

Systematics of M1 transition rates: RUL

(retrievals based on ENSDF: May 2008 version)

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Background

Evaluations of BM1(W.u.) by P.M. Endt: (isospin allowed M1 transitions)

1974En05: NP A **235**, 27: A=6-44 RUL=10 : Current ENSDF / NDS policy: A=6-44: **10**
1974EnAA: ADNDT **13**, 67: A=21-44 RUL=10
1979En05: ADNDT **23**, 3: A=6-44 RUL=10
1993En03: ADNDT **55**, 171: A=6-44 RUL=10 for 6-20; **5** for 21-44
1979En04: ADNDT **23**, 547: A=45-90 RUL=3: Current ENSDF / NDS policy: A=45-150: **3**
1981En06: ADNDT **26**, 47: A=91-150 RUL=1

Based on a user's request in March 2007, for more current survey of BM1(W.u.) values, we scanned the entire ENSDF, primarily to look for high values (>~0.4).

First report was represented at IAEA-NSDD-07 meeting in June 2007.

Many mistakes were found in these values in ENSDF database. Some of these have been corrected. More importantly RULER code was modified by Tom Burrows in the hope of avoiding such mistakes in future evaluations.

In the current report the highest and the lowest values in different mass regions have been checked Again, and we believe we have a better and more current estimation of RUL for BM1(W.u.) values



A=6-20: highest values

RUL=10 Endt (adopted in ENSDF)

Nuclide	E(level)	J _i	J _f	E(γ)	Half-life/ width(γ)	B(M1)(W.u.)
¹⁸ F	1041.5	0+	1+	1041	1.77(31) fs	10.9(21)
⁶ Li	3562.9	0+	1+	3561.8	8.19(17) eV	8.62(18)
¹⁴ N	8618	0+	1+	2414	5.25 eV	7.2
¹⁰ B	7428	1-	2-	2317	4.8(7) eV	5.8(15)
¹⁰ B	1740.0	0+	1+	1021.7	4.9(21) fs	4.2(18)
¹⁰ B	7559.9	0+	1+	2380.0	6.2(6) eV	3.1(6)

Proposed RUL: 12; based on 10.9(21)

(for isospin allowed M1 transitions)

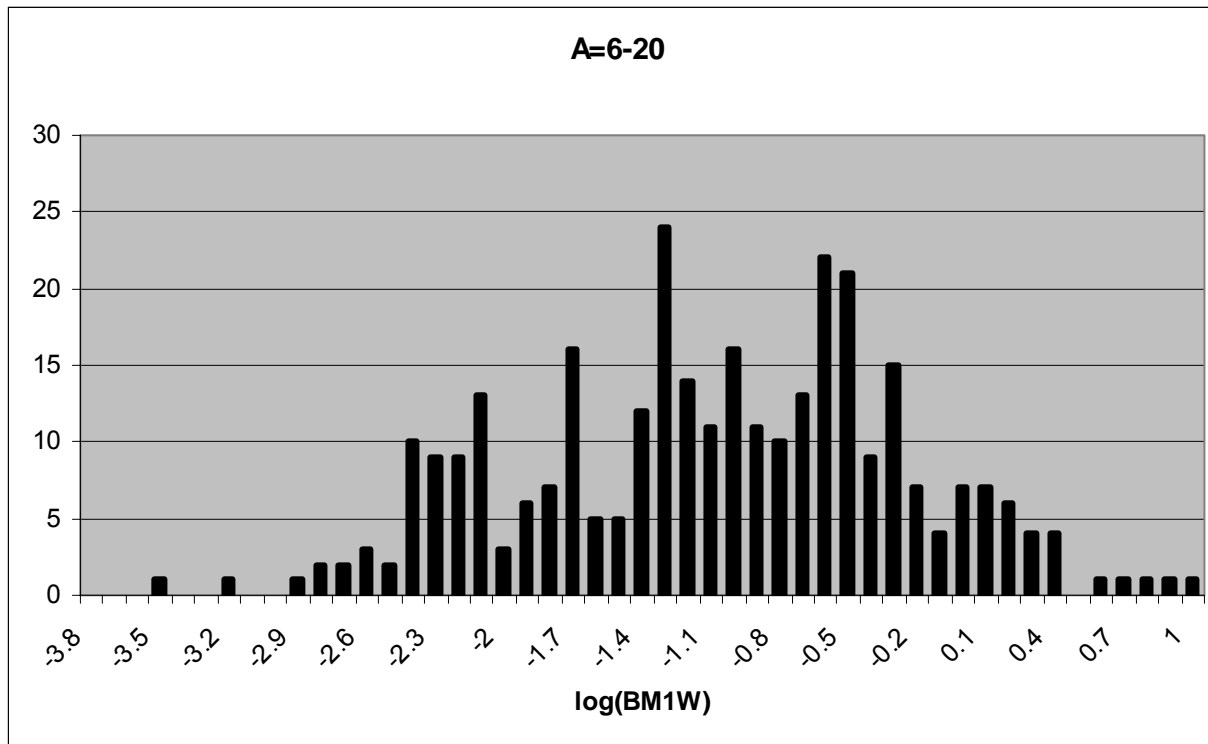


A=6-20: lowest values

Nuclide	E(level)	J_i	J_f	$E(\gamma)$	Half-life/ width(γ)	$\delta(E2/M1)$	B(M1)(W.u.)
^{18}F	3358.2	3+	3+	2421	0.30(2) ps	0	0.00047(17)
^{14}N	9703	1+	1+	9699	0.061(7) eV	0	0.00094(21)
^{14}N	6203.5	1+	1+	6202	111(14) fs	0.19(4)	0.0018(2)
^{14}N	7029.1	2+	1+	3080.7	3.7(4) fs	0	0.0018(6)
^{18}F	1700.8	1+	1+	1701	662(19) fs	0	0.00200(11)
^{18}F	3133.9	1-	0-	2053	0.27(1) ps		0.0023(2)



A=6-20



317 values

Mean value: 0.40

Most probable value: ~0.15



A=21-44: highest values

RUL=5 (Endt), RUL=10 (adopted in ENSDF)

Nuclide	E(level)	J_i	J_f	E(γ)	Half-life	$\delta(E2/M1)$	B(M1)(W.u.)
^{22}Na	657.16	0+	1+	73.9	19.6(7) ps		2.78(10)
^{43}Sc	1810.7	3/2-	3/2-	631.8	16(6) fs	0.22(7)	2.1(8)
^{41}Ca	3976.0	11/2+	9/2+	774.6	23(7) fs	0.09(2)	1.7(6)
^{26}Al	1057.7	1+	0+	829.4	25(5) fs		1.5(3)
^{44}Sc	666.7	1+	2+	666.7	51(12) fs	0	1.5(4)
^{40}K	2879.0	6+	7+	336.2	0.27(10) ps	<0.03	1.4(6)

Proposed RUL: 4; based on 2.78(10). (for isospin allowed M1 transitions)

Endt's (1993) RUL=5 based on 4.3(5) for 1669, 0+ to 1+ gamma from 11988, IAR in ^{40}Ca . We get 3.5(7) for this transition and 2.3(4) for a competing transition. This level decays mainly (92(9)%) by alpha decay, thus some uncertainty about partial gamma-width. A 404, 17/2+ to 15/2+ gamma from a 4591 level in ^{43}Ca was listed by Endt (1993) with B(M1)(W.u.)=3.8(12), but we find 0.38(13)!

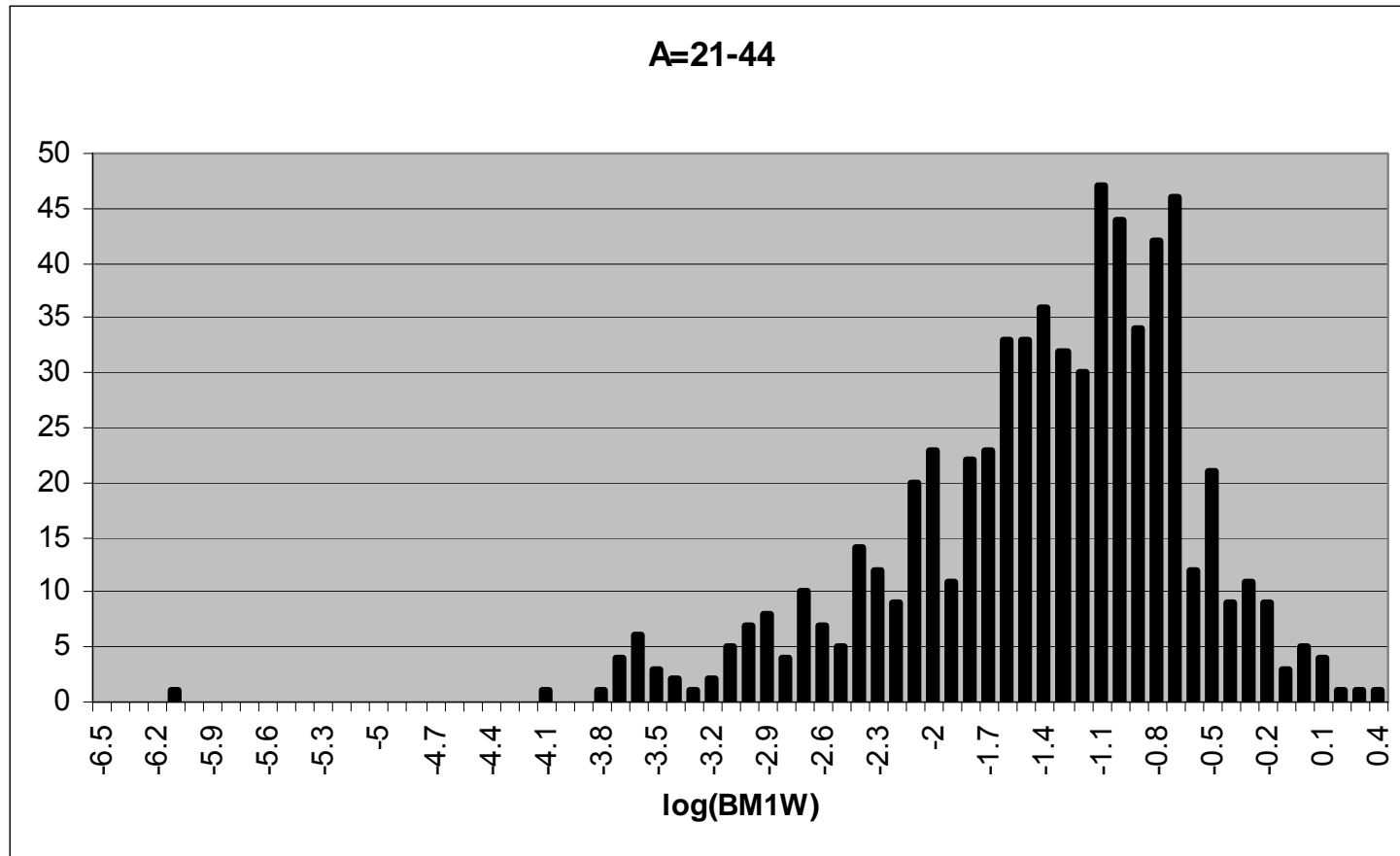


A=21-44: lowest values

Nuclide	E(level)	J_i	J_f	E(γ)	Half-life	$\delta(E2/M1)$	B(M1)(W.u.)
^{44}Sc	146.2	0-	1-	78.4	50.4(7) μs		8.7(4)E-7
^{32}S	7115.0	2+	2+	4884.2	1.73(35) ps	0.38(4)	8.1(17)E-5
^{22}Na	4771	3+	2+	2818	5.9(14) fs	0	1.7(4)E-4
^{30}P	4926.4	5-	4-	694.1	260(35) ps	0.29(4)	2.1(3)E-4
^{44}Sc	234.7	2-	1-	166.7	6.1(2) ns	<0.04	2.4(2)E-4



A=21-44



A=45-90: highest values

- RUL=3 (Endt; adopted in ENSDF)

Nuclide	E(level)	J _i	J _f	E(γ)	Half-life	δ(E2/M1)	B(M1)(W.u.)
⁸⁷ Y	7016.6	33/2(-)	31/2(-)	481.1	0.11(3) ps	0.10(15)	1.8(5)
⁸⁶ Rb	3411.9	(11+)	(10+)	129.9	5.5(14) ps		1.7(5)
⁹⁰ Zr	7223.9	(12)+	(11)+	29.6	59(10) ps		1.6(4)
⁴⁵ Sc	3629.9	19/2-	17/2-	122.9	1.39(14) ps	<0.003	1.5(6)
⁵⁰ V	836.3	5+	4+	516.0	54(22) fs	<0.01	1.5(6)
⁵⁰ V	1331.5	1+	2+	943.1	17(6) fs	<0.02	1.5(6)

RUL=3 based on 1.8(5); earlier RUL was based on erroneous value of 2.5(4) for 3756, 6+ level in ⁵⁶Fe.

Note: Highest value in current ENSDF is 2.3(11) for ⁵⁴Mn: 54.9 gamma (2+ to 3+) from 54.9 level (49(20) ps; g(theory) used for half-life deduced from gt value (1974Ke11))

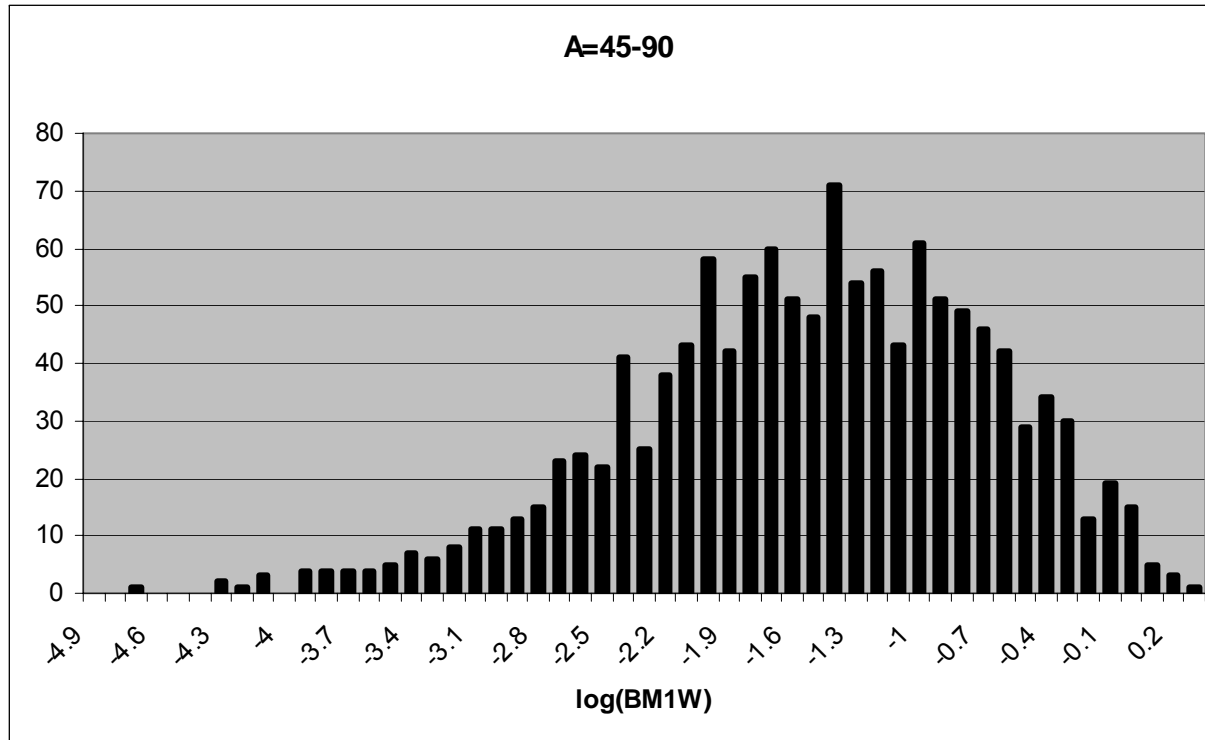


A=45-90: lowest values

Nuclide	E(level)	J_i	J_f	E(γ)	Half-life	$\delta(E2/M1)$	B(M1)(W.u.)
^{53}Mn	2875.8	3/2-	5/2-	2497.6	41(+14-11) ps	0.4(3)	2.5(10)E-5
^{51}Cr	3001.7	5/2-	7/2-	3001.6	15(+5-4) ps	<0.17	5.4(16)E-5
^{50}Cr	3629.5	1+	0+	3629.0	5(3) ps		6(+9-2)E-5
^{51}Mn	3680.6	17/2-	15/2-	430.1	1.43(6) ns		7.1(4)E-5
^{54}Mn	1454.4	1+	2+	1399.6	80(+50-30) ps	<0.12	10(5)E-5



A=45-90



1251 values

Mean: 0.14

Most probable value: ~0.04



A=91-150: highest values

RUL=1 (Endt), RUL=3 (ENSDF)

Nuclide	E(level)	J_i	J_f	E(γ)	Half-life	$\delta(E2/M1)$	B(M1)(W.u.)
^{92}Ru	5658.1	(15+)	(14+)	86.1	10(3) ps		2.0(7)
^{104}Ag	796.6	(8+)	(7+)	316.7	0.25(7) ps		1.7(7)
^{135}Nd	4006.7	(31/2-)	(29/2-)	226.0	1.012(14)ps	<0.14	1.50(14)
^{135}Nd	3649.9	(31/2-)	(29/2-)	291.3	0.52(6) ps		1.39(17)
^{142}Eu	2935.5+X	16-	15-	184.6	1.8(3) ps		1.3(2)
^{105}In	3957.9	23/2-	21/2-	130.2	1.73(14) ps		1.20(10)

Proposed RUL=3 based on 2.0(7)

Note: values for magnetic-dipole rotational bands structures in high-spin physics can be much higher and are not included here.

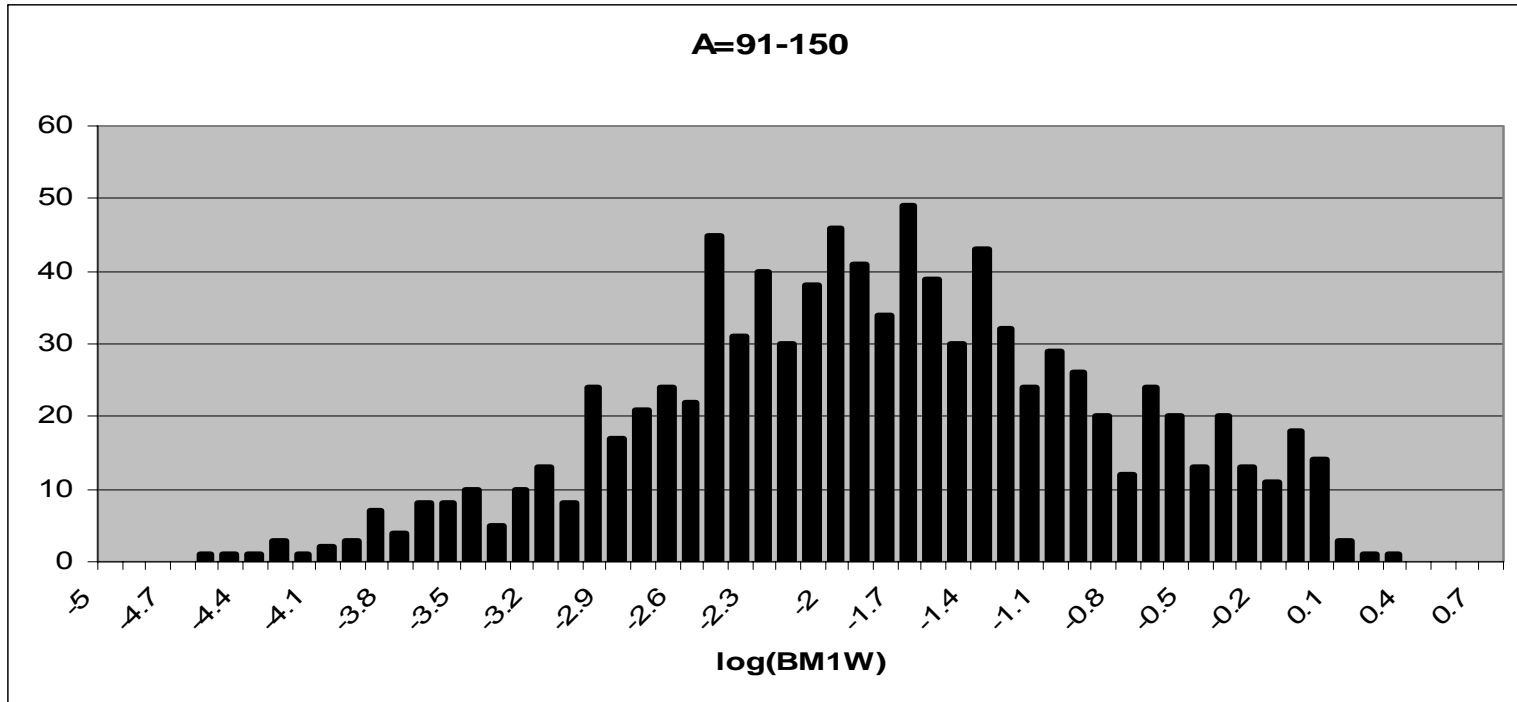


A=91-150: lowest values

Nuclide	E(level)	J_i	J_f	E(γ)	Half-life	$\delta(E2/M1)$	B(M1)(W.u.)
^{117}In	1891.9	1/2+	1/2+	1142.4	0.42(6) ns		1.8(3)E-6
^{100}Ru	2240.8	2+	2+	1701.3	83(6) ps	<0.06	2.9(5)E-5
^{98}Y	170.7	(2)-	(1)-	51.4	620(80) ns	0.32(7)	3.5(9)E-5
^{119}I	306.6	9/2+	7/2+	207.8	34.6(5) ns	0.11(5)	5.3(4)E-5
^{121}I	433.6	(9/2)+	7/2+	300.7	9.6(4) ns	0.13(7)	5.8(6)E-5
^{117}I	353.6	(9/2)+	(7/2)+	294.8	12.1(7) ns	0.05(5)	6.0(8)E-5



A=91-150



940 values

Mean: 0.10

Most probable value: ~0.02



A>150: highest values

RUL=2 : from ENSDF (~1980) scan by M. Martin
(current ENSDF / NDS policy)

Nuclide	E(level)	J _i	J _f	E(γ)	Half-life	δ(E2/M1)	B(M1)(W.u.)
²⁰⁸ Tl	39.8	4+	5+	39.9	6.5(8) ps		2.1(3)
¹⁶³ Lu	5505.1	(49/2-)	(47/2-)	373.4	0.11(+5-3) ps		1.7(+5-8)
¹⁶³ Lu	5131.8	(47/2-)	(45/2-)	371.0	0.15(5) ps		1.4(6)
¹⁶¹ Tm	5789	51/2-	49/2-	394.8	0.10(3) ps	<0.3	1.3(5)
¹⁶³ Lu	6334.1	(53/2-)	(51/2-)	417.2	0.09(+6-4) ps		1.3(+6-9)
¹⁶³ Lu	5916.9	(51/2-)	(49/2-)	411.5	0.12(+3-6) ps		1.2(+7-4)

Proposed RUL=3 based on 2.1(3)

Note: high values for magnetic-dipole rotational bands
are not included here.

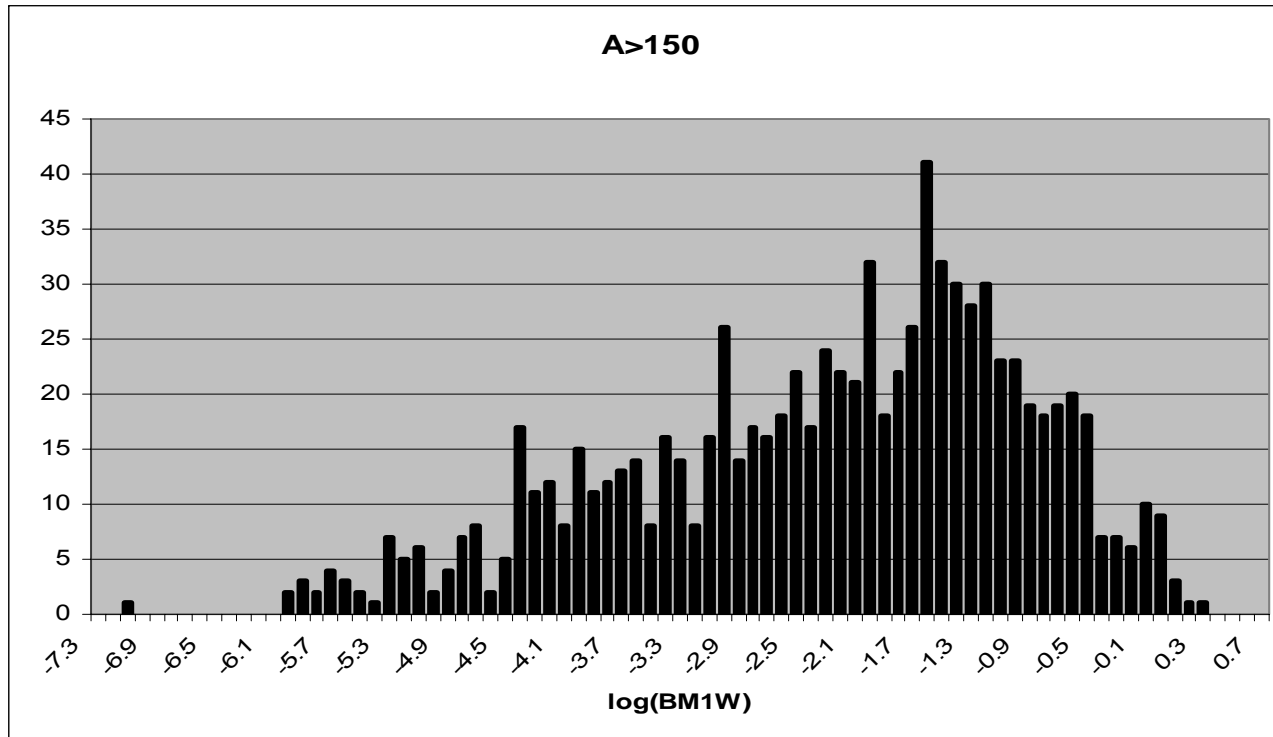


A > 150: lowest values

Nuclide	E(level)	J_i	J_f	E(γ)	Half-life/ width	$\delta(E2/M1)$	B(M1)(W.u.)
^{178}Hf	2573.5	(14)-	(13)-	140.3	68(2) us		1.72(9)E-8
^{175}Hf	1433.4	(19/2)+	(17/2)+	722.2	1.10(8) us		2.53(25)E-8
^{159}Dy	352.8	11/2-	9/2-	116.9	122(3) us		3.0(10)E-8
^{177}Ta	1355.0	21/2-	19/2-	311.3	5.31(25) us	0.29(+11-6)	9.3(8)E-8
^{169}Tm	316.1	7/2+	7/2+	177.2	660(3) ns	0.30(13)	1.25(10)E-6
^{180}Re	1496.0+X	(11-)	(10-)	416.8	70(3) ns		1.21(15)E-6



A > 150



881 Values

Mean: 0.18

Most probable value: ~0.04



Magnetic-dipole bands

- Transitions in magnetic-dipole rotational bands can have much higher $B(M1)(W.u.)$ values than RUL
- In our scan of ENSDF, we found ~50 transitions in these bands, which have $B(M1)(W.u.)$ values >1 , several of these higher than current recommended $RUL=3$
- We did not include these transitions in our estimation of the RUL for $A=91-150$ and $A>150$ region.
- A special note should be given in ENSDF policies about such transitions as has been done for high $B(E2)(W.u.)$ values for SD structures.

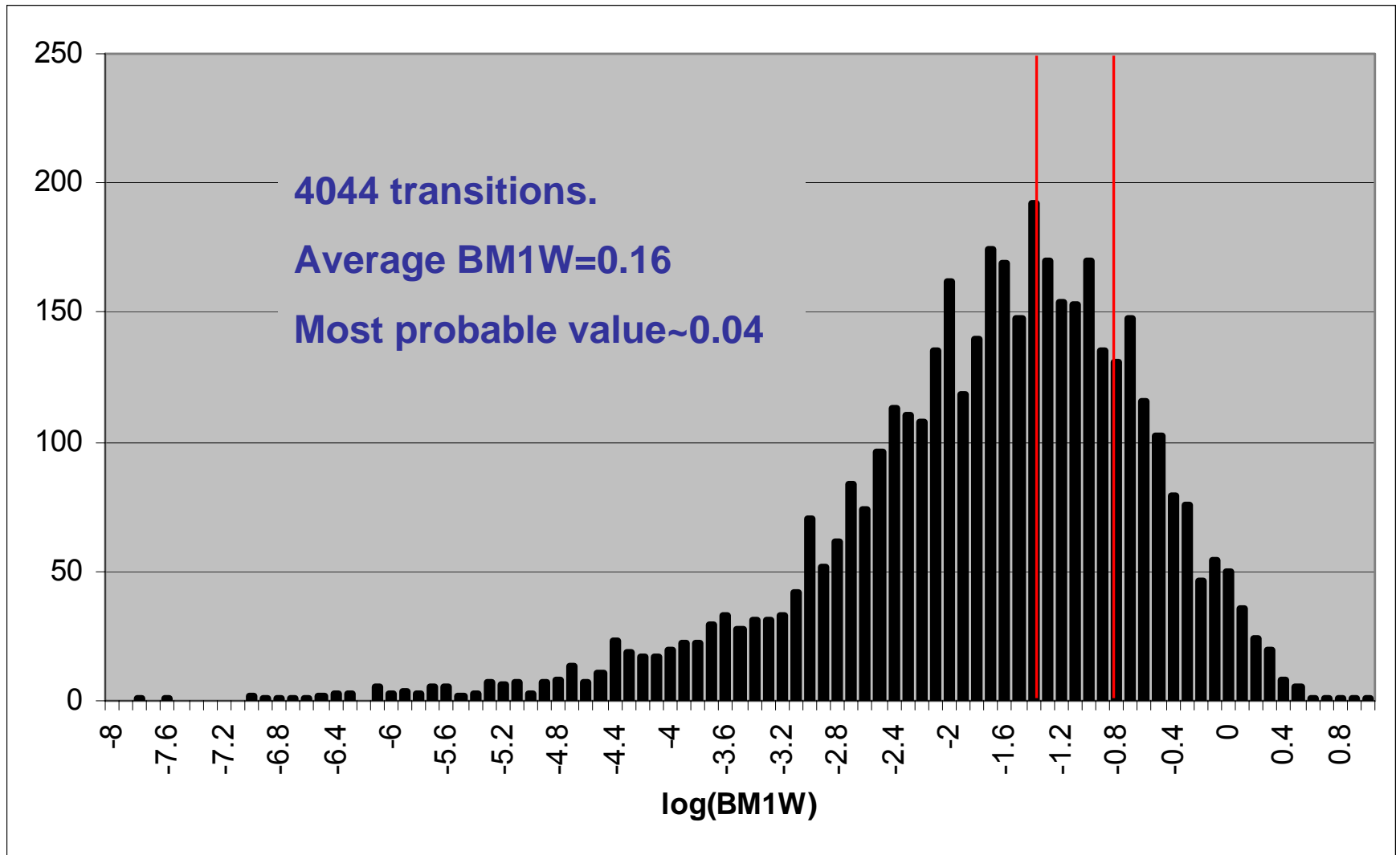


Magnetic-dipole rotational bands

Nuclide	E_{level}	J_i	$E(\gamma)$	Half-life	$B(M1)(W.u.)$
^{136}Nd	9492	(24+)	544	0.042(21) ps	3.3(17)
^{136}Nd	8947.7	(23+)	481	0.062(28) ps	3.2(15)
^{194}Pb	6813.3	(23-)	417.1	0.125(28) ps	1.7(7)
^{194}Pb	6396.1	(22-)	375.5	0.125(+35-20) ps	2.4(4)
^{194}Pb	6020.5	(21-)	336.2	0.146(14) ps	3.0(3)
^{194}Pb	5684.4	(20-)	260.1	0.159(+28-40) ps	4.8(+13-9)
^{197}Pb	6712.3	51/2+	446.1	0.111(14) ps	2.4(12)
^{198}Pb	8290.8	(27+)	374.4	0.097(21) ps	3.4(10)
^{198}Pb	5648.2	18-	155.7	0.44(7) ps	3.5(6)
^{199}Pb	1194.2+Y	(47/2+)	323.1	0.13(+10-6) ps	4(3)
^{199}Pb	7120.5+X	(49/2-)	316.3	0.090(+28-20) ps	5.4(20)
^{199}Pb	6804.2+X	(47/2-)	273.8	0.118(+42-20) ps	5.8(21)
^{199}Pb	6530.4+X	(45/2-)	240.1	0.21(+21-10) ps	4(+4-3)
^{199}Pb	6290.3+X	(43/2-)	234.6	0.26(+35-20) ps	4(+4-3)



All B(M1)(W.u.) values in ENSDF



Summary of RUL for M1

Mass Region	Endt RUL	ENSDF RUL	Number of values above RUL	Highest value	Proposed new RUL
6-20	10	10	1	10.9(21)	12
21-44	5	10	0	2.78(10)	4
45-90	3	3	0	1.8(5)	3
91-150	1	3	0*	2.0(7)	3
>150		2	1*	2.1(3)	3

*Other transitions above RUL, but these are associated with magnetic-dipole rotational bands in high-spin physics. Some footnotes needed.



Problem cases

While double-checking some of the B(M1)(W.u.) values in the ENSDF database, it was disconcerting that many were found in error.

Common mistakes found where:

1. For particle-unbound levels, total width was used in deducing B(M1)(W.u.). Some of these cases have now been corrected in ENSDF but not all have been identified as yet. In 2007, Tom Burrows modified the RULER code significantly so that such cases become easily visible.
2. Conversion coefficients were significant and were not listed and considered in calculation.
3. Either incorrect mixing ratio or assumed values were used but not stated.
4. Many uncertainties are incorrectly deduced. Minimum % uncertainty should correspond to that in T1/2. Sometimes we found uncertainties lower by a factor of 10.

The user, who in 2007 asked for a complete compilation of B(M1)(W.u.) values >0.3 or so, was supplied only with a partial listing scanned manually from ENSDF where entries looked reasonable.

We could not supply him a computer code-retrieved file, since we found a large number of incorrect entries in ENSDF, and it was difficult to double check or evaluate every one of 4000 or so BM1W entries in ENSDF database.

For ENSDF evaluations, please use great care in the use of RULER code and look through, critically, all the BELW's in your mass chain whether the values (and associated uncertainties) make sense.