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A SURVEY AND EVALUATION OF U^{233}
FISSION YIELD DATA

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OAK RIDGE NATIONAL LABORATORY

operated by

UNION CARBIDE CORPORATION

for the

U.S. ATOMIC ENERGY COMMISSION

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CHEMISTRY DIVISION

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and

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DATE ISSUED

JUL 13 1962

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R. L. Ferguson

G. D. O'Kelley

Abstract

A survey of the pertinent literature was made to ascertain the status of data on U^{233} fission-product yields. The various experimental determinations were evaluated, and the most recent mass-spectrometric results were used as a basis for deriving a set of preferred yields. These yields were compared with values reported in two other recent compilations, and for yields $> 1\%$, the three sets agreed with each other to an average precision of $< 5\%$. It was concluded that recent measurements have somewhat improved the reliability of U^{233} fission yield data, but some recommendations for additional experimental work were made. This report was prepared from an internal memorandum (CF-62-3-71) previously given limited distribution.

Introduction

Because of the importance of the thorium-uranium cycle in the breeder reactor concept, it is desirable to determine accurately the properties of U^{233} which affect its use as a reactor fuel. In particular, estimation of the effects of fission-product poisoning, evaluation of problems connected with the chemical reprocessing of irradiated fuel, and calculation of shielding requirements demand accurate values for the yields of the various fission products.

Compilations of fission-product yields from thermal-neutron fission of U^{233} have been made by several authors (1-6). Recently, Katcoff (7) reviewed all data available in late 1960 and revised the

selected values given in his earlier compilation. Walker also has evaluated the recent data (8). The latest tabulation was published by Garrison and Roos (9), who did not describe the method they used for obtaining their listed values. They apparently used the results of Walker (8) and of Katcoff (5), with some adjustment and smoothing of the data.

In addition, yields from fission of U^{233} induced by neutrons of energy greater than thermal have been reported by Bonyushkin et al. (10) for 14-Mev neutrons and by Regier et al. (11) for epithermal neutrons. The paper of Regier et al. reports relative "peak-to-valley" ratios for fission induced by resonance neutrons, compared to the value for thermal-neutron fission.

However, it was pointed out by several reviewers that data on U^{233} fission yields were incomplete and uncertain (12,13). Therefore, it seemed desirable that we evaluate independently all the published data and summarize the current status of the U^{233} fission yields. We have also attempted to point out several areas in which future work might profitably be done.

Summary of Published Values

We have surveyed the original literature (14-30) and have included in Table 1 of the Appendix all the published values for U^{233} thermal-neutron fission yields. The reported values are plotted in Fig. 1, which uses a linear ordinate scale to show details of the peaks; the logarithmic ordinate scale of Fig. 2 expands the detail of the valley region. It is obvious that large discrepancies exist. Only a few of these discrepancies were removed when the earlier relative yields were renormalized to the more recent absolute values tabulated by

Figure 1. Published Values of U-233 Thermal-Neutron Fission Yields from Table 1. Linear scale.

Figure 2. Published Values of U-233 Thermal-Neutron Fission Yields from Table 1. Semilogarithmic scale.

Katcoff (7). Table 2 of the Appendix summarizes the data from previous compilations of yields (1-9).

There have also been several measurements of the mass-yield distributions of the fission fragments from U^{233} by purely physical techniques (31-33). Although these techniques do not have the perfect mass resolution inherent in chemical methods, the use of semiconductor radiation detectors in determinations of fission yields at resonance energies may be very informative and is under consideration by Melkonian and Mehta (34).

Selection of Preferred Yields

Except for the two early series of radiometric measurements (14, 15) and the two recent sets of radiometric measurements (28, 30), essentially all the reported U^{233} yields have been determined mass-spectrometrically by groups at McMaster University (17, 19, 26, 29), in the U.S.S.R. (4, 20, 22-25, 27), and at the Argonne National Laboratory (18). In selecting his "best values", Katcoff (7) weighted the mass-spectrometrically determined yields more heavily than radiometrically determined ones. He averaged duplicate yields that he judged to be equally reliable; or, when one value was considered to be superior to others, he selected that one. Walker (8) selected a set of preferred values based primarily on recent mass-spectrometric yield determinations. Before we learned of Walker's work, we also had assumed that the most recent results of the mass-spectrometer groups (4, 18, 27, 29) represent the most reliable data and had selected these yields as the basis for our "best values". For convenience, these selected yields are listed again in Table 3 of the Appendix, and are plotted in Fig. 3. The

Figure 3. Selected Mass-Spectrometric Yield Values.

following paragraphs outline the procedure by which we obtained our set of preferred yields.

The most nearly complete set of yield data is given by Bidinosti et al. (29). Nearly all of these yields were normalized to each other mass-spectrometrically, and the number of fission product atoms produced was determined absolutely. Exceptions were the normalization of Ru yields to Mo yields using radiometric data and the adjustment of the Zr-Mo-Ru group of yields to force the light mass peak to total 100%. These authors state that, when they forced their measured and interpolated yields in the heavy peak to total 100%, the absolute number of fission product atoms was 2-4% greater than that calculated from flux monitors which they had included in their experiments.

We have reduced their reported absolute yields by 3%, in agreement with their flux measurements, and find that the sum of the measured and interpolated yields is then 100% for each peak. Obviously this kind of normalization depends somewhat on how one interpolates to obtain missing yields. We have used the radiometric yields* of Steinberg and Glendenin (3) to obtain some of the missing yields, especially in the valley, and have "reflected" measured yields from one peak to the other to obtain the shape of the mass-yield curve where several yields were missing. The reported values from Refs. 4, 18, and 27 have been

* We chose not to use the radiometric yields of Santry and Yaffe (30) because several of their values deviate widely from the mass-spectrometric data, and it was not possible to correct their data in any reasonable way to agree with the mass-spectrometric results.

renormalized to these corrected yields of Bidinosti et al., and are shown in Table 4 (Appendix), along with the average values and some radiometric data. For yields of $> 1\%$, differences between the values we have selected and those of Katcoff (7) are between 0.2 and 12.5%, with the average difference being 2.3%. The corresponding differences between our values and those of Walker (8) were between 0.0 and 23.5%, with the average difference being 3.6%. Since all three sets of preferred yields were obtained by independent evaluations of the published data, these differences are probably an indication of the reliability of such selected values. Our selected values are plotted in Fig. 4 together with those yields of $> 1\%$ reported by Katcoff and by Walker which differ from ours by more than the average differences.

Conclusions and Recommendations

While the selected yields given here are felt to be accurate to 5 - 10% for the most part, their absolute values depend somewhat on the yield values at several interpolated points (because of the normalization procedures used). The yields at masses 128, 129, and 130 are the most significant yields missing from the heavy peak. Two important normalization points in the light peak are at masses 99 and 103; the previously-reported (15, 30) absolute radiometric yields at these masses should perhaps be redetermined. In addition, there are several yields missing from the valley of the mass-yield curve, and most of the reported yields are from the early work of Steinberg et al. (15). It would also be valuable to use radiometric techniques to check the mass-spectrometrically determined yields wherever feasible.

Figure 4. Preferred Yields.

In addition to the absolute measurements suggested above, relative yield measurements utilizing radiometric techniques could provide valuable information. These relative measurements would be well suited to a study of variation of yield with excitation energy. Except for the ionization chamber work of Roeland et al. (33), the only measurements made on the variation of U^{233} fission yields with neutron energy are the "peak-to-valley" determinations at three resonances (11) and a fission yield curve for 14-Mev neutrons (10). The remainder of the energy range is unexplored. That one should observe variation of yields with energy has been demonstrated in Ref. 11 and more recently in the very interesting work of Cunninghame et al. (35) and of Levy et al. (36).

Another aspect of U^{233} fission which has been studied very little is the distribution of yield with the nuclear charge of the fission products. Considerable information has been obtained on charge distribution in the fission of U^{235} (37) from a study of the cumulative yields of early members of fission product chains and the independent yields of later chain-members. Similar work on the early-member cumulative yields has been performed recently at the Los Alamos Scientific Laboratory using U^{233} (38). Measurement of the appropriate independent yields for U^{233} , combined with the results from Los Alamos could be a significant contribution toward understanding nuclear charge distribution in fission. That knowledge of the charge distribution is important to reactor technology has been pointed out by Chernick (39) for the mass-135 chain.

Finally, there is the problem of the fine structure of the mass yield curve. As Hyde (6, pp. 142-145) has pointed out, it is

generally accepted that the fine structure effects are largely accounted for by shell-preference in the fission act, although there are some unaccountable discrepancies between experiment and theory, particularly in the fission of U^{233} . A careful series of experiments aimed at minimizing effects which perturb the true mass yields (such as neutron capture by the fission products) might provide some very interesting information on the effects of nuclear structure in the fission process.

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TABLE 1. PUBLISHED U^{233} FISSION YIELDS (%)

Mass	Element Det'd	Reference																
		(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)
		R ^a	R	R	M ^b	M	M	M	R	M	M	M	M	M	M	R	M	R
77	Ge		.008															
78	As		.010															
79																		
80	Br																	
81																		
82	Br																	.000746
83	Br		.77															
	Kr				1.20												1.18	
84	Kr				2.00												1.97	
85	10.3y Kr				.593													
	Rb																2.54	
86	Kr				3.36												3.30	
	Rb																	
87	Rb																4.61	
88	Sr											5.3			5.17		5.54	
89	Sr	4.1	5.6													5.87	6.15	5.56
	Y														6.36			
90	Sr	3.7									4.56	5.8			5.58		6.75	6.19
91	Sr															5.61		4.82
	Y	4.1																3.55

APPENDIX

TABLE I - continued

Mass	Element Det'd	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)
		R ^a	R	R	M ^b	M	M	M	R	M	M	M	M	M	M	R	M	R
92	Zr					6.58									6.48		6.45	
93	Zr					6.70									6.28		6.72	
94	Zr					7.10									6.75		7.01	
94	Zr					6.82									6.43		6.68	
95	Zr	3.9	5.7														6.23	5.01
	Nb																5.16	
96	Mo					6.10											6.23	
	Zr					5.60									5.47		5.67	
	Nb																	
97	Mo					5.35											5.51	
98	Nb																	
	Mo					5.18											5.22	
99	Mo		4.7						4.96									
100	Mo					4.40											4.49	
101	Ru					3.00											2.87	
102	Ru					2.37											2.10	
103	Ru	.21	.85															2.02
104	Ru					.96											.94	
105	Rh																	.146
106	Ru	.064	.24														.22	.259
107																		
108																		
109	Pd		.047															
110																		

TABLE I - continued

Mass	Element Det'd	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)
		R ^a	R	R	M ^b	M	M	M	R	M	M	M	M	M	M	R	M	R
111	Ag	.015	.022															.0187
112	Pd		.014															.0125
113																		
114																		
115m	Cd		.001															
115	Cd		.016															
115	total		.017															
116																		
117																		
118																		
119																		
120																		
121	Sn		~.02															
122																		
123	Sn		~.03															
124																		
125	Sn																	
126	Sb	.060																
127	Sb		.092															.59
128	Te	.067																
129	Te	.22																
130																		
131	I	2.4	2.7															2.84

TABLE I - continued

Mass	Element Det'd	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)
		R ^a	R	R	M ^b	M	M	M	R	M	M	M	M	M	M	R	M	R
132	Xe				3.59 ^c												3.52	4.32
	Te																	
	I	4.9																
	Xe				4.90												4.82	
133	I																	3.37
134	Cs				5.93					5.20 ^e				5.6			5.77	
	Xe				6.28					5.50							6.18	
135	I																	
	Xe													6.0				
	Cs				>4.74												6.02	
136	I			1.7														
	Xe				<8.51												6.89	
	Cs	~.01													.08			.0849
137	Cs	1.8			6.87					5.80							6.58	5.39
138	Ba									6.16					6.35			
139	Ba															5.59		
140	La		6.0										5.91				5.60	5.21
	Ba																	
	La	6.7																
	Ce							5.60		5.45							6.72	
141	La									6.16							6.17	

TABLE I - continued

Mass	Element Det'd	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)
		R ^a	R	R	M ^b	M	M	M	R	M	M	M	M	M	M	R	M	R
142	Ce												5.57					5.30
	Pr																	
143	Ce							5.60		{ 5.50 6.06							7.00	
	Ce																	6.99
	Nd						(1.000) ^d	5.15		{ 5.00 5.19				6.45			6.22	
144	Ce	2.2	3.4														4.87	3.69
	Nd						(.779)	3.37		{ 3.60 3.84							4.87	
145	Nd						(.587)	3.00		{ 2.82 2.88							3.66	
146	Nd						(.441)	2.34		{ 2.20 2.24							2.74	
147	Pm	~.6											1.53	2.1				
148	Sm						(2.81)											
	Nd						(.224)	1.15		{ 1.03 1.07							1.40	
149	Sm						(1.000)			{ .66 .70				.8			.790	
150	Nd						(.089)	.51		{ .51 .49							.567	
	Sm						(.000)										.567	

TABLE I - continued

Mass	Element Det'd	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)
		R ^a	R	R	M ^b	M	M	M	R	M	M	M	M	M	M	R	M	R
151	Sm						(.422)			(.60			.33	.3			.334	
152	Sm						(.278)			(.54			.21				.222	
153	Sm		.078															
	Eu												.13					
154	Sm						(.061)										.048	
155																		
156	Eu																	

(a) R indicates radiometric measurements.

(b) M indicates mass-spectrometric measurements.

(c) Values listed are from low neutron flux experiment.

(d) Relative yields given. Nd^{143} and Sm^{149} used as reference points.

(e) Upper value of each pair of data from isotope dilution method; lower value from "integral" method.

TABLE 2. YIELD VALUES FROM PREVIOUS COMPILATIONS (%)

Mass	Element	Reference								
		(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
77	Ge	.008		.010		.010	.010	.011		
	As	.018	.018 ^a	.019		.019	.019	.021	.02 ^a	
78			.03						.05	
79			.12						.12	
80			.3						.25	
81			.5						.4	.45
82			.7						.7	.7
83	Br	.70		.79		.79	.79	.87		
	Kr		1.20	1.14		1.14	1.14	1.17	1.2	1.2
84	Kr		1.96	1.90		1.90	1.90	1.95	2.0	1.9
85	Kr ^g			.562		.56	.562	.58		
	Rb		2.7					2.51	2.5	1.9
86	Kr		3.33	3.18		3.18	3.18	3.27	3.3	3.2
87	Rb		4.0					4.56	4.6	4.0
88	Sr		4.7					5.37	5.5	5.0
89	Sr	5.6,4.1	6.5	6.5	5.30	6.5	6.5,5.87	5.86	6.1	6.5
90	Sr		6.5		5.80			6.43	6.6	6.5
91	Sr						5.61	5.57		
	Y	4.1						5.1		
	Zr		6.5	6.53		6.53	6.53	6.43	6.5	6.5
92	Zr		6.7	6.70		6.70	6.70	6.64	6.7	6.7
93	Zr		7.1	7.10		7.10	7.10	6.98	7.0	7.0
94	Zr		6.8	6.82		6.82	6.82	6.68	6.7	6.8
95	Zr	5.7,3.9		5.9		5.9	5.9	6.1		
	Mo		6.1	6.10		6.10	6.10	6.11	6.1	6.2

TABLE 2 - continued

Mass	Element	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
96	Zr		5.6	5.60		5.60	5.60	5.58	5.6	5.7
97	Mo		5.3	5.35		5.35	5.35	5.37	5.4	5.3
98	Mo		5.1	5.18		5.18	5.18	5.15	5.2	5.2
99	Mo	4.7	5.1	5.1		4.8	5.1	4.80	5.0	4.8
100	Mo		4.4	4.40		4.40	4.40	4.41	4.4	4.4
101	Ru		3.0	3.00		3.00	3.00	2.91	2.9	3.0
102	Ru		2.5	2.37		2.37	2.37	2.22	2.2	2.4
103	Ru	.85, .21	1.6	1.6		1.6	1.6	1.8	1.6	1.6
104	Ru		1.0	.96		.96	.96	.94	.95	.97
105			.6						.48	.5
106	Ru	.24, .064	.24	.28		.28	.28	.24	.22	.28
107			.1						.09	.15
108			.07						.05	.06
109	Pd	.047	.047	.040		.040	.040	.044	.035	.04
110			.035						.028	.03
111	Ag	.022, .015	.022	.025		.025	.025	.024	.025	.025
112	Pd	.014	.014	.016		.016	.016	.016	.020	.02
113			.015						.019	.02
114			.015						.018	.02
115	Cd ^m	.001		.001		.001	.001	.0011		
115	Cd ^g	.016		.019		.019	.019	.020		
115	total		.017	.020		.020	.020	.021	.018	.02
116			.015						.018	
117			.015						.018	
118			.015						.018	

TABLE 2 - continued

Mass	Element	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
119			.01						.020	
120			.01						.022	
121	Sn	.018	.01	.018		.018	.018	.018	.024	
122			.01						.03	
123	Sn ^m	.0025	.0025						.04	
124			.03						.06	
125	Sn ^m	.054	.24	.050		.050	.050	.052	.11	
126			.6						.20	
127	Sb	.092						.60		.24
	Te ^m	.067	1.0						.4	.39
128			1.6						.7	1.0
129	Te ^m	.22	2.5						1.3	2
130			3.0						2.2	2.7
131	I	2.7, 2.4		2.7		2.7	2.7	2.9		
	Xe		3.6	3.40		3.74	3.40	3.39	3.5	3.7
132	Te	4.9						4.4		
	Xe		4.9	4.64		5.10	4.64	4.64	4.8	5.1
133	Cs		5.9	5.62	5.20, 5.50 ^b	6.18	5.62, 5.6, 5.5	5.78	5.7	6.2
134	Xe		6.3	5.93		6.54	5.95	5.95	6.1	6.6
135	I			5.1		5.1	5.1	5.5		
	Xe						6.0			
	Cs		4.7	>4.49		>4.9	>4.49	6.03	6.0	6.7
136	I	1.7		1.7		1.7	1.7	1.8		
	Xe		8.5	<8.06		<8.9	<8.06	6.63	6.8	6.9
137	Cs		6.9	6.51	5.80, 6.16	7.16	6.51, 6.16	6.58	6.5	7.2

TABLE 2 - continued

Mass	Element	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
138			6.8						6.2	6.8
139	Ba						5.59	6.45		
	La		6.8		5.91		5.91		6.3	6.4
140	Ba	6.0,6.7		6.0		6.0	6.0	5.4		
	Ce		6.7		5.45,6.16	5.6	6.16	6.47	6.7	6.1
141	La						6.17	7.1		
	Pr		6.5		5.57		5.57	6.4	6.9	5.9
142	Ce		6.5		5.50,6.06	5.6	6.06	6.83	6.9	5.7
143	Nd		4.6		5.00,5.19	5.2	5.19,6.45	5.99	6.2	5.2
144	Ce	3.4,2.2		4.1		4.1	4.1	4.5		
	Nd		3.4		3.80,3.84	4.0	3.84	4.61	4.8	4.1
145	Nd		2.7		2.82,2.88	3.0	2.88	3.47	3.6	3.0
146	Nd		2.1		2.20,2.24	2.3	2.24	2.63	2.7	2.3
147	Pm	.6			1.53		1.53,2.1	1.9		1.7
	Sm		1.46			1.71		1.98	2.0	
148	Nd		1.04		1.03,1.07	1.15	1.07	1.34	1.4	1.2
149	Sm		.52		.66, .70	.61	.70, .8	.76	.79	.62
150	Nd		.41		.51, .49	.48	.49	.56	.57	.48
151	Sm		.22		.33	.26	.33, .3	.335	.33	.26
152	Sm		.145		.21	.17	.21	.220	.22	.17
153	Sm	.078		.095		.095	.095	.11		
	Eu		.078		.13		.13	.13	.11	.095
154	Sm		.032			.037		.045	.033	.037
155									.010	.015
156	Eu							.011		.005

TABLE 2 - continued

Mass	Element	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
157										.0025
158										.001
159										.0005

(a) Values given are recommended total mass yields.

(b) First value of each data pair is isotope dilution method result; second value, "integral" method.

TABLE 3. SELECTED MASS-SPECTROMETRIC YIELDS (%)

Mass	Element	Reference		
		(18)	(4, 27)	(29)
83	Kr			1.18
84	Kr			1.97
85	Rb			2.54
86	Kr			3.30
87	Rb			4.61
88	Sr		5.17 ^a	5.54
89	Sr, Y		6.36	6.15
90	Sr, Zr		5.58	6.75
91	Zr	6.58	6.48	6.45
92	Zr	6.70	6.28	6.72
93	Zr	7.10	6.75	7.01
94	Zr	6.82	6.43	6.68
95	Zr, Mo	6.10		6.23
96	Zr	5.60	5.47	5.67
97	Mo	5.35		5.51
98	Mo	5.18		5.22
100	Mo	4.40		4.49
101	Ru	3.00		2.87
102	Ru	2.37		2.10
104	Ru	.96		.94
106	Ru			.22
131	Xe			3.52
132	Xe			4.82
133	Cs		5.50	5.77
134	Xe			6.18
135	Cs			6.02
136	Xe			6.89
137	Cs		6.16	6.58
138	Ba		6.35	
139	La		5.91	
140	Ce		6.16	6.72
141	Pr		5.57	
142	Ce		6.06	7.00
143	Nd		5.19	6.22
144	Ce, Nd		3.84	4.87
145	Nd		2.88	3.66
146	Nd		2.24	2.74
147	Pm, Sm		1.53	
148	Nd		1.07	1.40
149	Sm		.70	.790
150	Nd, Sm		.49	.567
151	Sm		.33	.334
152	Sm		.21	.222
153	Eu		.13	
154	Sm			.048

(a) Values from "integral" method only given.

TABLE 4. PREFERRED YIELDS (%)

Mass	Adjusted Mass-Spec. Data of Reference			Average Mass-Spec. Value	Radiomet. Data of Reference (3, 7, 21)	Preferred Value ^a
	(18)	(5, 27)	(29)			
<77						.03 ^b
77					.019	.02
78						.10 ^b
79						.19 ^b
80						.28 ^b
81						.46 ^b
82						.69 ^b
83			1.14			1.14
84			1.91			1.91
85			2.46			2.46
86			3.20			3.20
87			4.47			4.47
88		5.37	5.36	5.36		5.36+.00
89		6.60	5.96	6.28		6.28+.32
90		5.80	6.55	6.18		6.18+.38
91	6.53	6.72	6.45	6.57		6.57+.11
92	6.65	6.52	6.72	6.63		6.63+.08
93	7.05	7.01	7.01	7.02		7.02+.02
94	6.76	6.67	6.68	6.70		6.70+.04
95	6.21		6.23	6.22		6.22+.01
96	5.56	5.68	5.67	5.64		5.64+.05
97	5.45		5.51	5.48		5.48+.03
98	5.28		5.22	5.25		5.25+.03
99					4.96	4.96
100	4.49		4.49	4.49		4.49+.00
101	2.80		2.87	2.84		2.84+.03
102	2.22		2.10	2.16		2.16+.06
103					1.60	1.6
104	.90		.94	.92		.92+.02
105						.50 ^b
106			.22			.22
107						.12 ^b
108						.07 ^b
109					.040	.04
110						.03 ^b
111					.025	.03
112					.016	.02
113						.02 ^b
114						.02 ^b
115					.020	.02
116						.01 ^b
117						.01 ^b

TABLE 4 - continued

Mass	Adjusted Mass-Spec. Data of Reference			Average Mass-Spec. Value	Radiomet. Data of Reference (3, 7, 21)	Preferred Value ^a
	(18)	(5, 27)	(29)			
118						.02 ^b
119						.02 ^b
120						.02 ^b
121					.018	.02 ^b
122						.03 ^b
123						.04 ^h
124						.05 ^b
125						.10 ^b
126						.26 ^b
127						.61 ^b
128						1.05 ^b
129						1.70 ^b
130						2.33 ^b
131			3.41			3.41
132			4.68			4.68
133		6.15	5.60	5.88		5.88+.28
134			5.99			5.99
135			5.84			5.84
136			6.68			6.68
137		6.90	6.38	6.64		6.64+.26
138		7.10				7.10
139		6.61				6.61
140		6.90	6.52	6.71		6.71+.19
141		6.24				6.24
142		6.79	6.79	6.79		6.79+.00
143		5.80	6.03	5.91		5.91+.12
144		4.30	4.72	4.51		4.51+.21
145		3.22	3.55	3.38		3.38+.16
146		2.50	2.66	2.58		2.58+.08
147		1.71	2.15	1.93		1.93+.22
148		1.20	1.36	1.28		1.28+.08
149		.78	.766	.77		.77+.01
150		.55	.550	.55		.55+.00
151		.37	.324	.35		.35+.02
152		.23	.215	.22		.22+.01
153		.15				.15
154			.047			.047
155						.03 ^b
156					.011	.01
>156						<.01 ^b

(a) Uncertainties given are the standard deviation of the average of the mass spectrometric values and, therefore, reflect only the precision of agreement among the various evaluations.

Estimated errors for single mass-spectrometric values are 5-10%; for radiometric values (Refs. 3, 7, and 21), 10-15%.

(b) Extrapolated or interpolated value.

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