103)	....
	$Ba^{(145)}$	short (D109)	β^-	(A103)	C	....	....	....	fiss., desc. short $Cs^{(145)}$ prec. 1.8h $Ce^{(145)}$ (D109)	....
57	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 intensity) (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) abs. 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)	$\beta^-, \gamma(?)$	(H12, B107)	B	....	2.8(K105) abs. Al, F.	γ(?) (K105)	fiss., desc. 18m Ba^{141} (H12); prec. 28d Ce^{141} (B107, B109)	....

	$La^{(142)}$	74m (H12) 77m (K105)	β^-, γ	(H12)	C	....	....	γ (K105)	fiss., desc. 6m $Ba^{(142)}$ (H12)	....
	La^{143}	19m (G103) 20m (H12) ~15m (H14)	β^-	(H12, G103)	A	> 4.3(S152)	....	....	fiss., desc. <0.5m Ba^{143} (H12, H14, G103, B118, A103); prec. 33h Ce^{143} (G103)	....
	La^{144}	short (D103)	β^-	(D103)	A	....	....	....	fiss., desc. short Ba^{144} prec. 275d Ce^{144} (D103)	(O102)
	$La^{(145)}$	short (D109)	β^-	(A103)	C	....	....	....	fiss., desc. short $Ba^{(145)}$ prec. 1.8h $Ce^{(145)}$ (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	Ce(*d*,*p*) (P9, B122) Ce(*n*,γ) (P9, B114) Ce(*n*,2*n*) (P9, B114) Ba(α,*n*) (P9) Pr(*n*,*p*) (P9) fiss., desc. 3.7h La^{141} (B107, B109) 141(L110) mass spect.	(G131, P114)
	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	Ce(*d*,*p*) (P9) (B122, B114) Ce(*n*,γ) (P9, B114) fiss., desc. 19m La^{143} (G103); prec. 13.8d Pr^{143} (P9, B122, B114) 143(B114) not prod. by Ce(*n*,2*n*) 143 (L110) mass spect.	(B107, P112)
	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} (D103, A101); prec. 17.5m Pr^{144} (N107, B122, H14, S111, L110, G130) 144 (L110) mass spect.	(P115)
	$Ce^{(145)}$	1.8h (B108)	β^-	(B108, B104)	C	....	....	....	fiss., desc. short $La^{(145)}$ (B109, D109); prec. 4.5h $Pr^{(145)}$ (B108, K106)	(B104)
	$Ce^{(146)}$	14.6m (S103) ~15m (G7)	β^-	(G7)	C	....	....	....	fiss., prec. 24.6m $Pr^{(146)}$ (G7, H14, S103)	....

Z	Nucleus A	Half-life	Decay	Discovery in fission	Class	Fission yield, %	Energy of radiations in Mev: Particles	Energy of radiations in Mev: Gamma radiations	Produced by and mass assignment	Other references
59	Pr^{141}	stable								
	Pr^{143}	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^{143} (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 intensity) (S111) abs. Pb	fiss., desc. 275d Ce^{144} (N107, B122, H14, G130, S111, L110) 144 (L110) mass spect.	....
	$Pr^{(145)}$	4.5h (K106) 4.7h (B108)	β^-	(B101, B108)	C	....	3.1(K106) abs. Al, F.	no γ (K106)	fiss., desc. 1.8h $Ce^{(145)}$ (B108, K106)	....
	$Pr^{(146)}$	24.6m (S101) 25m (G7)	β^-, γ	(G7)	C	....	~3(S101) abs. Al	1.4(S101) abs. Pb	fiss., desc. 14.6m $Ce^{(146)}$ (G7, S103)	....
60	Nd^{143}	stable								
	Nd^{144}	stable								
	Nd^{145}	stable								
	Nd^{146}	stable								
	Nd^{147}	11.0d (M119)	β^-, γ, e^- X-ray	(D101, M103)	A	2.6(M119)	~0.4(40%), 0.90 (60%) (M119) abs. Al, F. e^-: 0.03(M119) abs. Al	0.58(M119)abs. Pb X-ray: ~0.040 (M119) abs. Al	Nd(n,γ) (M122, M103) fiss., prec. 3.7y 61^{147} (M120, M108) 147(M119, M103) fiss. yld. 147 (L110) mass spect.	(S110)
	Nd^{148}	stable								
	$Nd^{(149)}$	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^{149}	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. $Nd^{(149)}$ (M122, M106, M102) fiss., desc. 1.7h $Nd^{(149)}$(?)(M122) 149(M102, M105) fiss. yld.	(M108)
	$61^{(151)}$	12m (M122)	β^-	....	(D)	....	....	....	Nd(n,γ) desc. short $Nd^{(151)}$ (M122)	....
	61^{153}	<5m (W118)	β^-	....	A	....	....	....	hyp. prec. 47h Sm^{153} (W118)	
	61^{156}	<5m (W118)	β^-	....	B	....	....	....	hyp. prec. ~10h Sm^{156} (W118)	
62	Sm^{147}	stable								
	Sm^{149}	stable								
	$Sm^{(151)}$	long (L110)	....	(L109)	D	....	....	....	fiss. (L110) mass spect.	....
	Sm^{152}	stable								
	Sm^{153}	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.	0.10, 0.57(W116) abs. Cu, Pb 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^{153} (W118) 153 (W116) fiss. yld. 153(H113) mass spect.	....
	Sm^{154}	stable								
	Sm^{155}	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^{155} (?) (W118) 155 (W118) fiss. yld.-ener.	....
	Sm^{156}	~10h (W116)	β^-	(W113)	B	~0.016(W119)	~0.8(W119) abs. Al	....	fiss., hyp. prec. 15.4d Eu^{156} (W113, W116) hyp. desc. <5m 61^{156} (W118) 156 (W119) fiss. yld.	....
63	Eu^{151}	stable								
	Eu^{153}	stable								
	Eu^{155}	2y (W117)	β^-, γ	(W110)	A	~0.03 (W113)	~0.23(W110) abs. Al	0.0844(W110) critical abs. in Pt, Au, 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 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
	Eu^{157}	15.4h (W113)	β^-, γ	(W111)	B	0.0074 (W113)	~1.0(75%), ~1.7(25%) (W113) abs. Al, F.	0.2, 0.6(W113) abs. Pb	fiss. (W113) 157(W113) fiss. yld.-ener.	....
	Eu$^{(158)}$	60m (W113)	β^-	(W111)	C	0.002(W113)	~2.6(W113) abs. Al, F.	....	fiss. (W113)	....
64	Gd^{155}	stable								
	Gd^{156}	stable								
	Gd^{157}	stable								
	Gd^{158}	stable								
Unidentified fission product nuclei with daughters emitting neutrons instantaneously						% of fission neutrons				
	(1)	4.51s (H111) 4.5s (L114) 3s (B12)	β^- (*n*)	(B12)	...	0.21(H111)	*n*: 0.430(H111) abs. paraffin	....	fiss. (B12, H111)	....
	(2)	1.52s (H111) 1 8s (L114)	β^- (*n*)	(L114)	...	0.24(H111)	*n*: 0.620(H111) abs. paraffin	....	fiss. (L114, H111)	....
	(3)	0.43s (H111) 0.4s (L114)	β^- (*n*)	(L114)	...	0.084(H111)	*n*: 0.420(H111) abs. paraffin	....	fiss. (L114, H111)	(B12)
	(4)	0.05s H)112)	β^- (*n*)	(H112)	...	~0.029 (H112)	....	....	fiss. (H112)	....

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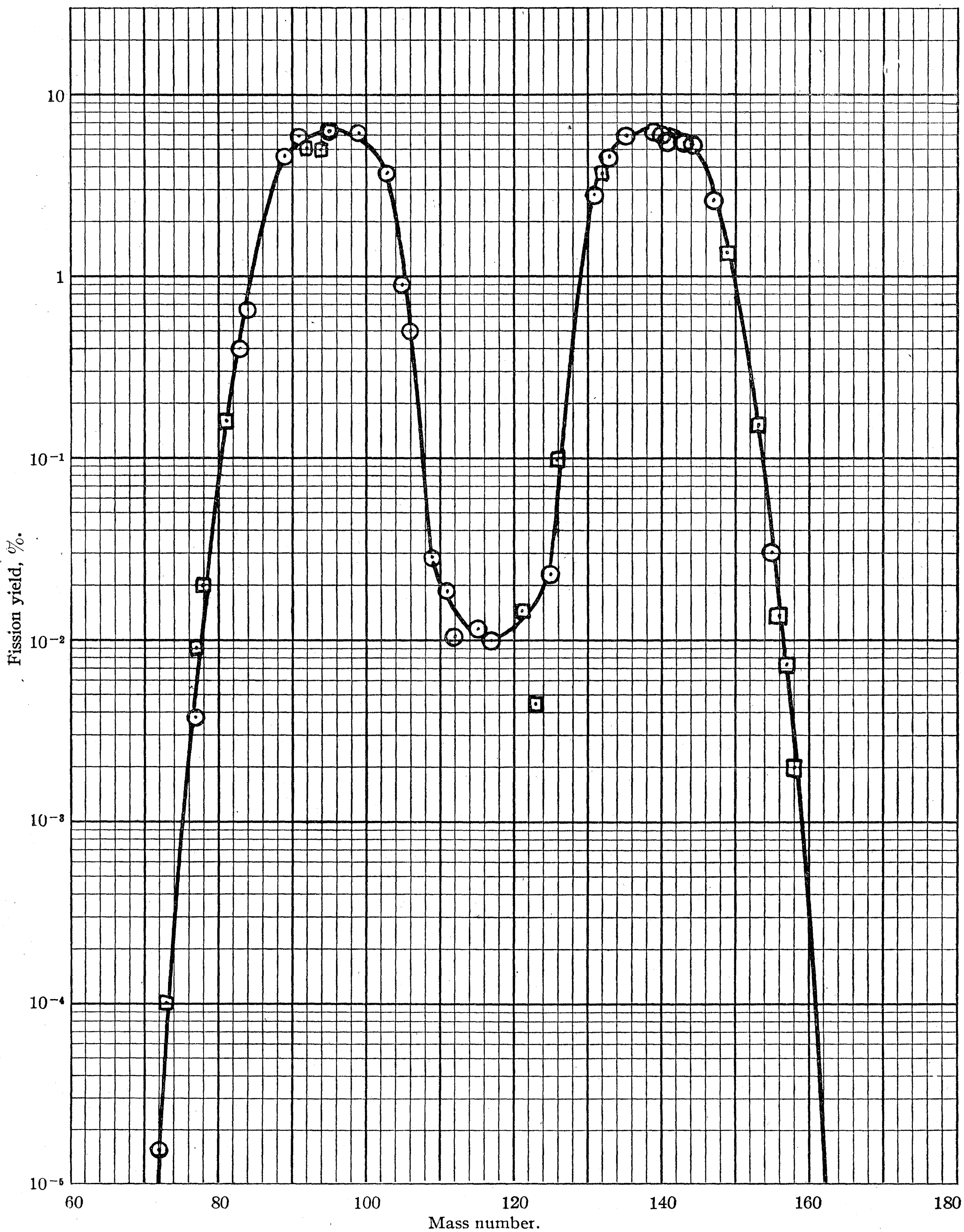

Fig. 1.—Yields of U^{235} fission product chains as a function of mass: ⊙, certain mass assignment; ⊡, uncertain mass assignment (mass 153 is now certain (H113)).

TABLE II

TABLE OF FISSION PRODUCTS: CHAINS AND YIELDS

Part 1. Light Group

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 Cb	42 Mo	43	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	Fission yield, %
71	•	stable	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
72	49h→14.3h→stable			•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	1.5×10^{-5}
73	<2m→5h→stable			•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	1.0×10^{-4}
74	•	•	stable	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
75	•	•	(89m)→stable		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
76	•	•	stable	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•		
77	•	•	12h→40h→stable			•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	0.0091
78	•	•	•	(80m)→stable		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
(78)	•	•	2.1h→90m→ ?			•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	0.02
79	•	•	•	•	{<10m or >7×10⁶y}→stable		•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
80	•	•	•	•	stable	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
81	•	•	•	•	59m	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	0.008
81	•	•	•	<10m→17m→stable			•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	0.125
82	•	•	•	•	stable	34h→stable		•	•	•	•	•	•	•	•	•	•	•	•	•	•	2.8×10^{-5} [a]
83	•	•	•	•	25m→2.4h→113m			•	•	•	•	•	•	•	•	•		•	•	•	•	0.40
83	•	•	•	•	•	•	stable	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
84	•	•	•	•	~2m→30m→stable			•	•	•	•	•	•	•	•	•	•	•	•	•	•	0.65
85	•	•	•	•	•	3.0m→4.5h→stable			•	•	•	•	•	•	•	•	•	•	•	•	•	
85	•	•	•	•	•	•	~10y		•	•	•	•	•	•	•	•	•	•	•	•	•	~0.24
86	•	•	•	•	•	•	stable	19.5d→stable		•	•	•	•	•	•	•	•	•	•	•	•	2×10^{-5} [b]
(87)	•	•	•	•	•	55.6s→instant.[d]		•	•	•	•	•	•	•	•	•	•	•				0.026[c]
(87)	•	•	•	•	•	•	?	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
87	•	•	•	•	•	50s→75m→6.3×10¹⁰y→stable				•		•	•		•	•	•	•	•	•	•	
88	•	•		•	•	•	3h→17.8m→stable			•		•	•	•	•	•	•	•	•	•	•	
89	•	•	•	•	•	•	2.6m→15.4m→53d→stable				•	•	•	•	•	•	•	•	•	•	•	4.6
90	•	•	•	•	•	•	~33s→short→25y→65h→stable					•	•	•	•	•	•	•	•	•	•	
91	•	•	•	•	•	•	•	•	•	51m (~40%)		•	•	•	•	•	•	•	•	•	•	
91	•	•	•	•	•	•	9.8s→short→9.7h→57d→stable					•	•	•	•	•	•	•	•	•	•	5.9
(92)	•	•	•	•	•	•	3s→short→2.7h→3.5h→stable					•	•	•	•	•	•	•	•	•	•	5.1
...	•	•	•	•	•	•	•	80s→?		•	•	•	•	•	•	•	•	•	•	•	•	

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 Cb	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	•	•	•	•	•	•	•	•	•	
(94)	•	•	•	•	•	•	1.4s →	short →	~2m →	20m →	stable	•	•	•	•	•	•	•	•	•	•	~5
95	•	•	•	•	•	•	•	•	•	•	•	90h (~2%)		•	•	•	•	•	•	•	•	
	•	•	•	•	•	•	•	•	•	<1.5h →	65d →	35d →	stable	•	•	•	•	•	•	•	•	~6.4
96	•	•	•	•	•	•	•	•	•	•	stable	•	•	•	•	•	•	•	•	•	•	
97	•	•	•	•	•	•	short →	short →	short →	short →	17.0h →	75m →	stable	•	•	•	•	•	•	•	•	
98	•	•	•	•	•	•	•	•	•	•	•	•	stable	•	•	•	•	•	•	•	•	
99	•	•	•	•	•	•	•	•	•	•	•	•	•	5.9h (~10%)		•	•	•	•	•	•	
	•	•	•	•	•	•	•	•	•	•	•	•	67h →	4 × 10⁵y →	stable	•	•	•	•	•	•	6.2
100	•	•	•	•	•	•	•	•	•	•	•	•	stable	•	•	•	•	•	•	•	•	
101	•	•	•	•	•	•	•	•	•	•	•	•	14.6m →	14.0m →	stable	•	•	•	•	•	•	
(102)	•	•	•	•	•	•	•	•	•	•	•	•	12m →	<1m →	stable	•	•	•	•	•	•	
103	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	56m (≥97%)	•	•	•	•	•	
	•	•	•	•	•	•	•	•	•	•	•	•	•	•	42d →	stable	•	•	•	•	•	3.7
104	•	•	•	•	•	•	•	•	•	•	•	•	•	•	stable	•	•	•	•	•	•	
105	•	•	•	•	•	•	•	•	•	•	•	•	short →	short →	4.5h →	36.5h →	stable	•	•	•	•	~0.9
106	•	•	•	•	•	•	•	•	•	•	•	•	•	•	1.0y →	30s →	stable	•	•	•	•	0.5
107	•	•	•	•	•	•	•	•	•	•	•	•	•	<1.5m →	4m →	24m →	{v.short or >3 × 10⁸y} →	stable	•	•	•	
108	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	stable	•	•	•	•	
109	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	(40.4s)	•	•	•	
	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	<1h →	13.4h →	stable	•	•	•	0.028
110	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	stable	•	•	•	•	
111	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	26m →	7.6d →	stable	•	•	0.018
112	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	21h →	3.2h →	stable	•	•	0.011
113	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	stable	•	•	
114	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	stable	•	•	
115	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	2.33d →	4.53h	•	0.011
	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	44d →	stable	•	0.0008
116	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	stable	•	•	
117	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	2.83h →	1.95h →	stable	0.01
…	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	48.7m	•	•	
	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	stable	•	•	
	Zn	Ga	Ge	As	Se	Br	Kr	Rb	Sr	Y	Zr	Cb	Mo	43	Ru	Rh	Pd	Ag	Cd	In	Sn	

[a] Yield of 34h Br^{82} formed directly in fission; not representative of total chain yield. [b] Yield of 19.5d Rb^{86} 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.

TABLE OF FISSION PRODUCTS: CHAINS AND YIELDS (*Continued*)

Part 2. Heavy Group

Mass No.	50 Sn	51 Sb	52 Te	53 I	54 Xe	55 Cs	56 Ba	57 La	58 Ce	59 Pr	60 Nd	61	62 Sm	63 Eu	64 Gd	Fission yield, %
118	stable	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
119	stable	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
120	stable	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
(121)	62h →	stable	•	•	•	•	•	•	•	•	•	•	•	•	•	0 014
(121, 123)	130d →	stable	•	•	•	•	•	•	•	•	•	•	•	•	•	0.0012
122	stable	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
(123)	10d →	stable	•	•	•	•	•	•	•	•	•	•	•	•	•	0.0044
124	stable	•	•	•	•	•	•	•	•	•	•	•	•	•	•	
125	(9m) →	~2.7y →	stable	•	•	•	•	•	•	•	•	•	•	•	•	0.023
(125)	~20m →	?	•	•	•	•	•	•	•	•	•	•	•	•	•	
(126)	70m →	60m →	stable	•	•	•	•	•	•	•	•	•	•	•	•	0.1
127	•	•	90d ↓	•	•	•	•	•	•	•	•	•	•	•	•	0.033
	•	93h → (⇢ 90d)	9.3h →	stable	•	•	•	•	•	•	•	•	•	•	•	
128	•	•	stable	•	•	•	•	•	•	•	•	•	•	•	•	
129	•	•	32d ↓	•	•	•	•	•	•	•	•	•	•	•	•	0.19
	•	4.2h → (⇢ 32d)	70m →	v. long →	stable	•	•	•	•	•	•	•	•	•	•	
130		•	stable	•	•	•	•	•	•	•	•	•	•	•	•	
131	•	•	30h ↓	•	•	•	•	•	•	•	•	•	•	•	•	~0.5
	•	•	25m →	8.0d →	stable	•	•	•	•	•	•	•	•	•	•	2.8
(132)	•	~5m →	77h →	2.4h →	stable	•	•	•	•	•	•	•	•	•	•	3.6
133	•	<10m →	60m →	22h →	5.3d →	stable	•	•	•	•	•	•	•	•	•	~4.5
(134)	•	<10m →	43m →	54m →	stable	•	•	•	•	•	•	•	•	•	•	~5.7
...	•	•	~1m →	?	•	•	•	•	•	•	•	•	•	•	•	
135	•	•	•	•	13m (~10%) ↓	•	•	•	•	•	•	•	•	•	•	
	•	•	<2m →	6.7h → (↗ 13m)	9.2h →	> 2.5 × 10⁴y →	stable	•	•	•	•	•	•	•	•	5.9
(136)	•	•	•	1.8m →	stable ←	← 13d →	stable	•	•	•	•	•	•	•	•	0.01[a]
(137)	•	•	•	22.0s →	instant.[c] (↑ stable)	•	•	•	•	•	•	•	•	•	•	0.17[b]
	•	•	•	• ↘	?	•	•	•	•	•	•	•	•	•	•	
137	•	•	•	30s →	3.4m →	33y →	stable	•	•	•	•	•	•	•	•	
138	•	•	•	•	17m →	32m →	stable	•	•	•	•	•	•	•	•	
139	•	•	•	•	41s →	7m →	85m →	stable	•	•	•	•	•	•	•	6.3
140	•	•	•	•	16s →	short →	12.8d →	40.0h →	stable	•	•	•	•	•	•	6.1
...		•	•	•	•	40s →	?	•	•	•	•	•	•	•	•	
141	•	•	•	•	3s →	short →	18m →	3.7h →	28d →	stable	•	•	•	•	•	5.7
(142)	•	•	•		•	~1–2m →	6m →	74m →	stable	•	•	•	•	•	•	
143	•	•	•	•	1s →	short →	<0.5m →	19m →	33h →	13.8d →	stable	•	•	•	•	5.4
144	•	•	•	•	short →	short →	short →	short →	275d →	17.5m →	stable	•	•	•	•	5.3
(145)	•	•	•	•	0.8s →	short →	short →	short →	1.8h →	4.5h →	stable	•	•	•	•	
...	•	•	•	•	(68m)	•	•	•	•	•	•	•	•	•	•	
(146)	•	•	•	•	•	•	•	•	14.6m →	24.6m →	stable	•	•	•	•	

Mass No.	50 Sn	51 Sb	52 Te	53 I	54 Xe	55 Cs	56 Ba	57 La	58 Ce	59 Pr	60 Nd	61	62 Sm	63 Eu	64 Gd	Fission yield, %
147	•	•	•	•	•	•	•	•	•	•	11.0d⟶	3.7y⟶	stable	•	•	2.6
148	•	•	•	•	•	•	•	•	•	•	stable	•	•	•	•	
149	•	•	•	•	•	•	•	•	•	•	(1.7h)---⟶	47h⟶	stable	•	•	1.4
150	•	•	•	•	•	•	•	•	•	•	stable	•	•	•	•	
(151)	•	•	•	•	•	•	•	•	•	•	(short)⟶	12m⟶	long⟶	stable	•	
152	•	•	•	•	•	•	•	•	•	•	•	•	stable	•	•	
153	•	•	•	•	•	•	•	•	•	•	•	<5m⟶	47h⟶	stable	•	0.15
154	•	•	•	•	•	•	•	•	•	•	•	•	stable	•	•	
155	•	•	•	•	•	•	•	•	•	•	•	•	25m---⟶	2y⟶	stable	~0.03
156	•	•	•	•	•	•	•	•	•	•	•	<5m⟶	~10h⟶	15.4d⟶	stable	0.013
157	•	•	•	•	•	•	•	•	•	•	•	•	•	15.4h⟶	stable	0.0074
(158)	•	•	•	•	•	•	•	•	•	•	•	•	•	60m⟶	stable	0.002
	Sn	Sb	Te	I	Xe	Cs	Ba	La	Ce	Pr	Nd	61	Sm	Eu	Gd	

[a] Yield of 13d $Cs^{(136)}$ formed directly in fission; not representative of total chain yield. [b] Delayed neutron yield based on fission neutrons rather than on fissions.
[c] Instantaneous, via delayed neutrons.

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