

**¹⁵³Sm - Comments on evaluation of decay data
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First evaluation was done in 2001 by R.G. Helmer and E. Schönfeld, it has been updated in June 2005, including new half-life and gamma intensity values.

1 Decay Scheme

There are many levels in ¹⁵³Eu below the decay energy, so other levels may be weakly populated in this decay.

2 Nuclear Data

The Q value is from Audi and Wapstra 2003 (2003Au03). Level energy, spin and parity data are from 1998He06.

The half-life values available are, in hours:

1942Ku03	47	1	as quoted in 1990Le13
1946Mi06	46		as quoted in 1990Le13
1952Ru10	46.5	1	as quoted in 1990Le13
1954Le08	47	0.3	as quoted in 1990Le13
1958Co76	47.1	0.1	
1958Gu09	46.7	1.6	
1960Wi10	45	8	outlier
1961Gr18	46.2	0.1	
1961Wy01	46.8	0.1	
1962Ca24	47.1	0.1	
1963Ho15	46.5	0.5	
1970Ch09	46.75	0.09	
1971Ba28	46.44	0.08	
1987Co04	46.27	0.01	superseded by 1992Un01
1989Ab05	46.70	0.05	
1989Po21	45.6	1.6	outlier
1992Un01	46.2853	0.0014	
1998Bo18	46.285	0.004	
1999Sc12	46.274	0.007	superseded by 2004Sc
2004Sc04	46.281	0.007	<i>Corrected value and uncertainty</i>
Adopted	46.2851	0.0013	or 1.92855 (5) d

A mistake appears in the value of the Sm-153 half-life published by 2004Sc04 in Applied Radiation Isotopes 60 (2004) 317 ; after discussion with the author the correct value is 1.92838 (29) d instead of 1.9284 (29) d.

Data are very discrepant, ranging from 46.281 (7) to two values of 47.1 (1), a difference of about 8 σ .

The Limitation of Relative Statistical Weight, LRSW, analysis (1985ZiZY, 1992Ra08), with the Lweight 3 program, shows that the values from 1960Wi10 and 1989Po21 are outlier due to Chauvenet's criterion, the reduced- χ^2 is 18.9 and the uncertainty of 1992Un01 value is increased to 0.0034 to reduce its weight to 50 %. The weighted mean is 46.2874 with a σ_{int} of 0.0024 and a σ_{ext} of 0.011. Then, the program recommends

the unweighted mean and expands the uncertainty to include the most precise value, this leads to a value of 46.64 (36) h.

The average of the measured values has decreased with time and the last three unreplaced values, which are from metrology laboratories, are among the lowest values and they are consistent. The weighted average of these three values is 46.2851 with a σ_{int} of 0.0013, a reduced- χ^2 of 0.18, and a σ_{ext} of 0.0006. This weighted average and the internal uncertainty are adopted.

2.1 β^- Transitions

The probabilities for the β^- branches are primarily from the intensity balances from the γ -ray transition probabilities for all levels including the ground state. This is possible because one has measurements of the absolute emission probabilities for the 69- and 103-keV γ -rays (1987Co04, 1998Bo18, 1999Sc12, 2006Le).

The measured β^- probabilities (in %) from the decomposition of the β^- spectra are:

Level (keV)	Values (%)
0	15 (1952Ba49), 20 (1954Gr19), 21 (1954Le08), 20 (1955Ma62), 22 (1956Du31), 20 (1957Jo24), and 20 (1958Co76) compared to the adopted value of 19.5(15) %.
103	67 (1950Hi17), 35 (1952Ba49), 49 (1954Gr19), 70 (1954Le08), 35 (1955Ma62), 38 (1956Du31), 65 (1957Jo24), and 40 (1958Co76) which have an average of 50(14) compared to the adopted value of 49.2(17)% from the probability balance.
172	50 (1952Ba49), 30 (1954Gr19), 43 (1955Ma62), 40 (1956Du31), 15 (1957Jo24), and 40 (1958Co76) which have an average of 36(11) compared to the adopted value of 30.4(8)% from the probability balance.

2.2 Gamma Transitions

The energies and multiplicities are from the adopted gamma data in Nuclear Data Sheets (1998He06) and they are based on the internal-conversion electron data of 1961Mo07, 1962Su01, 1969Sm04, and 1970PaZI. Gamma transition probabilities are deduced from the gamma emission intensities and the conversion electron coefficients interpolated from the tables of Band *et al.* (2002Ba85).

The 19-keV gamma transition probability is deduced from the probability balance at the 83-keV level.

3 Atomic Data

The fluorescence yields and K x-ray relative intensities are from 1996Sc06.

4 Emissions

4.1 Electron Emission

Data were computed by EMISSION for the Auger electrons and with LOGFT for the average β^- energies.

4.2 Photon Emission

From the evaluation 2000He14, the curved-crystal spectrometer data for the decay of ¹⁵³Sm and ¹⁵³Gd give the energies for the γ -rays of 69, 75, 83, 89, 97, 103, and 172 keV on a scale on which the strong line from the decay of ¹⁹⁸Au is 411.80205(17). The γ -ray energies from the (n, γ) study of 1970Mu04 have been adjusted to this energy scale to provide values at 54, 68, 96, 118, 151, 166, and 172 keV. The values for 14 and 19 keV are from level energy differences.

The other γ -ray energies are from the data in the following table 1.

Table 1: Gamma-ray energies

1969Un03	1985Ab08	1969Pa03	Adopted	
412.05 (20)	412.26 (30)	411.9 (1)	412.05 (20)	doubly placed
424.38 (20)	424.79 (32)	424.2 (2)	424.4 (3)	
	431.65 (10)			
436.83 (20)	437.10 (30)	436.7 (2)	436.9 (3)	
	443.24 (45)		443.2 (5)	
		462.0 (3)	462.0 (3)	
463.67 (15)	463.93 (35)	463.4 (2)	463.6 (2)	
485.03 (20)	485.12 (40)	484.5 (2)	485.0 (2)	
	487.75 (23)		487.75 (23)	
509.11 (15)	510.36 (35)	509.0 (1)	509.15 (20)	
521.28 (15)	521.62 (26)	521.1 (1)	521.30 (25)	
		523.8 (6)		
531.38 (15)	531.43 (34)	531.6 (3)	531.40 (15)	
533.34 (15)	533.17 (25)	533.1 (1)	533.2 (2)	
539.03 (10)	539.10 (20)	539.2 (3)	539.1 (2)	
542.60 (20)	543.01 (45)	542.7 (6)	542.7 (2)	
545.75 (15)	545.68 (42)		545.75 (15)	
554.94 (10)	554.73 (37)	555.0 (1)	554.94 (10)	
	555.71 (15)			
574.01 (30)	574.32 (51)		574.1 (3)	
578.66 (15)	578.94 (30)	578.8 (1)	578.75 (20)	
584.49 (20)	584.67 (32)	584.8 (5)	584.55 (20)	
587.47 (20)	587.73 (22)	587.7 (6)	587.60 (25)	
	589.3			
590.96 (20)	591.03 (21)	590.7 (6)	590.96 (20)	
596.72 (15)	596.29 (30)	596.9 (2)	596.7 (2)	
598.4 (3)	598.13 (30)		598.3 (3)	doubly placed
603.39 (15)	604.04 (26)	603.5 (2)	603.6 (4)	doubly placed
609.22 (10)	610.21 (42)	609.4 (1)	609.5 (3)	doubly placed
		612 (1)		
615.41 (20)	616.28 (22)	615.5 (6)	615.8 (4)	doubly placed
617.71 (20)	618.07 (24)	618.0 (6)	617.9 (3)	
	623.73 (24)			
630.70 (30)	630.33 (26)	630 (1)	630.5 (4)	
634.61 (30)	634.92 (32)		634.8 (3)	
636.45 (25)	636.73 (30)	636.4 (2)	636.5 (2)	
657.55 (25)	657.68 (25)	657.4 (4)	657.55 (25)	doubly placed
		662.4 (6)	662.4 (6)	
676.9 (5)	677.09 (30)	676 (1)	677.0 (3)	
		682.0 (6)	682.0 (6)	
685.6 (3)	686.64 (21)	685.9 (3)	686.0 (4)	
694.4 (4)	694.02 (25)	694 (1)	694.1 (3)	
701.5 (4)	702.08 (24)	701.7 (10)	701.8 (4)	
706.2 (4)	707.29 (28)	706 (1)	706.8 (5)	
713.6 (3)	713.98 (22)	714.1 (6)	713.9 (3)	
718.5 (4)	719.26 (28)	719.1 (6)	719.0 (4)	
760.2 (3)	760.92 (38)	760.3 (6)	760.5 (4)	
	763.8	763.8 (6)	763.8 (6)	

For the relative γ -ray emission probabilities, the data listed in Table 2 were available. The values of 1969Un03 and 1985Ab08 were not listed since they do not have individual uncertainties and those of 1969Sm04 were not used because the ¹⁵³Sm was just a background in an (n, γ) study.

Some gamma emissions with weak intensities and reported by only one or two authors are not listed in Table 2, they are : 54.1 ; 68.2 ; 96.8 ; 118.1 ; 166.5 ; 487.7 ; 574.1 ; 630.5 ; 677.0 ; 682.0 ; 694.1 ; 701.8 ; 706.8 ; 719.0 ; 763.8 keV.

The emission intensities assigned to each of the components of the doublets at 598, 603, 609, 615 and 657 -keV are equal, as there is no information on how to split the total intensity for the doublet.

For all cases with three or more values, the weighted average is computed by the Limitation of Relative Statistical Weight method. If the reduced- χ^2 is $>$ critical χ^2 and one value has a relative weight $>$ 50%, the uncertainty of this value is increased in order to reduce the relative weight to 50% and this is noted in the table. If the reduced- χ^2 is \leq critical χ^2 , no such change is made, but if the relative weight is over 70% this is noted. For all weighted averages the internal uncertainty is given, and if the reduced- χ^2 is $>$ 1.0 the external uncertainty is also given. In some cases the LRSW method expands the uncertainty to include the most precise value; this uncertainty is given as σ_{LRSW} . The adopted values are given in the last row.

The relative γ -ray emission probabilities adopted in Table 2 were normalized to γ 's per 100 decays by consideration of the absolute emission probabilities measured by 1987Co04, 1998Bo18, 1999Sc12 and 2006Le. Of the five γ rays that are given in all papers, the three strongest, at 69, 97, and 103 keV, were considered. Since the weighted average of the data for the 97-keV γ -ray gave a reduced- χ^2 value of 20, it was omitted.

For the 69-keV γ -ray, the weighted average of the four values is 4.668 γ 's per 100 decays with an internal uncertainty of 0.026, a reduced- χ^2 of 3.1, and an external uncertainty of 0.047. The latter uncertainty was adopted.

For the 103-keV γ ray, the weighted average of the four values is 29.19 γ 's per 100 decays with an internal uncertainty of 0.12, a reduced- χ^2 of 1.8, and an external uncertainty of 0.16. The value of 29.19 (16) was adopted and used to convert the relative values into absolute values as listed in the latest line in Table 2.

Table 3. Absolute emission intensities

	103.18 keV		69.6 keV		97.4 keV	
	I %	Uc	I %	Uc	I %	Uc
1987Co04	29.82	0.36	4.85	0.07	0.847	0.011
1998Bo18	28.5	0.5	4.67	0.05	0.794	0.017
1999Sc12	29.23	0.18	4.65	0.05	0.755	0.007
2006Le	29.07	0.2	4.59	0.05	0.738	0.013
chi2	1.8		3.1		19.7	
WM	29.19	0.16	4.668	0.047	0.778	0.024

X-ray emissions

The measured x-ray emission intensities (in %) are compared with the calculated values deduced from the decay scheme :

XK	K α 2	K α 1	K α	K β ' 1	K β ' 2	K β
1992Ch44			44.43 1.31	8.55 0.29	2.23 0.09	
1999Sc12	16.27 0.18	29.4 0.4	45.7 0.5	9.26 0.12	2.444 0.027	11.7 0.13
2006Le	16.03 0.27	28.53 0.20	44.56 0.3	9.03 0.07	2.37 0.06	11.4 0.12
LWM	16.20 0.15	28.70 0.35	44.85 0.35	9.07 0.10	2.417 0.041	11.54 0.15
Calculated	16.6 0.4	30.0 0.7	46.6 1.1	9.45 0.25	2.44 0.08	11.9 0.3

XL	LI		L α		L β		L γ	
1992Ch44	0.190	0.018	4.90	0.26	4.20	0.26	0.651	0.044
1999Sc12	0.216	0.011	4.94	0.11	4.26	0.09	0.615	0.01
2006Le	0.245	0.012	5.06	0.15	4.33	0.13	0.0628	0.022
LWM	0.222	0.014	4.97	0.08	4.28	0.07	0.40	0.22
Calculated	0.213	0.007	5.20	0.15	4.63	0.10	0.755	0.017

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Table 2 : gamma relative and absolute emission intensities (1)

keV	69		75		83		89		97		151		172		412 ^(d)	
1964Al09	1730 ^(o)	100	61	4	75	4	58	3	263	13	3.2	0.5	21 ^(o)	2		
1966B106															0.64	0.2
1969Pa03											5.1 ^(o)	1.6	24	5	0.73	0.13
1974HeYW	1620	140	110 ^(o)	12	63	6	32	4	233	20	3	0.5	28	3	0.8	0.1
1987Co04	1626	21	117 ^(o)	5	68	4			284	4			27	0.4		
1992Ch44	1620	50	55	2	63	2	59	2	255	4	3.5	0.1	25	0.4	0.65	0.02
1998Bo18	1639	18	65	4	58	4			279	6			25.3	1.1		
1999Sc12	1591	17	80 ^(o)	7	72	4	53.4	2.4	258.3	2.4	3.93	0.21	24.5	0.24	0.65	0.04
2006Le	1579	17	61	7	69.8	3.4	37	8	253.9	4.5	3.47	0.21	25	0.6	0.38 ^(o)	0.05
Chi2	1.53		2.02		2.55		10.71		8.14		1.34		4.91		0.63	
Chi2 crit	3.02		3.79		2.80		3.32		2.80		3.32		2.80		3.32	
UWM:	1612.5		60.500		66.971		47.880		260.886		3.42		25.543		0.694	
WM:	1606.644		57.839		66.094		53.918		262.783		3.538		25.151		0.656	
Uc (int):	8.865		1.590		1.276		1.277		1.613		0.081		0.175		0.017	
Uc (ext):	10.967		2.258		2.038		4.181		4.603		0.093		0.388		0.014	
LWM :	1607	11	58	2.3	66.1	2	54	5	262.8	4.6	3.54	0.09	25.2	0.7	0.656	0.017
Abs	4.691	0.041	0.169	0.007	0.193	0.006	0.158	0.015	0.767	0.014	0.01033	0.00027	0.0736	0.0021	0.00191	0.00005

Table 2 : gamma relative and absolute emission intensities (2)

keV	424		436		443		462		463		485		509	
1964Al09														
1966Bl06	0.75	0.2	0.48	0.12					5.1	0.8	0.12	0.06	0.85	0.16
1969Pa03	0.73	0.13	0.5	0.1			0.5	0.1	4.7	0.4	0.12	0.06	0.61	0.2
1974HeYW	0.7	0.1	0.8 ^(o)	0.1					5.3	0.4			1	0.1
1987Co04														
1992Ch44	0.65	0.02	0.53	0.02	0.030	0.005	0.7	0.2	4.3	0.8	0.13	0.01	0.62	0.03 ^(U)
1998Bo18														
1999Sc12	0.62	0.04	0.57	0.03					4.34	0.06	0.12	0.03	0.63	0.06
2006Le	0.758	0.036	0.546	0.038	0.243	0.041			3.93	0.25			0.46	0.10
Chi2	1.80		0.42		13.49		0.80		2.03		0.05		3.61	
Chi2 crit	3.02		3.32		6.63		6.63		3.02		3.79		3.02	
UWM:	0.701		0.525		0.137		0.60		4.612		0.123		0.695	
WM:	0.669		0.541		0.137		0.540		4.349		0.129		0.651	
Uc (int):	0.016		0.015		0.029		0.089		0.057		0.009		0.030	
Uc (ext):	0.021		0.010		0.107		0.080		0.081		0.002		0.058	
LWM :	0.669	0.021	0.541	0.015	0.140	0.11	0.54	0.09	4.35	0.08	0.129	0.009	0.65	0.06
Abs	0.00195	0.00006	0.001579	0.000045	0.00041	0.00032	0.00158	0.00026	0.01270	0.00024	0.000377	0.000026	0.00190	0.00018

Table 2 : gamma relative and absolute emission intensities (3)

keV	521		531		533		539		542		545		554	
1964Al09														
1966B106	3.5 ^(o)	0.7	22.3	2	11.6	1	9.1	1.4					1.93	0.3
1969Pa03	2.5	0.9	23	3	8.8	2.5	8.2	2.5	0.6	0.5			1.6	0.13
1974HeYW	2.8 ^(o)	0.2	23.8	2	11.9	0.8	8.6	0.6	1.4 ^(o)	0.1	0.3	0.1	2	0.2
1987Co04														
1992Ch44	2.3	0.1	18.9	1.3	10.4	0.1	7.2	0.2	0.77	0.08	0.26	0.01 ^(u)	1.61	0.04
1998Bo18			19.3	2.1	9.8	2.1								
1999Sc12	2.31	0.04	18.37	0.21	10.02	0.09	7.04	0.09	0.75	0.06	0.41	0.17	1.62	0.03
2006Le	2.281	0.024	18.74	0.17	9.91	0.07	7.09	0.05	0.85	0.048	0.368	0.027	1.484	0.047
Chi2	0.15		2.38		4.04		1.84		0.69		2.91		2.35	
Chi2 crit	3.79		2.80		2.80		3.02		3.79		3.79		3.02	
UWM:	2.348		20.63		10.347		7.872		0.743		0.335		1.707	
WM:	2.289		18.646		10.066		7.094		0.803		0.312		1.595	
Uc (int):	0.020		0.13		0.048		0.043		0.034		0.018		0.021	
Uc (ext):	0.008		0.20		0.097		0.058		0.028		0.031		0.032	
LWM :	2.29	0.02	18.65	0.2	10.07	0.16	7.09	0.06	0.803	0.034	0.312	0.031	1.595	0.032
Abs	0.00668	0.00007	0.0544	0.0007	0.02939	0.00049	0.02070	0.00021	0.00234	0.00010	0.00091	0.00009	0.00466	0.00010

Table 2 : gamma relative and absolute emission intensities (4)

keV	578		584		587		590		596		598 ^(d)		603 ^(d)	
1964Al09														
1966Bl06	1.38	0.2	0.54 ^(o)	0.1					4.4 ^(o)	0.7			2	0.4
1969Pa03	1.15	0.23	0.45	0.15	0.1	0.1	0.45	0.15	4.2 ^(o)	0.6			1.8	0.3
1974HeYW	1.3	0.2	0.4	0.1	0.2	0.03	0.5	0.1	4.5 ^(o)	0.3	0.4	0.1	1.9	0.2
1987Co04														
1992Ch44	1.07	0.03	0.36	0.01	0.16	0.04	0.38	0.01	3.8	0.1	0.61	0.09	1.53	0.05
1998Bo18														
1999Sc12	1.17	0.03	0.352	0.027	0.161	0.027	0.421	0.027	3.56	0.1	0.70	0.03	1.49	0.03
2006Le	1	0.019	0.405	0.02	0.154	0.022	0.448	0.009 ^(U)	3.11	0.05 ^(U)	0.725	0.032	1.388	0.031
Chi2	5.19		1.20		0.52		6.38		17.69		3.50		3.26	
Chi2 crit	3.02		3.32		3.32		3.32		4.61		3.79		3.02	
UWM:	1.178		0.393		0.155		0.440		3.490		0.609		1.685	
WM:	1.063		0.368		0.165		0.417		3.395		0.693		1.462	
Uc (int):	0.015		0.008		0.014		0.007		0.050		0.021		0.020	
Uc (ext):	0.034		0.009		0.010		0.017		0.210		0.039		0.035	
LWM :	1.18	0.18	0.368	0.009	0.165	0.014	0.417	0.031	3.4	0.29	0.693	0.039	1.68	0.19
Abs	0.0034	0.0005	0.001074	0.000027	0.000482	0.000041	0.00122	0.00009	0.0099	0.0008	0.00202	0.00011	0.0049	0.0006

Table 2 : gamma relative and absolute emission intensities (5)

keV	609 ^(d)		615 ^(d)		618		634		636		657 ^(d)		662	
1964Al09														
1966B106	5.5	0.8	0.6 ^(o)	0.12					0.81	0.12	0.13	0.03		
1969Pa03	5.2	0.8	0.21	0.1	0.32	0.14			0.74	0.08	0.12	0.03	0.03	0.01
1974HeYW	5.1	0.4	0.3	0.1	0.3	0.1	0.20	0.03	0.7	0.1	0.1	0.03		
1987Co04														
1992Ch44	4.5	0.1	0.14	0.02	0.2	0.02	0.20	0.05	0.7	0.02	0.14	0.01	0.007	0.002
1998Bo18														
1999Sc12	4.04	0.14	0.233	0.024	0.304	0.027	0.15	0.03	0.595	0.027	0.14	0.024		
2006Le	4.59	0.20	0.159	0.020	0.213	0.022	0.168	0.011	0.65	0.06	0.112	0.009	0.197	0.040
Chi2	2.88		2.80		2.82		0.61		2.45		1.09		11.06	
Chi2 crit	3.02		3.32		3.32		3.79		3.02		3.02		4.61	
UWM:	4.822		0.208		0.267		0.180		0.699		0.124		0.078	
WM:	4.420		0.173		0.230		0.171		0.668		0.125		0.023	
Uc (int):	0.073		0.012		0.013		0.010		0.015		0.006		0.007	
Uc (ext):	0.125		0.020		0.022		0.007		0.023		0.006		0.023	
LWM :	4.42	0.12	0.173	0.020	0.230	0.022	0.171	0.01	0.668	0.023	0.125	0.006	0.023	0.023
Abs	0.01290	0.00036	0.00050	0.00006	0.00067	0.00006	0.000499	0.000029	0.00195	0.00007	0.000365	0.000018	0.00007	0.00007

Table 2 : gamma relative and absolute emission intensities (6)

keV	686		713		760	
1964Al09						
1966B106			0.11	0.03	0.013	0.004
1969Pa03	0.09	0.01	0.066	0.02	0.027	0.015
1974HeYW			0.1	0.03		
1987Co04						
1992Ch44	0.077	0.008	0.077	0.008	0.01	0.002
1998Bo18						
1999Sc12	0.072	0.021	0.09	0.04		
2006Le						
Chi2	0.62		0.53		0.81	
Chi2 crit	4.61		3.32		4.61	
UWM:	0.080		0.089		0.017	
WM:	0.081		0.079		0.011	
Uc (int):	0.006		0.007		0.002	
Uc (ext):	0.005		0.005		0.002	
LWM :	0.081	0.006	0.079	0.007	0.011	0.0018
Abs	0.000236	0.000018	0.000231	0.000020	0.000032	0.000005

^(u) Original uncertainty given, was increased in LRSW analysis to reduce the relative weight to 50%.

^(o) Omitted or outlier

^(a) γ is doubly placed, an undivided intensity is given