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Energy and Intensity Calibration Standards

by

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DISCLAIMER

INTRODUCTION

The following table of energy and intensity standards includes isotopes with a proven track record at this laboratory and elsewhere, as well as isotopes which offer the possibility of future application. Data is also included for some of those trespassing isotopes which appear in the background or as common impurities in experiments, and which might be useful for calibration. It is likely that other isotopes not reported here can be useful, and some of those mentioned may have only special application due to half-life or other considerations.

Energy and intensity values presented in this table are chosen by various critereon. Energies measured by bent crystal spectrometer were usually given stronger consideration, although certain Ge(Li) work (e.g. Idaho Falls) was given great weight. No effort is made to average different values, and given error estimates were weighted strongly in choosing energies. Efficiency data is much more difficult to judge, and it was usually considered most feasible to choose all values from one author. Given errors were not used as a strong critereon, in general, because it is questionable whether these errors contain more than statistical fluctuations. In addition many authors clearly miscalculated their errors. The track record of certain groups was given added weight (e.g. Livermore) as was the date the work was completed (more recent work is favored). Additional references are provided for those who wish to follow up the available measurements on a given isotope, but no attempt at completeness is made, and older work is generally referenced in Lederer's Table of the Isotopes, 6th Ed., (Led68).

An index of γ-ray standards is supplied to provide quick reference to the isotopes in this table. Half-lives and suggested means of production are presented, as well as the energy range covered by the isotope. The standard is delineated into general categories as to whether it contains primary or secondary quality measurements, and the numbers of each. Primary energy standards have high accuracy and are usually better than 0.01 keV at low energies and 0.05 keV at higher energies. Secondary energy standards are slightly less accurate, but are usually better than 0.10 keV. Primary intensity standards were measured by painstaking methods or involved simple decay systematics which lead to very accurate values. Secondary intensity standards were usually measured with the primary standards. The primary and secondary classifications are a bit arbitrary and are used only as a general guideline.

Some of the values in this table will be subject to change as new, better techniques are applied to the measurements. No warrantee is implied to any of the numbers in this table, and the user is advised to be careful in accepting any numbers or errors with less than a jaundiced eye. Standard calibration is a difficult game, and even veteran experimenters may miss a measurement. The author will appreciate updated information for inclusion in this table as well as any corrections or suggestions.

Index of γ-ray Standards Compiled

Isotope	$t_{1/2}$ [a]	Production [b]	Energy Range (keV) 0-100	100-500	500-1500	>1500	Standard [c] Quality Energy	Efficiency
^{7}Be	53.28d	(p,n),C		X			P(1)	
^{16}N	7.11s	(n,p)				X	P(2)	
^{22}Na	2.601y	C			X		P(1)	
^{24}Na	15.02h	(n,γ),C			X	X	P(2)	P(2)
^{28}Aℓ	2.240m	(n,γ)				X	S(1)	
^{40}K	$1.28{\times}10^{9}$y	N,C			X		S(1)	
^{46}Sc	83.8d	(n,γ),C			X		P(2)	P(2)
^{51}Cr	27.71d	(p,n)(n,γ), C		X			P(1)	
^{54}Mn	312.5d	C		X			P(1)	
^{56}Co	77.3d	(p,n),C			X	X	S(13)	S(13)
^{57}Co	271d	(p,γ),C	X	X			P(3)	P(3)
^{58}Co	71.3d	(p,γ),C			X		P(1)	
^{59}Fe	44.6d	(n,γ),C)			X		P(2)	P(2)
^{60}Co	5.272y	(n,γ),C			X		P(2)	P(2)
^{65}Zn	243.7d	(n,γ),C			X		P(1)	
^{66}Ga	9.5h	(p,n)(α,3n)			X	X	S(19)	S(19)
^{75}Se	120d	(n,γ)(p,2n), C	X	X			P(9)	S(9)
^{82}Br	35.4h	(n,γ),C			X		P(8)	S(8)
^{85}Sr	65.2d	(p,n),C			X		P(1)	
^{88}Y	106.6d	(p,n),C			X	X	P(2)	P(2)

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^{90m}Y	64.0h	(n,γ),C		X			P(2)	P(2)
^{94}Nb	2.0×10^{4}y	(n,γ),C			X		P(2)	P(2)
^{95}Zr	65.5d	(n,γ),C			X		P(2)	
^{95}Nb	35.1d	(β^-),C			X		P(1)	
^{95m}Tc	61d	(p,n)		X	X		P(5)	S(7)
^{99}Mo	66.02h	(n,γ),C	X	X	X		P(5)	S(6)
^{108m}Ag	1.3×10^{2}y	(n,γ)		X	X		S(3)	P(3)
^{109}Cd	453d	(p,n),C	X				P(1)	
^{110m}Ag	252d	(n,γ),C		X	X	X	P(9)	S(15)
^{113}Sn	115d	(p,3n)(n,γ), C		X			P(1)	
^{124}Sb	60.20d	(n,γ),C			X	X	P(9)	S(11)
^{125}Sn	9.65d	(n,γ)		X	X	X	P(3)	S(19)
^{132}Cs	6.47d	(p,n)		X	X		P(1)	S(8)
^{133}Ba	10.4y	C	X	X			P(5)	S(5)
^{134}Cs	2.06y	(n,γ),C		X	X			S(9)
^{137}Cs	30.1	C			X		P(1)	
^{139}Ce	137.5d	(p,n),C		X			P(1)	
^{141}Ce	32.53d	(n,γ),C		X			P(1)	
^{152}Eu	12y	(n,γ),C		X	X		P(12)	S(12)
^{153}Gd	241.5d	C	X	X			P(6)	S(9)
^{154}Eu	8.6y	(n,γ),C		X	X		P(11)	S(13)
^{155}Eu	4.8y	C	X	X			P(5)	S(4)
^{160}Tb	72.3d	(n,γ),C	X	X	X		P(12)	S(14)
^{166m}Ho	1.2×10^{3}y	(n,γ),C	X	X	X		S(22)	S(24)
^{169}Yb	31d	(p,n),C	X	X			P(2)	S(11)
^{170}Tm	129d	(n,γ),C	X				P(1)	
^{177m}Lu	161.0d	(n,γ)	X	X			S(30)	S(32)

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^{182}Ta	115d	(n,γ),C	X	X	X		P(30)	S(24)
^{183}Ta	5.0d	C	X	X			P(12)	S(12)
^{185}Os	84d	(p,n)			X		P(5)	S(5)
^{191}Os	15.3d	(n,γ),C	X	X			P(2)	
^{192}Ir	74.3d	(n,γ),C		X	X		P(9)	S(11)
^{198}Au	2.695d	(n,γ),C		X	X		P(3)	S(3)
^{203}Hg	46.60g	(n,γ),C		X			P(1)	
^{207}Bi	38y	C		X	X	X	P(3)	S(3)
^{226}Ra	1.6×10^{2}y	C	X	X	X	X	S(23)	S(23)
^{228}Th	1.913y	C		X	X	X	P(3)	S(3)
^{241}Am	435y	C	X				P(2)	S(2)
^{243}Cm	28y	C	X	X				S(4)

a) Chart of Nuclides, Knolls Atomic Power Laboratory, 11th Ed., 1972.

b) Mode(s) of production, C = commercially available, N = naturally abundant.

c) P = primary standard (extreme accuracy); S = secondary standard.
Number of useful transitions are given in parenthesis.

γ-Ray Energy and Intensity Standards

Isotope	Energy	Intensity	References
^{7}Be	477.59 ± 0.01	-	1. He71
^{16}N	6129.96 ± 0.46		1. Ch67
	7117.02 ± 0.49		
^{22}Na	1274.52 ± 0.03[1]		1. He71
			2. Wh67
			3. Leg68
			4. Ram67
			5. Ja71
^{24}Na	1368.60 ± 0.03[2]	100.0[1]	1. Ja71
	2754.10 ± 0.18[1]	100.0[1]	2. Gr73
^{28}Aℓ	1778.70 ± 0.17		1. Wh67

^{40}K	1460.85 ± 0.10		1. ND13
^{46}Sc	889.25 ± 0.02[1]	100.0[2]	1. He71
	1120.52 ± 0.03[1]	100.0[2]	2. ND13
			3. Ga72
^{51}Cr	320.078 ± 0.008[1]		1. Gr70
			2. Wh67
			3. Leg68
^{54}Mn	834.82 ± 0.02[1]		1. He71
			2. Ram67
			3. Leg68
			4. Ja71

	Energy	Intensity	
^{56}Co	263.40 ± 0.10[1,2]	22 ± 4[1]	1. Ca71
	411.37 ± 0.08[1,2]	25 ± 5[1]	2. Ge71
	486.53 ± 0.11[1,2]	55 ± 5[1]	3. Ch67
	733.70 ± 0.15[1,2]	200 ± 10[1]	4. Gu68
	787.86 ± 0.07[1,2]	310 ± 10[1]	5. Phe70
	846.74 ± 0.03[2]	100000[1]	
	896.55 ± 0.20[1,2]	70 ± 5[1]	
	977.46 ± 0.06[1,2]	1440 ± 15[1]	
	997.30 ± 0.16[1,2]	112 ± 6[1]	
	1037.84 ± 0.05[2]	14000 ± 100[1]	
	1089.00 ± 0.24[1,2]	50 ± 10[1]	
	1140.25 ± 0.10[1,2]	150 ± 10[1]	
	1160.05 ± 0.16[1,2]	100 ± 10[1]	
	1175.13 ± 0.08[1,2]	2280 ± 20[1]	
	1198.75 ± 0.20[1,2]	50 ± 10[1]	
	1238.28 ± 0.04[1,2]	67600 ± 400[1]	
	1272.15 ± 0.60[1,2]	20 ± 2[1]	
	1335.53 ± 0.08[1,2]	125 ± 5[1]	
	1360.26 ± 0.04[2]	4330 ± 40[1]	
	1442.71 ± 0.08[1,2]	200 ± 10[1]	
	1462.30 ± 0.12[1,2]	77 ± 5[1]	
	1640.50 ± 0.13[1,2]	60 ± 10[1]	
	1771.49 ± 0.06[1,2]	15700 ± 150[1]	
	1810.40 ± 0.50[1,2]	640 ± 10[1]	

	Energy		Intensity	
^{56}Co	1963.94	± 0.06[1,2]	720 ± 15[1]	
	2015.36	± 0.05[1,2]	3080 ± 30[1]	
	2034.92	± 0.06[1,2]	7890 ± 70[1]	
	2113.80	± 0.15[1,2]	385 ± 5[1]	
	2213.10	± 0.15[1,2]	350 ± 10[1]	
	2276.30	± 0.16[1,2]	110 ± 5[1]	
	2373.65	± 0.40[1,2]	80 ± 10[1]	
	2523.80	± 0.20[1,2]	60 ± 5[11]	
	2598.53	± 0.06[2]	16900 ± 150[1]	
	3010.20	± 0.23[1,2]	1000 ± 10[1]	
	3202.30	± 0.16[1,2]	3040 ± 30[1]	
	3253.60	± 0.16[1,2]	7410 ± 65[1]	
	3273.25	± 0.16[1,2]	1750 ± 20[1]	
	3369.60	± 0.30[1,2]	11 ± 2[1]	
	3451.55	± 0.20[1,2]	875 ± 10[1]	
	3540.05	± 0.20[1,2]	180 ± 5[1]	
	3600.60	± 0.40[1,2]	16 ± 1[1]	
	3611.60	± 0.40[1,2]	7 ± 1[1]	

^{57}Co	14.408 ± 0.005[1]	11410 ± 500[1]	1. Ko71
	122.06 ± 0.01[2]	100000[1]	2. Gr70
	136.47 ± 0.01[2]	13000 ± 400[1]	3. Ja71
^{58}Co	810.75 ± 0.02		1. He71
^{59}Fe	1099.23 ± 0.03[1]	0.565[2]	1. He71
	1291.57 ± 0.03[1]	0.432[2]	2. ND13
			3. Leg70
^{60}Co	1173.21 ± 0.03[1]	99.88 ± 0.02	1. He71
	1332.47 ± 0.03[2]	100	2. Gr73
			3. NDA8
			4. Wh67
^{65}Zn	1115.53 ± 0.03[1]		1. He71
			2. Ram67
			3. Leg68

^{66}Ga	290.1 ± 0.1[1]	140 ± 10[1]	1. Ca71
	410.30 ± 0.10[1]	250 ± 25[1]	2. Phe70
	448.90 ± 0.10[1]	290 ± 10[1]	
	459.60 ± 0.20[1]	230 ± 10[1]	
	578.70 ± 0.10[1]	160 ± 10[1]	
	686.34 ± 0.08[1]	680 ± 20[1]	
	833.65 ± 0.08[11]	16200 ± 700[1]	
	853.08 ± 0.08[1]	200 ± 5[1]	
	856.70 ± 0.10[1]	320 ± 10[1]	
	981.02 ± 0.10[1]	140 ± 10[1]	
	1009.35 ± 0.14[1]	150 ± 10[1]	
	1039.35 ± 0.08[1]	100000[1]	
	1060.50 ± 0.40[1]	33 ± 10[1]	
	1148.05 ± 0.14[1]	215 ± 15[1]	
	1190.44 ± 0.10[1]	350 ± 10[1]	
	1232.55[1]	125 ± 30[1]	
	1232.65[1]	1385 ± 40[1]	
	1333.37 ± 0.09[1]	3260 ± 30[1]	
	1356.45[1]	980 ± 100[1]	
	1356.55[1]	335 ± 45[1]	
	1357.07[1]	465 ± 90[1]	
	1418.97 ± 0.09[1]	1680 ± 20[1]	
	1458.95 ± 0.10[1]	260 ± 10[1]	
	1508.37 ± 0.09[1]	1520 ± 25[1]	
	1741.8 ± 0.4[1]	100 ± 10[1]	
	1899.20 ± 0.15[1]	1130 ± 25[1]	

^{66}Ga	1918.66 ± 0.09[1]	5650 ± 20[1]	
	2066.4 ± 0.4[1]	90 ± 5[1]	
	2174.00 ± 0.15[1]	260 ± 20[1]	
	2190.20 ± 0.15[1]	15050 ± 150[1]	
	2213.75 ± 0.15[1]	370 ± 15[1]	
	2292.60 ± 0.15[1]	110 ± 10[1]	
	2393.10 ± 0.15[1]	655 ± 20[1]	
	2422.50 ± 0.15[1]	5140 ± 50[1]	
	2492.50 ± 0.15[1]	65 ± 10[1]	
	2589.00 ± 0.15[1]	75 ± 10[1]	
	2752.27 ± 0.10[1]	61100 ± 500[1]	
	2780.65 ± 0.15[1]	335 ± 10[1]	
	2934.38 ± 0.15[1]	570 ± 10[1]	
	2977.50 ± 0.40[1]	60 ± 10[1]	
	2993.20 ± 0.40[1]	85 ± 10[1]	
	3047.25 ± 0.20[1]	160 ± 10[1]	
	3229.35 ± 0.20[1]	3920 ± 30[1]	
	3256.60 ± 0.20[1]	250 ± 10[1]	
	3381.30 ± 0.20[1]	3730 ± 30[1]	
	3422.50 ± 0.20[1]	2170 ± 40[1]	
	3432.95 ± 0.20[1]	740 ± 10[1]	
	3724.80 ± 1.00[1]	6 ± 1[1]	
	3736.80 ± 0.60[1]	32 ± 3[1]	
	3767.25 ± 0.25[1]	365 ± 10[1]	
	3791.56 ± 0.10[1]	2670 ± 30[1]	
	3806.30 ± 1.00[1]	6 ± 1[1]	

^{66}Ga	3811.70 ± 0.80[1]	21 ± 2[1]	
	3827.50 ± 0.80[1]	17 ± 2[1]	
	4086.45 ± 0.15[1]	3020 ± 40[1]	
	4295.50 ± 0.20[1]	9180 ± 100[1]	
	4462.10 ± 0.14[1]	1870 ± 20[1]	
	4806.60 ± 0.20[1]	3860 ± 40[1]	
^{75}Se	66.05 ± 0.03[1]	1.77 ± 0.20[1]	1. Ge71
	96.732 ± 0.007[1]	5.60 ± 0.50[1]	2. Gr70
	121.11 ± 0.01[1]	28.19 ± 1.40[1]	3. Pr71
	136.00 ± 0.01[1]	98.25 ± 4.6[1]	4. McN73
	198.60 ± 0.02[1]	2.43 ± 0.12[1]	
	264.65 ± 0.02[1]	100[1]	
	279.53 ± 0.01[1]	43.22 ± 2.2[1]	
	303.90 ± 0.02[1]	2.31 ± 0.12[1]	
	400.64 ± 0.02[1]	19.56 ± 1.2[1]	
^{82}Br	554.33 ± 0.02[1]	846 ± 9[2]	1. Ga72
	619.05 ± 0.02[2]	520 ± 7[2]	2. Ra70
	698.32 ± 0.02[2]	335 ± 5[2]	
	776.50 ± 0.03[1]	1000[2]	
	827.81 ± 0.03[2]	292 ± 5[2]	

^{82}Br	1043.98 ± 0.03[2]	334 ± 5[2]	
	1317.47 ± 0.05[2]	330 ± 5[2]	
	1474.82 ± 0.08[2]	200 ± 4[2]	
^{85}Sr	514.00 ± 0.02[1]		1. He71
			2. Leg68
^{88}Y	898.02 ± 0.02[1]	91.4 ± 0.7[1]	1. Ja71
	1836.01 ± 0.04[2]	99.999 ± 0.001[1]	2. Gr73
			3. Wh67
			4. Leg68
			5. Gu68
			6. He71
			7. Ar74
^{90m}Y	202.53 ± 0.03	1.072 ± 0.004	1. Han73
	479.51 ± 0.05	1.000	

^{94}Nb	702.62 ± 0.02[1]	100.0[2]	1. He71
	871.09 ± 0.02[1]	100.0[2]	2. Led68
^{95}Zr	724.18 ± 0.02[1]	0.43[2]	1. He71
	756.71 ± 0.02[1]	0.546[2]	2. ND13
^{95}Nb	765.78 ± 0.02		1. He71
^{95m}Tc	203.94 ± 0.08[1]	100	1. Chi69
	252.89 ± 0.15[1]	1.1 ± 0.1	2. He71
	582.06 ± 0.01[2]	55 ± 5	
	786.18 ± 0.02[2]	15.0 ± 1.1	
	820.60 ± 0.02[2]	8.0 ± 0.8	
	835.13 ± 0.02[2]	45.0 ± 4.5	
	1039.24 ± 0.02[2]	5.0 ± 0.5	

^{99}Mo	40.585 ± 0.002[1]	2.2 ± 1[2]	1. Ga72
	140.508 ± 0.004[1]	100[2]	2. Ei68
	181.063 ± 0.008[1]	7.5 ± 0.2[2]	
	366.43 ± 0.03[1]	1.63 ± 0.10[2]	
	739.58 ± 0.06[1]	15.4 ± 0.6[2]	
	778.2 ± 0.1[2]	5.4 ± 0.3[2]	
^{108m}Ag	434.00 ± 0.10[1]	100[1]	1. Ham71
	614.37 ± 0.10[1]	99.3 ± 2.0[1]	2. Das73
	722.95 ± 0.08[1]	100.4 ± 2.0[1]	
^{109}Cd	88.035 ± 0.006[1]		1. Rae70
			2. Gr70
^{110m}Ag	446.60 ± 0.20[1]	3.57 ± 0.71	1. La73a
	620.18 ± 0.10[1]	2.79 ± 0.06	2. Ga72
	657.75 ± 0.02[2]	100	3. He71
	677.59 ± 0.04[2]	11.93 ± 0.41	4. Phi72
	687.01 ± 0.04[2]	7.25 ± 0.33	
	706.69 ± 0.03[2]	17.15 ± 0.85	

^{110m}Ag	744.25 ± 0.06[2]	4.43 ± 0.13[1]	1. La73a
	763.91 ± 0.03[2]	23.73 ± 0.72[1]	2. Ga72
	818.03 ± 0.04[2]	7.81 ± 0.39[1]	3. He71
	884.67 ± 0.03[2]	80.28 ± 4.01[1]	4. Phi72
	937.48 ± 0.04[2]	37.31 ± 1.42[1]	
	1383.85 ± 0.20	28.26 ± 1.42[1]	
	1475.42 ± 0.16	4.44 ± 0.16[1]	
	1504.65 ± 0.29	15.19 ± 0.49[1]	
	1561.92 ± 0.20	1.40 ± 0.09[1]	
^{113}Sn	391.69 ± 0.01[1]		1. Gr70
			2. Gu68
^{124}Sb	602.71 ± 0.02[2]	100.0[1]	1. Au69
	645.85 ± 0.03[2]	7.42 ± 0.11[1]	2. ND13
	709.44 ± 0.10[1]	1.46 ± 0.15[1]	3. Gu68
	713.84 ± 0.13[1]	2.35 ± 0.17[1]	4. Wh67
	722.78 ± 0.04[1]	11.27 ± 0.18[1]	
	968.20 ± 0.04[1]	1.92 ± 0.06[1]	
	1045.10 ± 0.04[1]	1.94 ± 0.09[1]	
	1325.59 ± 0.06	1.57 ± 0.09	
	1368.21 ± 0.05	2.78 ± 0.14	

^{124}Sb	1691.06 ± 0.04[1]	53.2 ± 2.7[1]	
	2091.00 ± 0.05[1]	6.57 ± 0.44[1]	
^{125}Sn	332.0 ± 0.5[1]	0.0122[1]	1. ND13
	350.9 ± 0.5[1]	0.0023[1]	2. Gr73
	469.7 ± 0.5[1]	0.0138[1]	
	800.5 ± 0.5[1]	0.0097[1]	
	822.6 ± 0.5[1]	0.0387[1]	
	893.7 ± 0.5[1]	0.0025[1]	
	915.5 ± 0.5[1]	0.0376[1]	
	934.7 ± 0.5[1]	0.0012[1]	
	1017.1[1]	0.0028[1]	
	1066.6[1]	0.0887[1]	
	1087.4[1]	0.0093[1]	
	1088.9[1]	0.0429[1]	
	1151.3[1]	0.0011[1]	
	1173.2[1]	0.0029[1]	
	1221.0[1]	0.0023[1]	
	1419.5[1]	0.0047[1]	
	1806.65 ± 0.04[2]	0.0015[1]	
	2002.02 ± 0.04[2]	0.0211	
	2275.71 ± 0.05[2]	0.0019	

^{132}Cs	464.5[1]	0.0197[1]	1. ND13
	505.7[1]	0.0083[1]	2. Gr73
	567.0[1]	0.0026[1]	
	629.8[1]	0.010[1]	
	667.7[1]	1.00[1]	
	1031.4[1]	0.0012[1]	
	1135.2[1]	0.0050[1]	
	1317.89 ± 0.03[2]	0.0061[1]	
^{133}Ba	80.998 ± 0.008[1]	0.36[2]	1. Gr70
	276.40 ± 0.01[1]	0.075[2]	2. ND13
	302.85 ± 0.02[1]	0.196[2]	
	356.01 ± 0.02[1]	0.67[2]	
	383.85 ± 0.02[1]	0.094[2]	
^{134}Cs	475.3	0.015	1. ND13
	563.1	0.08	
	569.2	0.14	
	604.6	0.98	
	795.8	0.88	
	801.8	0.09	
	1038.4	0.011	

^{134}Cs	1167.7	0.019	
	1365.0	0.034	
^{137}Cs	661.65 ± 0.02		1. He71
^{139}Ce	165.853 ± 0.007		1. Gr70
^{141}Ce	145.41 ± 0.03[1]		1. Wh67
			2. Leg68
^{152}Eu	121.780 ± 0.004[1]	105.0 ± 2.1[2]	1. Rae70
	244.69 ± 0.01[1]	27.8 ± 0.6[2]	2. Mo70
	295.93 ± 0.04[1]	1.8 ± 0.15[3]	3. No70
	344.27 ± 0.01[1]	100	
	411.07 ± 0.03[1]	7.96 ± 0.16[2]	
	443.98 ± 0.05[2]	10.9 ± 0.2[2]	
	778.87 ± 0.05[2]	47.4 ± 0.9[2]	
	964.01 ± 0.05[2]	56.3 ± 1.1[2]	

^{152}Eu	1085.83 ± 0.07[2]	39.6 ± 0.8[2]	1. Rae70
	1089.73 ± 0.07[2]	6.42 ± 0.13[2]	2. Mo70
	1112.04 ± 0.05[2]	50.9 ± 1.0[2]	3. No70
	1408.02 ± 0.05[2]	80.7 ± 1.6[2]	
^{153}Gd	14.07[1]		1. Led68
	19.82[1]		2. Se72
	41.5 (Kα)[2]	1.00[2]	3. ND13
	68.23[1]	0.0001[3]	4. Rae70
	69.672 ± 0.002[4]	0.024[3]	
	75.421 ± 0.002[4]	0.00091[3]	
	83.367 ± 0.002[4]	0.0021[3]	
	89.485 ± 0.003[4]	0.00068[3]	
	97.429 ± 0.003[4]	0.317[3]	
	103.179 ± 0.004[4]	0.24[3]	
	172.8[3]	0.000048[3]	
^{154}Eu	123.070 ± 0.004[1]	116 ± 6[2]	1. Rae70
	188.25 ± 0.01[1]	0.61 ± 0.12[2]	2. Ri70
	247.939 ± 0.008[1]	20.1 ± 1.0[2]	3. Me68
	444.44 ± 0.07[1]	1.69 ± 0.15[2]	
	581.91 ± 0.11[1]	2.53 ± 0.23[2]	

^{154}Eu	591.81 ± 0.04[1]	14.8 ± 0.8[2]	
	692.43 ± 0.11[2]	4.97 ± 0.30[2]	
	723.30 ± 0.04[3]	60.1 ± 3.1[2]	
	756.92 ± 0.06[1]	12.9 ± 0.6[2]	
	873.24 ± 0.08[1]	34.8 ± 1.7[2]	
	996.32 ± 0.04[3]	29.4 ± 1.5[2]	
	1004.76 ± 0.04[3]	50.6 ± 2.5[2]	
	1274.45 ± 0.09[3]	100[2]	
^{155}Eu	45.297 ± 0.001[1]	3.6 ± 0.7[2]	1. Rae70
	57.98 ± 0.002[1]	–	2. Re71
	60.010 ± 0.002[1]	4.3 ± 0.3[2]	
	86.545 ± 0.003[1]	100 ± 3[2]	
	105.308 ± 0.003[1]	68.3 ± 2.7[2]	
^{160}Tb	86.788 ± 0.002[1]	13.7 ± 2.0[1]	1. Lu68
	197.035 ± 0.008[1]	5.22 ± 0.29[1]	2. He71
	215.646 ± 0.008[1]	3.93 ± 0.22[1]	3. La74
	298.58 ± 0.01[1]	27.1 ± 1.6[1]	4. Ke70
	309.56 ± 0.02[1]	0.90 ± 0.04[1]	
	337.30 ± 0.03[1]	0.33 ± 0.03[1]	
	392.51 ± 0.03[1]	1.36 ± 0.05[1]	
	765.19 ± 0.11[1]	2.03 ± 0.18[1]	
	879.36 ± 0.02[2]	30.0[1]	

^{160}Tb	962.29 ± 0.02[2]	10.2 ± 0.7[1]	
	966.14 ± 0.02[2]	24.7 ± 1.5[1]	
	1177.93 ± 0.02[2]	14.8 ± 0.5[1]	
	1271.84 ± 0.03[2]	7.4 ± 0.2[1]	
	1311.90 ± 0.20[2]	2.79 ± 0.17[1]	
^{166m}Ho	80.57 ± 0.02	14.48 ± 0.48[2]	1. Li74
	94.65 ± 0.03[1]	0.21 ± 0.03[1]	2. Lav74
	119.04 ± 0.03[1]	0.23 ± 0.03[1]	3. Bu67
	121.16 ± 0.03[1]	0.54 ± 0.05[1]	
	160.06 ± 0.05[1]	0.16 ± 0.03[1]	
	161.75 ± 0.05[1]	0.16 ± 0.03[1]	
	184.41 ± 0.02[1]	100[2]	
	190.71 ± 0.03[1]	0.31 ± 0.04[2]	
	215.88 ± 0.03[1]	3.94 ± 0.09[2]	
	231.28 ± 0.04[1]	0.36 ± 0.03[2]	
	259.72 ± 0.02[1]	1.77 ± 0.12[2]	
	280.46 ± 0.02[1]	38.61 ± 0.46[2]	
	300.74 ± 0.02[1]	4.77 ± 0.09[2]	
	339.78 ± 0.08[1]	0.23 ± 0.04[1]	
	365.74 ± 0.03[1]	2.93 ± 0.06[2]	
	410.94 ± 0.03[1]	15.50 ± 0.19[2]	
	451.52 ± 0.03[1]	3.48 ± 0.07[2]	
	464.83 ± 0.04[1]	2.00 ± 0.07[2]	

^{166m}Ho	529.81 ± 0.03[1]	10.16 ± 0.32[2]	
	571.00 ± 0.03[1]	6.77 ± 0.14[2]	
	594.48 ± 0.08[1]	1.28 ± 0.18[2]	
	611.52 ± 0.07[1]	1.48 ± 0.27[2]	
	670.51 ± 0.04[1]	7.01 ± 0.25[2]	
	691.21 ± 0.05[1]	1.85 ± 0.09[2]	
	711.69 ± 0.04[1]	71.65 ± 0.68[2]	
	736.67 ± 0.08[1]	0.46 ± 0.04[2]	
	752.27 ± 0.04[1]	16.06 ± 0.40[2]	
	778.82 ± 0.04[1]	3.72 ± 0.07[2]	
	810.31 ± 0.04[1]	76.38 ± 0.82[2]	
	830.56 ± 0.04[1]	12.07 ± 0.28[2]	
	875.64 ± 0.05[1]	1.14 ± 0.07[2]	
	950.94 ± 0.06[1]	3.5 ± 0.14[2]	
	1241.44 ± 0.06[1]	1.22 ± 0.05[2]	
	1282.12 ± 0.07[1]	0.38 ± 0.04[2]	
	1401.30 ± 0.15[1]	0.86 ± 0.05[2]	
	1427.50 ± 0.20[1]	0.65 ± 0.03[2]	
^{169}Yb	50.5 ± 0.2[1]	409 ± 24[1]	1. La73a
	57.5 ± 0.2[1]	106 ± 6.31[1]	2. Ne70
	63.125 ± 0.003[2]	125.37 ± 6.58[1]	
	93.607 ± 0.003[2]	5.07 ± 0.16[1]	

^{169}Yb	109.88 ± 0.28[1]	49.09 ± 1.70[1]	
	118.28 ± 0.23[1]	3.71 ± 0.11[1]	
	130.47 ± 0.16[1]	29.73 ± 0.87[1]	
	177.14 ± 0.21[1]	62.08 ± 2.02[1]	
	198.02 ± 0.09[1]	100	
	261.11 ± 0.21[1]	3.70 ± 0.092[1]	
	307.77 ± 0.28[1]	27.97 ± 0.90[1]	
^{170}Tm	84.257 ± 0.003[1]		1. Rae70
			2. Gr70
			3. Ne70
	(Error)	(Error)	
^{177m}Lu	69.2	0.08	1. Ha67
	71.66 (6)	6.8 (4)	
	105.31 (5)	100	
	112.95 (5)	179 (13)	
	115.96 (10)	5.0 (4)	
	117.17 (13)	1.8 (2)	
	121.63 (5)	52 (4)	
	128.50 (5)	127 (8)	
	136.72 (5)	11.7 (8)	
	145.78 (10)	6.6 (9)	

^{177m}Lu	147.15 (8)	29 (2)	
	153.29 (6)	133 (8)	
	159.75 (8)	5.4 (5)	
	171.85 (10)	37 (4)	
	174.42 (6)	96 (8)	
	177.03 (8)	26 (3)	
	181.98 (10)	0.75 (13)	
	195.52 (6)	7.0 (6)	
	204.08 (6)	114. (8)	
	208.34 (6)	485 (40)	
	214.45 (6)	48 (4)	
	218.06 (6)	27 (3)	
	228.44 (6)	287 (26)	
	233.83 (6)	45 (4)	
	249.65 (6)	47 (4)	
	268.79 (6)	25 (3)	
	281.78 (7)	108 (9)	
	283.42 (13)	4.7 (1.2)	
	291.42 (10)	7.7 (9)	
	292.51 (10)	7.8 (9)	
	296.45 (8)	38 (4)	
	299.03 (10)	12 (2)	
	305.52 (8)	14 (1)	
	313.69 (8)	9.4 (7)	
	318.98 (8)	78 (8)	
	321.32 (12)	9 (1)	
	327.66 (8)	136 (8)	

^{177m}Lu	341.64 (8)	13 (1)	
	367.41 (8)	23 (2)	
	378.51 (8)	222 (17)	
	385.02 (8)	24 (2)	
	413.64 (12)	131 (10)	
	418.51 (10)	161 (12)	
	426.29 (10)	3.4 (4)	
	465.96 (12)	19 (2)	
^{182}Ta	31.736 ± 0.001[1]		1. He71
	42.715 ± 0.002[1]		2. La74
	67.750 ± 0.001[1]	121.00 ± 5.20[2]	3. Ja71
	84.680 ± 0.002[1]	7.82 ± 0.16[2]	4. Wh69
	100.105 ± 0.001[1]	37.43 ± 0.80[2]	5. Sa69
	113.68 ± 0.10[2]	6.15 ± 0.14[2]	6. Ne70
	152.434 ± 0.002[1]	18.70 ± 0.60[2]	
	156.387 ± 0.003[3]	7.78 ± 0.20[2]	
	179.393 ± 0.004[3]	8.57 ± 0.25[2]	
	198.29 ± 0.15[2]	3.75 ± 0.12[2]	
	222.109 ± 0.005[3]	21.26 ± 0.62[2]	
	229.322 ± 0.005[3]	10.3 ± 0.3[3]	
	264.072 ± 0.009[3]	9.46 ± 0.29[2]	
	891.98 ± 0.02[4]	0.15 ± 0.02[4]	
	928.00 ± 0.02[4]	2.10 ± 0.08[2]	
	959.73 ± 0.02[4]	1.12 ± 0.06[2]	

^{182}Ta	1001.69 ± 0.02[4]	6.43 ± 0.11	
	1044.41 ± 0.02[4]	0.69 ± 0.08[4]	
	1113.40 ± 0.05[4]	1.11 ± 0.07[2]	
	1121.30 ± 0.01[4]	100[2]	
	1157.31 ± 0.01[4]	1.84 ± 0.35[4]	
	1158.08 ± 0.02[4]	0.99 ± 0.28[4]	
	1189.05 ± 0.01[4]	46.10 ± 1.52[2]	
	1221.40 ± 0.01[4]	78.4 ± 1.16[2]	
	1231.01 ± 0.01[4]	32.60 ± 0.52[2]	
	1257.41 ± 0.01[4]	4.31 ± 0.08[2]	
	1273.73 ± 0.01[4]	1.83 ± 0.05[2]	
	1289.15 ± 0.01[4]	3.96 ± 0.08[2]	
	1342.71 ± 0.05[4]	0.74 ± 0.03[2]	
	1373.80 ± 0.01[4]	0.65 ± 0.03[2]	
	1387.40 ± 0.01[4]	0.21 ± 0.01[2]	
	1410.10 ± 0.10[4]	0.12 ± 0.01[4]	
	1453.12 ± 0.01[4]	0.12 ± 0.01[4]	
^{183}Ta	46.484 ± 0.002[3]	0.22[2]	1. Gr70
	52.596 ± 0.001[1]	0.24[2]	2. ND13
	82.919 ± 0.001[1]	0.011[2]	3. Ne70
	84.712 ± 0.002[1]	0.007[2]	
	99.080 ± 0.002[1]	0.22[2]	
	107.932 ± 0.001[1]	0.35[2]	
	144.127 ± 0.002[1]	0.085[2]	

^{183}Ta	192.646 ± 0.005[1]	0.009[2]	
	291.724 ± 0.006[1]	0.20[2]	
	353.999 ± 0.004[1]	0.40[2]	
	365.615 ± 0.007[1]	0.035[2]	
	406.589 ± 0.006[1]	0.090[2]	
^{185}Os	592.06 ± 0.01[1]	0.0132[2]	1. He71
	646.11 ± 0.02[1]	0.813[2]	2. ND13
	717.42 ± 0.02[1]	0.0425[2]	
	874.81 ± 0.02[1]	0.0672[2]	
	880.26 ± 0.02[1]	0.0549[2]	
^{191}Os	82.43 ± 0.01[1]	0.001[2]	1. Rae70
	129.431 ± 0.005[1]	1.00[2]	2. ND13
^{192}Ir	205.70 ± 0.10[1]	4.66 ± 0.11[1]	1. La74
	295.949 ± 0.006[2]	35.70 ± 1.02[1]	2. Gr70
	308.445 ± 0.007[2]	36.70 ± 1.05[1]	3. He71
	316.497 ± 0.007[2]	100[1]	4. Ge73
	374.50 ± 0.15[1]	0.73 ± 0.05[1]	5. Leg70

^{192}Ir	468.06 ± 0.01[3]	60.05 ± 1.16[1]	6. In73
	484.57 ± 0.01[3]	4.88 ± 0.20[1]	
	588.57 ± 0.01[3]	4.86 ± 0.18[1]	
	604.40 ± 0.01[3]	10.92 ± 0.21[1]	
	612.45 ± 0.01[3]	7.35 ± 0.32[1]	
	884.52 ± 0.02[3]	0.48 ± 0.02[1]	
^{198}Au	411.794 ± 0.008[1]	0.947[2]	1. He71
	675.88 ± 0.02[1]	0.0105[2]	2. ND13
	1087.67 ± 0.02[1]	0.00227[2]	
^{203}Hg	279.188 ± 0.006[1]		1. Gr70
^{207}Bi	569.68 ± 0.01[1]	0.98[2]	1. He71
	1063.64 ± 0.02[1]	0.77[2]	2. Led68
	1770.19 ± 0.04[3]	0.09[2]	3. Gr73

		(%Error)	
^{226}Ra	53.24 ± 0.02[1,2]	0.123 (7.0)[1]	1. Me72
	186.180 ± 0.004[2]	0.032[1]	2. Mo70
	242.00 ± 0.02[2]	0.079 (3.5)[1]	
	258.99 ± 0.06[1,2]	0.0058 (4.9)[1]	
	274.67 ± 0.06[1,2]	0.0050 (4.4)[1]	
	295.241[1,2]	0.202 (3.6)[1]	
	351.96 ± 0.02[2]	0.401 (3.6)[1]	
	405.7 ± 0.1[1,2]	0.0017 (7.4)[1]	
	454.8 ± 0.1[1,2]	0.0033 (7.0)[1]	
	461.8 ± 0.1[1,2]	0.0022 (7.5)[1]	
	469.0 ± 0.1[1,2]	0.0013 (10.5)[1]	
	474.5 ± 0.1[1,2]	0.00076(13)[1]	
	480.44 ± 0.1[1,2]	0.0033 (7.0)[1]	
	487.13 ± 0.1[1,2]	0.0045 (6.2)[1]	
	580.2 ± 0.1[1,2]	0.0036 (7.0)[1]	
	609.27 ± 0.05[1,2]	0.484 (3.3)[1]	
	665.40 ± 0.07[1,2]	0.0165 (4.7)[1]	
	702.10 ± 0.1[1,2]	0.00545(8.0)[1]	
	719.85 ± 0.1[1,2]	0.0042 (8.0)[1]	
	768.453[1,2]	0.0532 (3.5)[1]	
	785.80 ± 0.1[1,2]	0.0121 (4.6)[1]	
	806.16 ± 0.1[1,2]	0.0131 (4.5)[1]	
	839.04 ± 0.1[1,2]	0.0060 (5.5)[1]	
	934.06 ± 0.6[1,2]	0.0334 (3.8)[1]	
	964.12 ± 0.1[1,2]	0.00427(8.1)[1]	
	1051.96 ± 0.1[1,2]	0.00324(9.0)[1]	

		(%Error)	
^{226}Ra	1120.28 ± 0.06[1,2]	0.160 (3.3)[1]	
	1155.17 ± 0.07[1,2]	0.0182 (4.4)[1]	
	1207.52 ± 0.08[1,2]	0.0048 (8.0)[1]	
	1238.13 ± 0.06[1,2]	0.062 (3.6)[1]	
	1280.98 ± 0.08[1,2]	0.0156 (4.8)[1]	
	1377.64 ± 0.05[1,2]	0.0418 (4.6)[1]	
	1385.33 ± 0.06[1,2]	0.0086 (5.7)[1]	
	1401.44 ± 0.06[1,2]	0.0144 (5.2)[1]	
	1407.98 ± 0.06[1,2]	0.0260 (4.9)[1]	
	1509.22 ± 0.07[1,2]	0.0230 (4.4)[1]	
	1583.12 ± 0.1[1,2]	0.0076 (6.4)[1]	
	1661.24 ± 0.07[1,2]	0.0121 (6.0)[1]	
	1729.55 ± 0.07[1,2]	0.0307 (4.0)[1]	
	1764.49 ± 0.07[1,2]	0.166 (3.3)[1]	
	1838.33 ± 0.1[1,2]	0.0041 (5.2)[1]	
	1847.44 ± 0.07[1,2]	0.022 (5.7)[1]	
	2118.52 ± 0.1[1,2]	0.0123 (5.0)[1]	
	2204.14 ± 0.1[1,2]	0.0530 (4.0)[1]	
	2293.21 ± 0.1[1,2]	0.0034 (7.0)[1]	
	2447.63 ± 0.1[1,2]	0.0165 (4.1)[1]	
^{228}Th	238.62 ± 0.01[1]	0.448[1]	1. ND13
	583.17 ± 0.01[2]	0.287[1]	2. Gr71
	2614.61 ± 0.10[1]	0.345[1]	

^{241}Am	26.345 ± 0.001[1]	7.0[2]	1. Ne70
	59.537 ± 0.001[3]	100	2. Led68
			3. Gr70
^{243}Cm	57.26	0.14 ± 0.01	1. AH72
	99.536	13.5 ± 0.5	
	103.750	20.8 ± 7.6	
	117.1	7.6 ± 0.3	
	120.6	2.6 ± 0.1	
	209.76	3.30 ± 0.10	
	228.20	10.6 ± 0.3	
	254.41	0.11 ± 0.01	
	272.87	0.08 ± 0.01	
	277.62	14.0 ± 0.4	
	285.47	0.73 ± 0.02	
	311.7	0.017 ± 0.002	
	315.91	0.018 ± 0.000	
	322.3	0.007 ± 0.001	
	334.33	0.024 ± 0.002	

REFERENCES:

Ar74 G. Ardisson, S. Laribi, and C. Marsol, Nucl. Phys. A223 (1974) 616.

Ah71 I. Ahmad and M. Wahlgren, Nucl. Instr. Meth. 99, (1972) 333.

Au69 F. P. Auer, J. J. Reidy, and M. L. Wiedenbeck, Nucl. Phys. A124 (1969) 199.

Bu67 S. B. Burson, P. F. A. Goudsmit, and J. Konijn, Phys. Rev. 158 (1967) 1161.

Ca71 D. C. Camp and G. L. Meredith, Nucl. Phys. A166 (1971) 349.

Ch67 C. Chasman, K. W. Jones, R. A. Ristinen, and D. E. Alburger, Phys. Rev. 159 (1967) 830.

Chi69 G. Chilosi, E. Eichler, and N. K. Aras, Nucl. Phys. A123 (1969) 327.

Das73 B. K. Das Mahapatra and P. Mukherjee, Nucl. Instr. Meth. 107 (1973) 611.

Ei68 C. W. E. Van Eijk, B. Van Nooijen, F. Schutte, S. M. Brahmavar, J. H. Hamilton, and J. J. Pinajian, Nucl. Phys. A121 (1968) 440.

Ga72 P. L. Gardulski and M. L. Wiedenbeck, Nucl. Instr. Meth. 105 (1972) 169.

Ge71 R. J. Gehrke, J. E. Cline, and R. L. Heath, Nucl. Instr. Meth. 91 (1971) 349.

Ge73 R. J. Gehrke, Nucl. Phys. A204 (1973) 26.

Gr70	R. C. Greenwood, R. G. Helmer, and R. J. Gehrke, Nucl. Instr. Meth. 77 (1970) 141.
Gr73	R. G. Greenwood, R. G. Helmer, and R. J. Gehrke, unpublished.
Gu68	R. Gunnink, R. A. Meyer, J. B. Niday, and R. P. Anderson, Nucl. Instr. Meth. 65 (1968) 26.
Ha67	A. J. Haverfield, F. M. Bernthal, and J. M. Hollander, Nucl. Phys. A94 (1967) 337.
Ham71	J. H. Hamilton, S. M. Brahmavar, J. B. Gupta, R. W. Lide, and P. H. Stelson, Nucl. Phys. A172 (1971) 139.
Han73	A. Hanser, Nucl. Instr. Meth. 107 (1973) 187.
He71	R. G. Helmer, R. C. Greenwood, and R. J. Gehrke, Nucl. Instr. Meth. 96 (1971) 173.
In73	H. Inoue and Y. Yoshizawa, Nucl. Instr. Meth. 108 (1973) 385.
Ja71	L. J. Jardine, Nucl. Instr. Meth. 96, (1971) 259.
Ke70	G. E. Keller and E. F. Zganjar, Nucl. Phys. A147 (1970) 527.
Ko71	J. Konijn and E. W. A. Lingeman, Nucl. Instr. Meth. 94 (1971) 389.
La74	N. Lavi, Nucl. Instr. Meth. 116 (1974) 457.
La73a	N. Lavi, Nucl. Instr. Meth. 107 (1973) 197.
La73b	N. Lavi, Nucl. Instr. Meth. 109 (1973) 265.
Led68	C. M. Lederer, J. M. Hollander, and I. Perlman, *Table of Isotopes*, 6th ed., John Wiley & Sons, Inc. (1968).

Leg68 J. Legrand, J. P. Boulanger, and J. P. Brethon, Nucl. Phys. A107 (1968) 177.

Leg70 J. Legrand, J. Morel, and C. Clement, Nucl. Phys. A142 (1970) 63.

Li74 E. W. A. Lingeman, F. W. N. De Boer, and B. J. Meijer, Nucl. Instr. Meth. 118 (1974) 609.

Lu68 M. A. Ludington, J. J. Reidy, M. L. Wiedenbeck, D. J. McMillan, J. H. Hamilton, and J. J. Pinajian, Nucl. Phys. A119 (1968) 398.

MeN73 L. A. McNelles and J. L. Campbell, Nucl. Instr. Meth. 109 (1973) 241.

Me68 R. A. Meyer, Phys. Rev. 170 (1968) 1089.

Me72 R. A. Meyer, unpublished.

Mo70 R. S. Mowatt, Can. J. Phys. 48 (1970) 2606.

ND13 Nucl. Data Tables 13 (1972).

NDA8 Nucl. Data Tables A8 (1970).

Ne70 G. C. Nelson and B. G. Saunders, Nucl. Instr. Meth. 84 (1970) 90.

No70 A. Notea and E. Elias, Nucl. Instr. Meth. 86 (1970) 269.

Phe70 M. E. Phelps, D. G. Sarantites, and W. G. Winn, Nucl. Phys. A149 (1970) 647.

Phi72 G. B. Phillips, S. M. Brahmavar, J. H. Hamilton, and T. Kracikova, Nucl. Phys. A182 (1972) 606.

Pr71 W. W. Pratt, Nucl. Phys. A170 (1971) 223.