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YIELDS OF FISSION PRODUCTS FOR SEVERAL FISSIONABLE NUCLIDES AT VARIOUS INCIDENT NEUTRON ENERGIES

by

K. F. Flynn and L. E. Glendenin

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Printed in the United States of America
Available from
National Technical Information Service
U.S. Department of Commerce
5285 Port Royal Road
Springfield, Virginia 22151
Price: Printed Copy $3.00; Microfiche $0.95

ANL-7749
Chemistry

ARGONNE NATIONAL LABORATORY
9700 South Cass Avenue
Argonne, Illinois 60439

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Chemistry Division

December 1970

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ABSTRACT

This report consists of a summary of recommended values for fission-product yields from fissioning systems pertinent to the physics of reactors based on a survey of the literature through October 1970. Recommended experimental and estimated values for total chain yields in the form of tables and mass-yield curves are presented for neutron-induced fission of ^{232}Th, ^{233}U, ^{235}U, ^{238}U, ^{239}Pu, and ^{241}Pu at various neutron energies.

This report has been prepared in response to a request for a summary of recommended fission-product yields from fissioning systems pertinent to the physics of reactors.* The most comprehensive reviews of fission-product yields in the current literature are included in Refs. 1-5. Unless otherwise noted, the experimental data for total chain yields presented here have been taken from these compilations. Information on the independent or cumulative yields for isobars (along a given chain) can be found in Refs. 25-29. The most recent information on the genetic relationships in the fission-product radioactive decay chains is shown schematically in Ref. 1 and is not repeated here.

For each mass number, the total chain yields from neutron fission of ^{232}Th, ^{233}U, ^{235}U, ^{238}U, ^{239}Pu, and ^{241}Pu have been tabulated in Tables I-VI, respectively. These tables include data for thermal-neutron, fission-spectrum-neutron, 8-MeV-neutron, and 14-MeV-neutron fission. Fission-spectrum-neutron fission refers to fission induced by unmoderated neutrons produced in a nuclear reactor; 8-MeV neutron fission refers to fission induced by neutrons from the α,n reaction on lithium; and 14-MeV neutron fission refers to fission induced by neutrons from the d,n reaction on tritium. The chain yields given in this compilation are based on both radiochemical and mass-spectrometric techniques. Estimated absolute errors in the

*This survey covers the literature through October 1970. Evaluations and summaries of other pertinent data concerning fission-neutron spectra and fission energy release are contained in companion reports.[23,24]

fission yield values range from 5 to 20%, depending on the experimental technique used, and on the particular fission product measured. The accuracy is highest in cases such as mass-spectrometric measurements of the rare gas (krypton and xenon) yields and in the cases of a few radiochemical measurements such as ^{99}Mo, ^{137}Cs, and ^{140}Ba, where determinations based on absolute fission counting have been made by several independent investigators. The error for a particular fission yield value can best be estimated by referring both to the original work and to one or more of the summaries referred to in Refs. 1-5. For chain yields not experimentally determined, values based on interpolations from the smooth mass-yield curves are given wherever possible; these estimated values (enclosed in parentheses) should be considered open to error as large as ±50%. Each of these tables also includes a column labeled "Fission Product," which indicates the particular fission-product nuclide measured.

Total yields for the light and heavy mass groups in the various fissioning systems are given in Table VII. Since these group-yield summations are close to the desired value of 100% (ranging from 95 to 106%), no attempt was made to renormalize the experimental fission-yield data.

Characteristics of some of the mass distributions for neutron-induced fission are summarized in Table VIII.

Mass-yield curves (constructed from the experimental data in the tables) for thermal-neutron fission of ^{233}U, ^{235}U, ^{239}Pu, and ^{241}Pu are presented in Figs. 1-4, respectively. Similar curves for fission-spectrum-neutron fission of ^{232}Th, ^{233}U, ^{235}U, ^{238}U, and ^{239}Pu are shown in Figs. 5-9, respectively. The mass-yield curves for 14-MeV neutron fission of ^{232}Th, ^{235}U, and ^{238}U are given in Figs. 10-12, respectively.

The results of this survey indicate the need for better fission-yield information in the vicinity of symmetric fission for all the fissioning systems. There is also a scarcity of data for fission-spectrum-neutron fission of ^{233}U, and no data at all are available for fission-spectrum-neutron fission of ^{241}Pu. Mass-yield curves for thermal-neutron fission of ^{227}Th, ^{229}Th, ^{245}Cm, and ^{249}Cf have been published,[19-22] and these data can be used for estimating fission yields from fissionable nuclides of atomic number and mass outside the range covered in this report. Although approximate values for fission yields from fissioning systems for which no information is available can be estimated by interpolation or extrapolation from available mass-yield curves, such values should not be relied upon where accuracy in the yield is important.

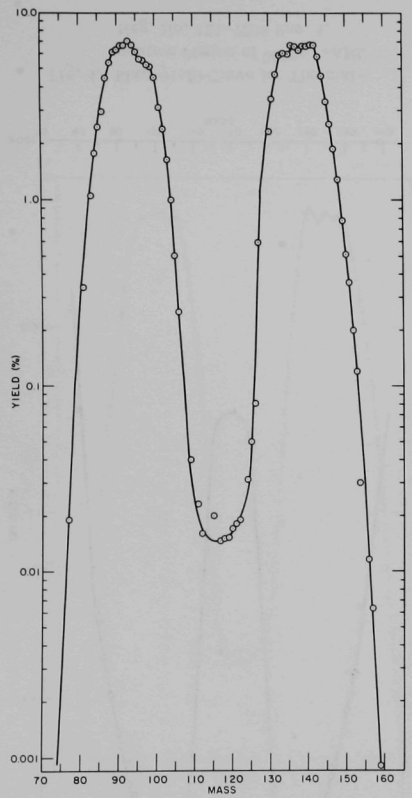

Fig. 1. Mass-yield Curve for Thermal-neutron Fission of ^{233}U. ANL Neg. No. 121-7199 Rev. 1.

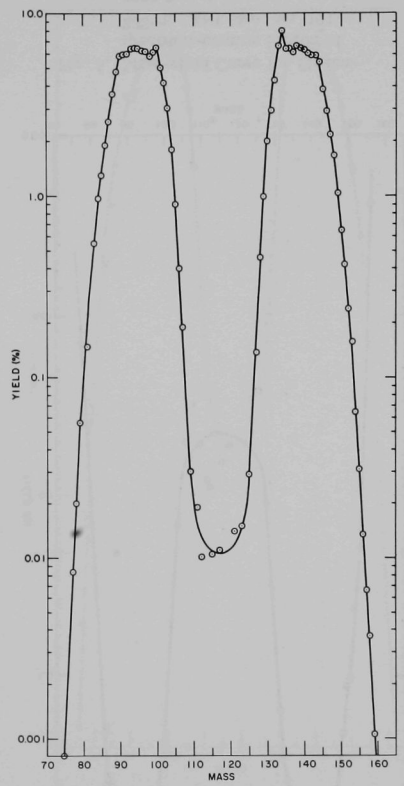

Fig. 2. Mass-yield Curve for Thermal-neutron Fission of ^{235}U. ANL Neg. No. 121-7201 Rev. 1.

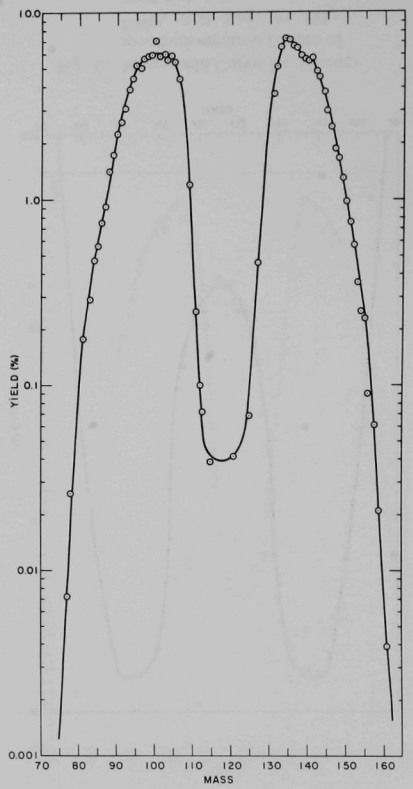

Fig. 3. Mass-yield Curve for Thermal-neutron Fission of ^{239}Pu. ANL Neg. No. 121-7204 Rev. 1.

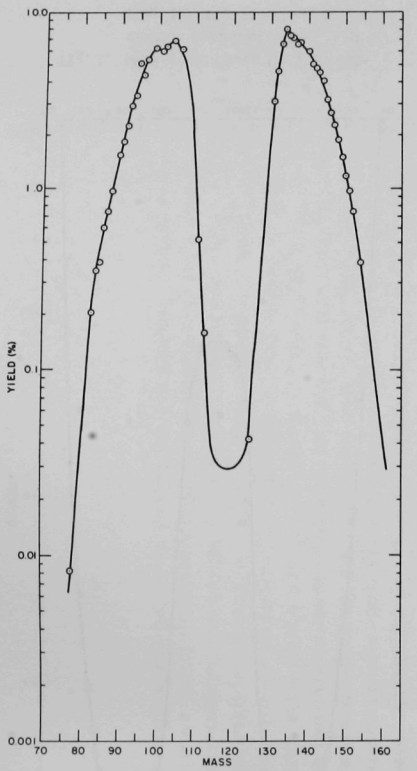

Fig. 4. Mass-yield Curve for Thermal-neutron Fission of ^{241}Pu. ANL Neg. No. 121-7203 Rev. 1.

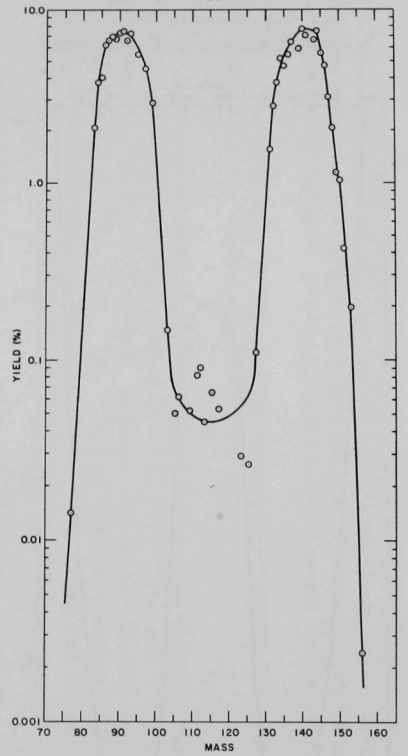

Fig. 5. Mass-yield Curve for Fission-spectrum-neutron Fission of ^{232}Th. ANL Neg. No. 121-7205 Rev. 1.

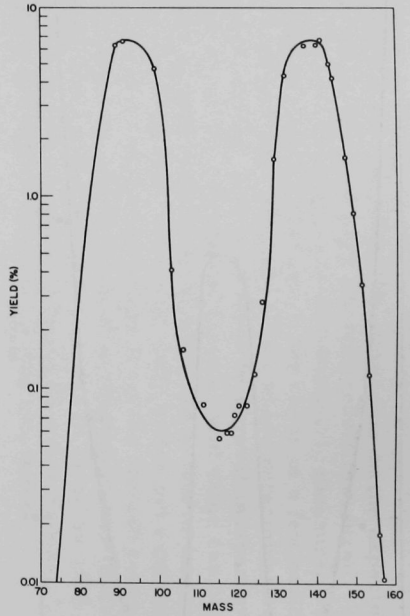

Fig. 6. Mass-yield Curve for Fission-spectrum-neutron Fission of ^{233}U. ANL Neg. No. 121-7395 Rev. 1.

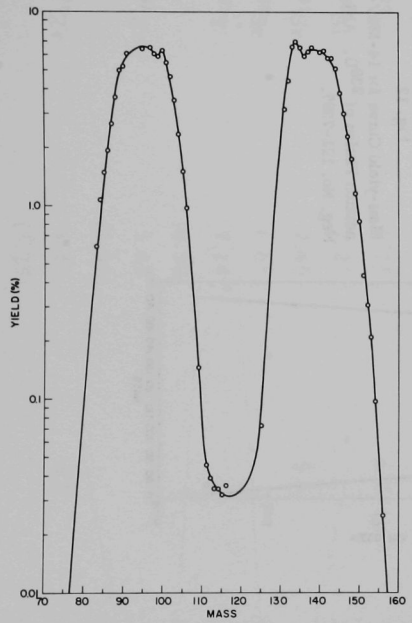

Fig. 7. Mass-yield Curve for Fission-spectrum-neutron Fission of ^{235}U. ANL Neg. No. 121-7296.

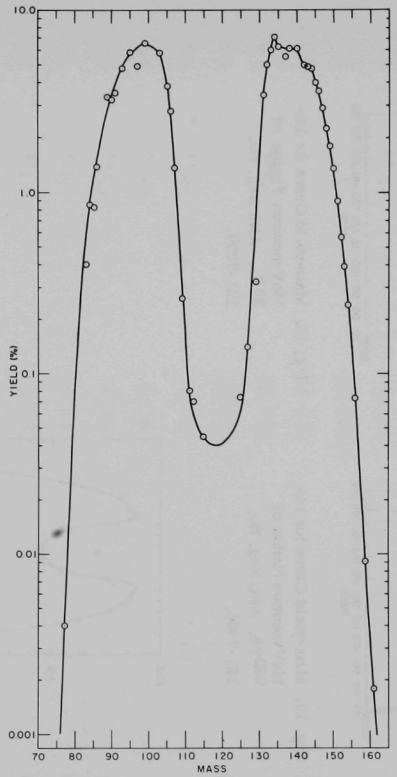

Fig. 8. Mass-yield Curve for Fission-spectrum-neutron Fission of ^{238}U. ANL Neg. No. 121-7200 Rev. 1.

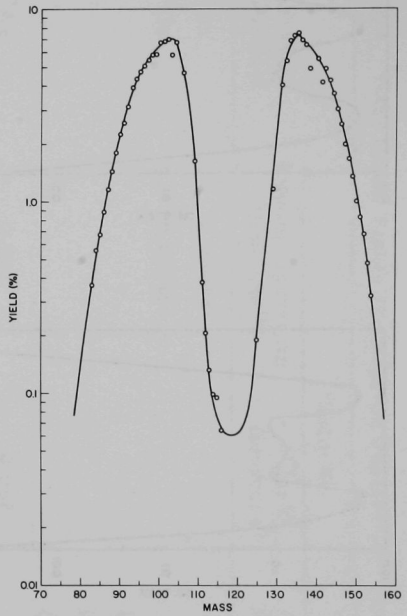

Fig. 9. Mass-yield Curve for Fission-spectrum-neutron Fission of ^{239}Pu. ANL Neg. No. 121-7297.

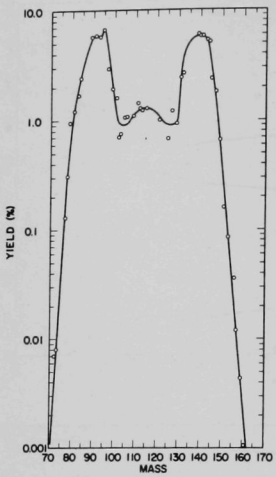

Fig. 10. Mass-yield Curve for 14-MeV-neutron Fission of ^{232}Th. ANL Neg. No. 121-7396.

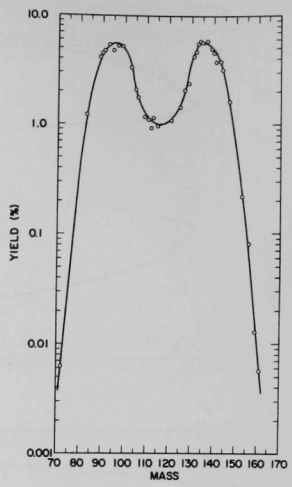

Fig. 11. Mass-yield Curve for 14-MeV-neutron Fission of ^{235}U. ANL Neg. No. 121-7399.

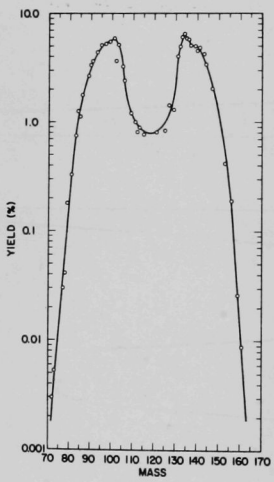

Fig. 12
Mass-yield Curve for 14-MeV-neutron Fission of ^{238}U. ANL Neg. No. 121-7397.

TABLE I. Total Chain Yields for Neutron Fission of ^{232}Th

Mass Number	Fission Product	Yield, %		
		Fission-spectrum Neutrons[15]	8-MeV Neutrons[5]	14-MeV Neutrons[2]
72	^{72}Zn	0.00033[3]		0.0070[8]
73	^{73}Ga	0.00045[3]		0.008[10]
74				(0.015)
75				(0.035)
76				(0.075)
77	^{77}As	0.014	0.052	0.13[10]
78	^{78}As	(0.035)		0.31[10]
79	^{79}As	(0.085)		0.95[10]
80		(0.17)		(0.90)
81	^{81}Se	(0.38)		1.21[10]
82		(0.83)		(1.6)
83	^{83}Br, ^{83}Kr	2.06	2.72	1.69[12]
84	^{84}Kr	3.78		2.41[12]
85	^{85}Kr	4.01		(3.0)
86	^{86}Kr	6.21		(3.55)
87	^{87}Kr	6.57		(4.2)
88	^{88}Kr	6.92		(4.9)
89	^{89}Sr	6.7[3]	6.7	5.7
90	^{90}Sr	7.2[3]		(5.8)
91	^{91}Sr	7.45	5.6	5.88
92	^{92}Sr	6.6[3]		(5.9)
93	^{93}Y	7.24[16]		5.78
94		(6.55)		(6.3)
95	^{95}Zr	5.43		6.7
96		(5.35)		(5.4)
97	^{97}Zr	4.52	5.0	2.93[12]
98		(3.75)		(2.8)

TABLE I (Contd.)

Mass Number	Fission Product	Yield, %		
		Fission-spectrum Neutrons[15]	8-MeV Neutrons[5]	14-MeV Neutrons[2]
99	^{99}Mo	2.86	3.1	1.92
100		(1.35)		(1.5)
101	^{101}Mo	(0.67)		1.60
102	^{102}Mo	(0.33)		0.70
103	^{103}Ru	0.146	0.50	0.75
104		(0.085)		(0.9)
105	^{105}Rh	0.05[3]		1.06
106	^{106}Ru	0.062[17]	0.53	1.07
107		(0.057)		(1.0)
108		(0.054)		(1.05)
109	^{109}Pd	0.052[3]		1.10
110		(0.050)		(1.15)
111	^{111}Ag	0.082[17]	0.63	1.42
112	^{112}Pd	0.090[17]		1.29
113	^{113}Ag	0.045[3]		1.23
114		(0.045)		(1.3)
115	^{115}Cd	0.065[3]	0.76	1.28
116		(0.045)		(1.3)
117	^{117}In	0.053[3]	0.37	(1.26)
118		(0.046)		(1.24)
119		(0.047)		(1.19)
120		(0.049)		(1.14)
121	^{121}Sn	(0.050)		1.0
122		(0.052)		(1.02)
123	^{123}Sn	0.029[3]		(0.95)
124		(0.058)		(0.92)
125	^{125}Sn	0.026[3]		0.58

TABLE I (Contd.)

Mass Number	Fission Product	Yield, %		
		Fission-spectrum Neutrons[15]	8-MeV Neutrons[5]	14-MeV Neutrons[2]
126		(0.071)		(0.90)
127	^{127}Sb	0.110[3]		1.21
128		(0.205)		(0.92)
129	^{129}Sb	(0.42)		0.93[12]
130		(0.85)		(1.45)
131	^{131}I, ^{131}Xe	1.56	2.3	2.44[12]
132	^{132}Te, ^{132}Xe	2.76	1.8	2.68
133	^{133}I	3.75		(4.35)
134	^{134}Xe	5.18		(4.75)
135	^{135}I	4.66		(5.15)
136	^{136}Xe	5.44		(5.4)
137	^{137}Cs	6.46[16]		(5.6)
138		(6.85)		(5.75)
139	^{139}Cs, ^{139}Ba	5.92[16]	9.0	6.02
140	^{140}Ba	7.64[16]		5.8[8]
141	^{141}Ce	7.05[16]		5.84
142		(7.65)		(5.55)
143	^{143}Ce, ^{143}Pr	6.72[16]		5.35
144	^{144}Ce	7.52[16]	7.2	5.12
145	^{145}Nd	5.52		2.38[12]
146	^{146}Nd	4.73		(2.05)
147	^{147}Nd	3.09[16]		1.81[8]
148	^{148}Nd	2.08		(0.93)
149	^{149}Pm	1.15[16]		0.66
150	^{150}Nd	1.04		(0.31)
151	^{151}Pm	0.422[16]		0.16
152		(0.30)		(0.15)

TABLE I (Contd.)

Mass Number	Fission Product	Yield, %		
		Fission-spectrum Neutrons[15]	8-MeV Neutrons[5]	14-MeV Neutrons[2]
153	^{153}Sm	0.198[16]		0.085
154		(0.036)		(0.057)
155		(0.009)		(0.034)
156	^{156}Eu	0.0024[16]		0.036
157	^{157}Eu			0.012
158				(0.0075)
159	^{159}Gd			0.0044[8]
160				(0.0028)
161	^{161}Tb			0.00106[8]

TABLE II. Total Chain Yields for Neutron Fission of ^{233}U

Mass Number	Fission Product	Yield, %		
		Thermal Neutrons[4]	Fission-spectrum Neutrons[5]	14-MeV Neutrons[5]
75		(0.0022)		
76		(0.0068)		
77	^{77}As	0.019		
78		(0.062)	(0.12)	
79		(0.135)	(0.195)	
80		(0.265)	(0.35)	
81	^{81}Se	0.34[3]	(0.55)	
82		(0.78)	(0.82)	
83	^{83}Kr	1.05	(1.2)	
84	^{84}Kr	1.76	(1.75)	
85	^{85}Rb	2.42	(2.35)	
86	^{86}Kr	2.96	(3.1)	

TABLE II (Contd.)

Mass Number	Fission Product	Yield, % Thermal Neutrons[4]	Fission-spectrum Neutrons[5]	14-MeV Neutrons[5]
87	^{87}Rb	4.47	(3.95)	
88	^{88}Sr	5.37	(4.95)	
89	^{89}Sr	6.10	6.30	
90	^{90}Sr	6.30	(6.6)	
91	^{91}Zr	6.60	6.61[3]	
92	^{92}Zr	6.63	(6.7)	
93	^{93}Zr	7.02	(6.7)	
94	^{94}Zr	6.70	(6.6)	
95	^{95}Zr, ^{95}Mo	6.13	(6.4)	
96	^{96}Zr	5.64	(6.2)	
97	^{97}Mo	5.59	(5.8)	
98	^{98}Mo	5.25	(5.4)	
99	^{99}Mo	5.12	4.75	3.5
100	^{100}Mo	4.49	(3.7)	
101	^{101}Ru	3.10	(2.6)	
102	^{102}Ru	2.38	(1.55)	
103	^{103}Ru	1.63	0.413	2.31
104	^{104}Ru	1.00	(0.23)	
105	^{105}Ru	0.50	(0.17)	
106	^{106}Ru	0.25	0.16	1.52
107		(0.12)	(0.12)	
108		(0.055)	(0.105)	
109	^{109}Pd	0.040	(0.09)	
110		(0.022)	(0.08)	
111	^{111}Ag	0.023	0.0837	1.22
112	^{112}Pd	0.016	(0.067)	
113		(0.016)	(0.064)	

TABLE II (Contd.)

Mass Number	Fission Product	Yield, %		
		Thermal Neutrons[4]	Fission-spectrum Neutrons[5]	14-MeV Neutrons[5]
114		(0.015)	(0.062)	
115	^{115}Cd	0.020	0.056	1.05
116		(0.0145)	(0.061)	
117[a]	^{117}Sn	0.0146[6]	0.060[6]	
118[a]	^{118}Sn	0.0151[6]	0.060[6]	
119[a]	^{119}Sn	0.0153[6]	0.074[6]	
120[a]	^{120}Sn	0.0170[6]	0.083[6]	
121	^{121}Sn	0.018	(0.081)	
122[a]	^{122}Sn	0.0190[6]	0.083[6]	
123		(0.022)	(0.108)	
124[a]	^{124}Sn	0.0312[6]	0.120[6]	
125	^{125}Sb	0.050	(0.165)	
126[a]	^{126}Sn	0.0810[6]	0.286[6]	
127	^{127}Sb	0.59[3]	(0.33)	
128		(1.10)	(0.55)	
129		(1.94)	1.57	
130	^{130}Te	2.33	(2.4)	
131	^{131}I, ^{131}Xe	3.46	(3.4)	
132	^{132}I, ^{132}Xe	4.74	4.36	3.98
133	^{133}Xe, ^{133}Cs	5.96	(5.3)	
134	^{134}Xe	6.09	(5.8)	
135	^{135}Cs	6.0[3]	(6.1)	
136	^{136}Xe	6.68	(6.4)	
137	^{137}Cs	6.58	6.28	4.7
138	^{138}Ba	6.3	(6.6)	
139	^{139}Ba	6.64	(6.6)	
140	^{140}Ce	6.59	6.31	

TABLE II (Contd.)

Mass Number	Fission Product	Yield, %		
		Thermal Neutrons[4]	Fission-spectrum Neutrons[5]	14-MeV Neutrons[5]
141	^{141}Ce	6.77	6.74	5.0
142	^{142}Ce	6.72	(6.3)	
143	^{143}Ce, ^{143}Nd	5.86	5.0[3]	
144	^{144}Ce, ^{144}Nd	4.62	4.2[3]	
145	^{145}Nd	3.38	(3.1)	
146	^{146}Nd	2.54	(2.3)	
147	^{147}Nd, ^{147}Sm	1.86	1.60[3]	
148	^{148}Nd	1.29	(1.15)	
149	^{149}Sm	0.77	0.82[3]	
150	^{150}Nd	0.51	(0.73)	
151	^{151}Sm	0.36	0.35[3]	
152	^{152}Sm	0.186[9]	(0.22)	
153	^{153}Sm, ^{153}Eu	0.12	0.12[3]	
154	^{154}Sm	0.0458[9]		
155		(0.03)		
156	^{156}Eu	0.0116	0.018[3]	
157	^{157}Eu	0.00635	0.0105[3]	
158		(0.0024)		
159	^{159}Gd	0.000905	0.0018[3]	
160				
161	^{161}Tb	0.000117	0.00049[3]	

[a]Relative fission yields for tin isotopes were determined mass-spectrometrically.[6] These yields were normalized in the case of thermal-neutron fission to 0.017% fission yield for ^{120}Sn, and in the case of fission-spectrum-neutron fission to 0.060% fission yield for ^{117}Sn.

TABLE III. Total Chain Yields for Neutron Fission of ^{235}U

Mass Number	Fission Product	Yield, %			
		Thermal Neutrons[1]	Fission-spectrum Neutrons[1]	8-MeV Neutrons[5]	14-MeV Neutrons[2]
72	^{72}Zn	0.000016			0.0063[8]
73	^{73}Ga	0.00010			(0.010)
74	^{74}Ga	0.00035			(0.016)
75	^{75}GE	0.0008[5]			(0.028)
76		(0.0025)			(0.046)
77	^{77}As	0.0083	(0.012)		(0.078)
78	^{78}As	0.020	(0.025)		(0.13)
79	^{79}As	0.056	(0.050)		(0.24)
80		(0.104)	(0.097)		(0.39)
81	^{81}Se	0.148	(0.195)		(0.59)
82		(0.32)	(0.315)		(0.84)
83	^{83}Br, ^{83}Kr	0.544	0.615		1.23
84	^{84}Kr	0.97	1.07[9]		(1.5)
85	^{85}Rb	1.30	1.49[9]		(1.90)
86	^{86}Kr	1.89	1.93		(2.35)
87	^{87}Rb	2.53	2.66		(2.85)
88	^{88}Sr	3.58	3.63		(3.4)
89	^{89}Sr	4.76	5.0		4.16
90	^{90}Sr	5.83	5.24		4.5
91	^{91}Zr	5.90	6.1[3]		4.71
92	^{92}Zr	5.98	(6.2)		(5.05)
93	^{93}Zr	6.39	(6.4)		5.4[8]
94	^{94}Zr	6.44	(6.5)		(5.45)
95	^{95}Zr, ^{95}Mo	6.41	6.47[9]		4.80
96	^{96}Zr	6.29	(6.6)		(5.6)
97	^{97}Zr, ^{97}Mo	6.21	6.55		5.29

TABLE III (Contd.)

Mass Number	Fission Product	Yield, %			
		Thermal Neutrons[1]	Fission-spectrum Neutrons[1]	8-MeV Neutrons[5]	14-MeV Neutrons[2]
98	^{98}Mo	5.86	6.04[9]		(5.45)
99	^{99}Mo	6.16	5.9	5.4	5.25
100	^{100}Mo	6.44	6.35[9]		(4.85)
101	^{101}Ru	5.02	5.46		(4.5)
102	^{102}Ru	4.17	4.65		(4.0)
103	^{103}Ru	3.0	3.5		3.35
104	^{104}Ru	1.81	2.35		(2.6)
105	^{105}Ru, ^{105}Rh	0.90	1.50		2.09
106	^{106}Ru	0.399	0.97		1.76
107	^{107}Rh	0.19	(0.50)		(1.55)
108		(0.075)	(0.17)		(1.4)
109	^{109}Pd	0.030	0.146		1.17
110		(0.020)	(0.078)		(1.21)
111	^{111}Ag	0.019	0.0456[9]		1.11
112	^{112}Pd	0.010	0.039[9]		0.93
113	^{113}Ag	(0.012)	0.0342[9]		1.15
114	^{114}Cd	(0.011)	0.0342[9]		(1.03)
115	^{115}Cd	0.0104	0.032		0.97
116	^{116}Cd	(0.0104)	0.0359[9]		(1.00)
117	^{117}Cd	0.011	(0.032)		(1.01)
118		(0.0105)	(0.032)		(1.02)
119		(0.0107)	(0.033)		(1.05)
120		(0.0113)	(0.034)		(1.08)
121	^{121}Sn	0.014	(0.036)		1.09
122		(0.013)	(0.040)		(1.19)
123	^{123}Sn	0.015[5]	(0.045)		(1.27)

TABLE III (Contd.)

Mass Number	Fission Product	Yield, %			
		Thermal Neutrons[1]	Fission-spectrum Neutrons[1]	8-MeV Neutrons[5]	14-MeV Neutrons[2]
124		(0.017)	(0.056)		(1.38)
125	^{125}Sb	0.0291[9]	0.073[9]		1.45
126		(0.064)	(0.20)		(1.7)
127	^{127}Sb	0.137	(0.38)		2.09
128	^{128}Sn	0.46	(0.71)		(2.5)
129	^{129}I, ^{129}Sb	1.0	(1.40)		(2.40)
130	^{130}Sb	2.0[3]	(2.4)		(3.95)
131	^{131}I, ^{131}Xe	2.93	3.17		4.23
132	^{132}Te, ^{132}Xe	4.33	4.45[9]		4.70
133	^{133}Xe, ^{133}Cs	6.69	6.69		5.6
134	^{134}Xe	7.92	7.09		5.9
135	^{135}Xe, ^{135}Cs	6.43	6.54		5.7
136	^{136}Xe	6.46	5.93		(5.7)
137	^{137}Cs	6.18	6.25		5.9
138	^{138}Ba	6.71	6.60		(5.5)
139	^{139}Ba	6.48	(6.45)		5.0
140	^{140}Ba, ^{140}Ce	6.34	6.21[9]		4.61
141	^{141}Ce	6.1	6.3		3.8
142	^{142}Ce	5.90	5.82		(4.25)
143	^{143}Ce, ^{143}Nd	5.91	5.80		3.81
144	^{144}Ce, ^{144}Nd	5.40	5.15	3.6	3.20
145	^{145}Nd	3.88	3.85		(2.50)
146	^{146}Nd	2.95	3.00		(1.98)
147	^{147}Nd, ^{147}Sm	2.19	2.3	2.05	1.64[8]
148	^{148}Nd	1.67	1.75		(1.16)
149	^{149}Pm, ^{149}Sm	1.04	1.16	1.25	(0.85)

TABLE III (Contd.)

Mass Number	Fission Product	Yield, %			
		Thermal Neutrons[1]	Fission-spectrum Neutrons[1]	8-MeV Neutrons[5]	14-MeV Neutrons[2]
150	^{150}Nd	0.65	0.832		(0.62)
151	^{151}Sm	0.42	0.438		(0.45)
152	^{152}Sm	0.24	0.309		(0.31)
153	^{153}Sm, ^{153}Eu	0.158	0.21	0.185	0.22[8]
154	^{154}Sm	0.064	0.098	0.035	(0.153)
155	^{155}Eu	0.031	(0.050)		(0.105)
156	^{156}Eu	0.0134	0.025		0.08
157	^{157}Eu	0.0066			(0.038)
158	^{158}Eu	0.0037			(0.023)
159	^{159}Gd	0.00105	0.0034	0.0063	0.0127[8]
160					(0.0076)
161	^{161}Tb	0.000082	0.00046	0.0020	0.0056[8]

TABLE IV. Total Chain Yields for Neutron Fission of ^{238}U

Mass Number	Fission Product	Yield, %		
		Fission-spectrum Neutrons[1]	8-MeV Neutrons[5]	14-MeV Neutrons[1]
72	^{72}Zn			0.003[8]
73	^{73}Ga			0.0053[10]
74				(0.007)
75				(0.012)
76		(0.0011)		(0.021)
77	^{77}As	0.0040		0.030[10]
78	^{78}As	(0.010)		0.041[10]
79	^{79}As	(0.031)		0.18[10]
80		(0.087)		(0.20)

TABLE IV (Contd.)

Mass Number	Fission Product	Yield, %		
		Fission-spectrum Neutrons[1]	8-MeV Neutrons[5]	14-MeV Neutrons[1]
81	^{81}Se	(0.17)		0.33[10]
82		(0.32)		(0.56)
83	^{83}Br, ^{83}Kr	0.40		0.75[11]
84	^{84}Kr	0.85		1.26[11]
85	^{85}Kr	0.83		1.12[11]
86	^{86}Kr	1.38		1.76[11]
87		(1.93)		(2.0)
88		(2.36)		(2.4)
89	^{89}Sr	3.3		2.66
90	^{90}Sr	3.2		3.35
91	^{91}Sr	3.50[18]		3.66[11]
92	^{92}Sr	(4.45)		(4.0)
93	^{93}Y	4.77[18]		4.4[8]
94		(5.35)		(4.7)
95	^{95}Zr	5.8		5.11
96		(6.0)		(5.2)
97	^{97}Zr	(6.2)		5.27[11]
98		(6.45)		(5.5)
99	^{99}Mo	6.56	6.2	5.50[11]
100		(6.55)		(5.7)
101	^{101}Mo	(6.35)		5.90[2]
102	^{102}Mo	(6.1)		3.65[2]
103	^{103}Ru	5.8		5.15[11]
104		(4.9)		(4.3)
105	^{105}Rh	3.81[18]		3.23[2]
106	^{106}Ru	2.8		2.40[2]
107	^{107}Rh	1.36[18]		(1.7)

TABLE IV (Contd.)

Mass Number	Fission Product	Yield, %		
		Fission-spectrum Neutrons[1]	8-MeV Neutrons[5]	14-MeV Neutrons[1]
108		(0.68)		(1.4)
109	^{109}Pd	0.26		1.20[2]
110		(0.165)		(1.1)
111	^{111}Ag	0.080		1.00[14]
112	^{112}Pd	0.07		0.81[14]
113	^{113}Ag	(0.053)		0.89[14]
114		(0.048)		(0.86)
115	^{115}Cd	0.045		0.77
116		(0.042)		(0.82)
117		(0.041)		(0.80)
118		(0.040)		(0.80)
119		(0.041)		(0.80)
120		(0.042)		(0.81)
121	^{121}Sn	(0.043)		0.81[2]
122		(0.045)		(0.86)
123		(0.048)		(0.89)
124		(0.053)		(0.94)
125	^{125}Sn	0.074		0.84
126		(0.081)		(1.18)
127	^{127}Sb	0.14		1.43
128		(0.34)		(1.40)
129	^{129}Sb	0.329[18]		1.30[2]
130		(1.45)		(2.45)
131	^{131}I, ^{131}Xe	3.40[13]		4.02[11]
132	^{132}Te, ^{132}Xe	4.98[13]		4.94[11]
133	^{133}Xe	6.00[13]		6.08[11]
134	^{134}Xe	7.00[13]		6.50[11]

TABLE IV (Contd.)

Mass Number	Fission Product	Yield, %		
		Fission-spectrum Neutrons[1]	8-MeV Neutrons[5]	14-MeV Neutrons[1]
135	^{135}Cs	6.23[13]		5.89[11]
136	^{136}Xe	6.28[13]		5.74[11]
137	^{137}Cs	5.52[13]		5.08[11]
138	^{138}Ba	6.10[13]		(5.1)
139	^{139}Ba	(6.10)		5.02[11]
140	^{140}Ba	6.15[13]		4.54[11]
141	^{141}Ce	(5.40)		4.84[11]
142	^{142}Ce	4.92[13]		(4.2)
143	^{143}Ce, ^{143}Nd	4.84[13]		4.26[11]
144	^{144}Ce, ^{144}Nd	4.77[13]	4.1	3.4
145	^{145}Nd	3.99[13]		(2.9)
146	^{146}Nd	3.60[13]		(2.5)
147	^{147}Nd, ^{147}Pm	2.9	2.7	2.03[11]
148	^{148}Nd	2.23[13]		(1.8)
149	^{149}Pm	1.80[13]	1.9	(1.5)
150	^{150}Nd	1.37[13]		(1.2)
151	^{151}Sm	0.90[13]		(0.95)
152	^{152}Sm	0.57[13]		(0.75)
153	^{153}Sm	0.39	0.41	0.42[8]
154	^{154}Sm	0.24[13]	0.090	(0.38)
155		(0.15)		(0.25)
156	^{156}Eu	0.073		0.19
157		(0.038)		(0.10)
158		(0.018)		(0.05)
159	^{159}Gd	0.0091	0.017	0.026[8]
160		(0.0038)		(0.015)
161	^{161}Tb	0.0018	0.0043	0.0089[8]

TABLE V. Total Chain Yields for Neutron Fission of ^{239}Pu

Mass Number	Fission Product	Yield, %		
		Thermal Neutrons[1]	Fission-spectrum Neutrons[1]	14-MeV Neutrons[1]
72	^{72}Zn	0.00011		
73				
74				
75				
76				
77	^{77}As	0.0072		
78	^{78}As	0.026		
79		(0.030)	(0.090)	
80		(0.088)	(0.135)	
81	^{81}Se	0.178	(0.19)	
82		(0.24)	(0.265)	
83	^{83}Kr	0.29	0.366[9]	
84	^{84}Kr	0.47	0.559[9]	
85	^{85}Rb	0.56	0.672[9]	
86	^{86}Kr	0.75	0.882[9]	
87	^{87}Rb	0.91	1.16[9]	
88	^{88}Sr	1.41	1.44[9]	
89	^{89}Sr	1.73	1.8	2.4[5]
90	^{90}Sr	2.24	2.24[9]	
91	^{91}Zr	2.60	2.58[9]	2.7[5]
92	^{92}Zr	3.06	3.13[9]	
93	^{93}Zr	3.89	3.91[9]	
94	^{94}Zr	4.42	4.39[9]	
95	^{95}Zr, ^{95}Mo	5.20	4.78[9]	
96	^{96}Zr	5.06	5.11[9]	
97	^{97}Zr, ^{97}Mo	5.61	5.47[9]	5.3[5]
98	^{98}Mo	5.84	5.81[9]	

TABLE V (Contd.)

Mass Number	Fission Product	Yield, %		
		Thermal Neutrons[1]	Fission-spectrum Neutrons[1]	14-MeV Neutrons[1]
99	^{99}Mo	5.91	5.88	5.5[5]
100	^{100}Mo	7.05	6.76[9]	
101	^{101}Ru	5.86	6.88[9]	
102	^{102}Ru	5.94	6.97[9]	
103	^{103}Ru	5.60	5.85	6.25[5]
104	^{104}Ru	5.88	6.77[9]	
105	^{105}Rh	5.47	(5.75)	
106	^{106}Ru	4.40	4.7	4.16[5]
107		(3.55)	(3.65)	
108		(2.5)	(2.65)	
109	^{109}Pd	1.20	1.64	
110		(0.48)	(0.85)	
111	^{111}Ag	0.25	0.38	1.46[5]
112	^{112}Pd	0.10	0.207[9]	
113	^{113}Ag	0.072	0.133[9]	
114	^{114}Cd	(0.052)	0.099[9]	
115	^{115}Cd	0.039	0.095	1.03[5]
116	^{116}Cd	(0.044)	0.064[9]	
117		(0.042)	(0.062)	
118		(0.041)	(0.061)	
119		(0.041)	(0.061)	
120		(0.042)	(0.062)	
121	^{121}Sn	0.041	(0.064)	
122		(0.045)	(0.071)	
123		(0.049)	(0.082)	
124		(0.056)	(0.115)	
125	^{125}Sn	0.069	0.19[9]	

TABLE V (Contd.)

Mass Number	Fission Product	Yield, % Thermal Neutrons[1]	Fission-spectrum Neutrons[1]	14-MeV Neutrons[1]
126		(0.22)	(0.33)	
127	^{127}Sb	0.46	(0.56)	
128		(0.92)	(0.93)	
129		(1.8)	1.17[5]	
130		(3.15)	(2.7)	
131	^{131}I, ^{131}Xe	3.69	4.06[9]	
132	^{132}Te, ^{132}Xe	5.20	5.42[9]	4.58[5]
133	^{133}Cs	6.60	6.91[9]	
134	^{134}Xe	7.31	7.35[9]	
135	^{135}Xe, ^{135}Cs	7.21	7.54[9]	
136	^{136}Xe	6.66	6.92[9]	
137	^{137}Cs	6.56	6.58[9]	5.1[5]
138	^{138}Ba	5.91	4.97[9]	
139	^{139}Ba	5.67	(6.0)	
140	^{140}Ba, ^{140}Ce	5.51	5.59	4.35[5]
141	^{141}Ce	5.75	(5.15)	
142	^{142}Ce	4.87	4.95[9]	
143	^{143}Ce, ^{143}Nd	4.52	4.30[9]	
144	^{144}Ce, ^{144}Nd	3.79	3.68[9]	
145	^{145}Nd	2.99	3.05[7]	
146	^{146}Nd	2.45	2.53[7]	
147	^{147}Nd, ^{147}Pm	1.87	2.0	
148	^{148}Nd	1.68	1.69[7]	
149	^{149}Sm	1.30	1.36[9]	
150	^{150}Nd	0.98	1.01[7]	
151	^{151}Sm	0.76	0.839[9]	
152	^{152}Sm	0.57	0.683[9]	

TABLE V (Contd.)

Mass Number	Fission Product	Yield, % Thermal Neutrons[1]	Fission-spectrum Neutrons[1]	14-MeV Neutrons[1]
153	^{153}Sm	0.36	0.48	
154	^{154}Sm	0.25	0.324[9]	
155	^{155}Sm	0.23[5]	(0.21)	
156	^{156}Eu	0.09	(0.14)	
157		(0.090)	(0.09)	
158	^{158}Gd	0.0615[5]		
159	^{159}Gd	0.021		
160		(0.0094)		
161	^{161}Tb	0.0039		

TABLE VI. Total Chain Yields for Thermal-neutron Fission of ^{241}Pu

Mass Number	Fission Product	Yield,[1] %	Mass Number	Fission Product	Yield,[1] %
77	^{77}As	0.000465	90	^{90}Sr	1.53
78	^{78}As	0.0082	91	^{91}Zr	1.82
79		(0.016)	92	^{92}Zr	2.23
80		(0.030)	93	^{93}Zr	2.90
81		(0.058)	94	^{94}Zr	3.33
82		(0.104)	95	^{95}Zr	5.03
83	^{83}Br, ^{83}Kr	0.204	96	^{96}Zr	4.33
84	^{84}Kr	0.347	97	^{97}Zr	5.31
85	^{85}Rb	0.387	98		(5.9)
86	^{86}Kr	0.601	99	^{99}Mo	6.17[9]
87	^{87}Rb	0.741	100		(6.05)
88	^{88}Sr	0.954	101	^{101}Mo	5.94[9]
89		(1.20)	102	^{102}Mo	6.32[9]

TABLE VI (Contd.)

Mass Number	Fission Product	Yield,[1] %	Mass Number	Fission Product	Yield,[1] %
103		(6.60)	132	^{132}Xe	4.56
104	^{104}Te	6.80[9]	133	^{133}Xe, ^{133}Cs	6.59
105		(6.45)	134	^{134}Xe	7.94
106	^{106}Ru	6.08	135	^{135}I, ^{135}Cs	7.30
107		(5.15)	136	^{136}Xe	7.04
108		(4.15)	137	^{137}Cs	6.49
109		(2.9)	138	^{138}Ba	6.65
110		(1.4)	139		(6.30)
111	^{111}Ag	0.513	140	^{140}Ba, ^{140}Ce	5.95
112		(0.32)	141	^{141}Ce	5.02
113	^{113}Ag	0.158	142	^{142}Ce	4.75
114		(0.065)	143	^{143}Nd	4.50
115		(0.037)	144	^{144}Ce, ^{144}Nd	4.09
116		(0.033)	145	^{145}Nd	3.15
117		(0.031)	146	^{146}Nd	2.66
118		(0.030)	147	^{147}Sm	2.28
119		(0.029	148	^{148}Nd	1.87
120		(0.029)	149	^{149}Sm	1.49
121		(0.030)	150	^{150}Nd	1.17
122		(0.031)	151	^{151}Sm	0.959
123		(0.032)	152	^{152}Sm	0.741
124		(0.036)	153		(0.57)
125	^{125}Sn	0.0416[9]	154	^{154}Sm	0.389
126		(0.10)	155		(0.29)
127		(0.21)	156		(0.20)
128		(0.41)	157		(0.14)
129		(0.82)	158		(0.095)
130		(1.65)	159		(0.065)
131	^{131}Xe	3.10	160		(0.045)

TABLE VII. Total Yields for Light and Heavy Mass Groups in Various Fissioning Systems

Fissioning System	Total Yield, %	
	Light Group	Heavy Group
^{232}Th (fission-spectrum neutron)	97.9	99.9
^{232}Th (14-MeV neutron)	97.9	95.2
^{233}U (thermal neutron	100.4	100.4
^{233}U (fission-spectrum neutron)	97.0	96.0
^{235}U (thermal neutron)	99.8	100.9
^{235}U (fission-spectrum neutron)	104.9	101.9
^{235}U (14-MeV neutron)	105.9	101.2
^{238}U (fission-spectrum neutron)	103.1	98.7
^{238}U (14-MeV neutron)	102.6	99.2
^{239}Pu (thermal neutron)	99.1	99.8
^{239}Pu (fission-spectrum neutron)	104.4	100.2
^{241}Pu (thermal neutron)	102.2	99.8

TABLE VIII. Characteristics of Mass Distributions for Neutron-induced Fission

Fissile Nuclide	Median Mass-Number at Half-maximum Height		Width of the Peaks, Mass Units		Symmetric Yield, %	Peak-to-Valley Ratio
	Light Group	Heavy Group	Half Maximum	Tenth Maximum		
Thermal-neutron Fission						
^{227}Th	89	138.5	12	20	0.035	230
^{229}Th	88	140	12	18	0.017	500
^{233}U	93.5	138	15	23	0.015	440
^{235}U	95	138.5	15	22	0.0105	620
^{239}Pu	99.5	137.5	15	25	0.04	150
^{241}Pu	101	138	15	24	0.029	230
^{245}Cm	104.5	137.5	13	26.5	0.045	155
^{249}Cf	106	139	16	28	<0.2	>30
Fission-spectrum-neutron Fission						
^{232}Th	91	139.5	14	20	0.045	170
^{231}Pa	91	139	13	22	0.07	100
^{233}U	93	138	14	21	0.06	110
^{235}U	95	138.5	15	23	0.032	205
^{238}U	97	138.5	16	24	0.04	160
^{237}Np	97	137	14	22	0.04	175
^{239}Pu	100	137.5	15	24.5	0.06	115
14-MeV-neutron Fission						
^{232}Th	91.5	138	13	-	1.3	5
^{235}U	95.5	137	16	-	1.0	6
^{238}U	97	137.5	16	-	0.8	7

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