

<sup>156</sup>Gd( $\gamma,\gamma'$ ),(e,e')    **1985Bo31,1989Pi05,1986Bo25**

Type	Author	History Citation	Literature Cutoff Date
Full Evaluation	C. W. Reich	NDS 113, 2537 (2012)	1-Mar-2012

**Additional information 1.**

Experimental studies:

**1985Bo31:** (e,e'). Details of experiment given in **1984Bo09**. Search for 2<sup>+</sup> levels in region of 3 MeV. Report ≈16 such levels below ≈4.7 MeV. Give B(E2) values for 2<sup>+</sup> levels at 88 and 3096 keV and present such values graphically for the others. No level energies given for these latter ones.

**1986Bo25:** (e,e') on enriched (93.6%) target up to an excitation energy of 10 MeV. e' measured in magnetic spectrometer. ( $\gamma,\gamma'$ ) on (94.5%) enriched target using 3.5-MeV bremsstrahlung.  $\gamma'$  measured at 90, 127 and 150° using 3 high resolution Ge(Li) detectors. Report 6 levels and B(M1)↑ values.

**1989Pi05:** ( $\gamma,\gamma'$ ) using 4.1-MeV bremsstrahlung. Enriched (94.4%) oxide target with mass < 3 g.  $\gamma$ 's measured using 3 Ge(Li) or HPGE detectors at 90 (or 95), 127 and 150°. Report 10 transitions having  $\Delta K=1$  and 6 with  $\Delta K=0$ . Report  $\Gamma$  data and B(E1)↑ and B(M1)↑.

For other studies, see **1984Be54**, **1984Bo09**, **1986KnZY**. Details are summarized in the ENSDF file.

The occurrence and properties of 1<sup>+</sup> states in the region of ≈3 MeV has attracted a great deal of interest, both experimental and theoretical, in the <sup>156</sup>Gd level scheme. Numerous papers giving the results of nuclear-model calculations on the nature of these 1<sup>+</sup> excitations have been published. Some of these are as follows: **1985Ca03**; **1987Ca31**; **1987Ra29**; **1988No05**; **1988Ra32**; **1988Sp03**; **1990Fa09**; **1990Ot01**; **1991Ma08**; **1992De21**; **1993Ik01**; **1994Sa08**; **1996He01**; **1996Ma42**; **1996No01**. **2000BeZQ**, from (n, $\gamma$ ) studies, searched for scissors M1 resonances built on excited states of several nuclides, including <sup>156</sup>Gd.

Surveys and theoretical studies of various features of the low-lying dipole transitions in <sup>156</sup>Gd and nearby nuclides are given in **1991Zi01**, **1994Vo19**, **1996Su18** and **1997PiZZ**.

**1985Bo31** show a plot of B(E2) values for 8 levels between ≈1.6 and 2.4 MeV in <sup>156</sup>Gd. Because of uncertainties involved in associating these with established levels, the evaluator has not given them here.

<sup>156</sup>Gd Levels

For the 1<sup>+</sup> levels above 2.96 MeV, the summed orbital M1 strength is 2.1 4 (**1989Pi05**), 2.3 5 (**1986Bo25** from (e,e')), and 2.1 3 (**1986Bo25** from ( $\gamma,\gamma'$ )) (values in  $\mu(n)^2$ ).

B(M1) values are given explicitly by **1989Pi05**, **1986Bo25**, **1984Be54**, and **1984Bo09**. B(E1) values are given by **1989Pi05**. B(E2) values are from **1986Bo25**. Those B(E2) values to the 89 and 3096 levels are listed by these authors. The others are deduced by the evaluator from their graphical data. Note that, where these values can be compared with those from other sources, they are systematically smaller.

E(level) <sup>†</sup>	J <sup>π</sup> @	T <sub>1/2</sub> <sup>‡</sup>	S#&	Comments
0	0 <sup>+</sup>			
89	2 <sup>+</sup>			B(E2)↑=4.48 5
1129 <sup>b</sup>				B(E2)↑≈0.022
1154 <sup>b</sup>				B(E2)↑≈0.137
1243 1	1 <sup>-</sup>	31 fs +22-9	2.9 11	B(E1)↑=1.0×10 <sup>-4</sup> 4
1258 <sup>b</sup>				B(E2)↑≈0.011
1367 1	1 <sup>-</sup>	11 fs +6-3	4.5 16	B(E1)↑=1.6×10 <sup>-4</sup> 6
1946 1	1 <sup>-</sup>	23 fs +12-6	2.0 7	B(E1)↑=2.3×10 <sup>-5</sup> 9
				T <sub>1/2</sub> : Computed by the evaluator from $\Gamma_{\gamma 0}^2/\Gamma$ and the Adopted $\gamma$ branching (from the <sup>156</sup> Eu $\beta^-$ decay).
2027 1	1 <sup>+</sup>	41 fs +17-9	3.9 12	B(M1)↑=0.20 6
				B(M1)↑: See the comment on the level T <sub>1/2</sub> value.
				T <sub>1/2</sub> : Computed by the evaluator from $\Gamma_{\gamma 0}^2/\Gamma$ and the Adopted $\gamma$ branching (from the <sup>156</sup> Eu $\beta^-$ decay).
2403 1	1 <sup>+</sup>	17 fs +5-3	10.9 21	J <sup>π</sup> : <b>1989Pi05</b> do not assign a $\pi$ value to this level.
				T <sub>1/2</sub> : Computed by the evaluator from the $\Gamma$ data of <b>1989Pi05</b> and their $\gamma$ branching.

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<sup>156</sup>Gd( $\gamma,\gamma'$ ),(e,e') **1985Bo31,1989Pi05,1986Bo25 (continued)**

<sup>156</sup>Gd Levels (continued)

E(level) <sup>†</sup>	J <sup>π</sup> @	T <sub>1/2</sub> <sup>‡</sup>	S#&	Comments
2539 <i>I</i>	1 <sup>-</sup>	13 fs +5-3	6.2 15	B(E1)↑=2.7×10 <sup>-5</sup> 7
2745 <i>I</i>	1 <sup>-</sup>	4.3 fs +10-7	13.5 26	B(E1)↑=5.4×10 <sup>-5</sup> 11
2785 <i>I</i>	1 <sup>+</sup>	15 fs +4-3	12.0 24	T <sub>1/2</sub> : Computed by the evaluator from the $\Gamma$ data of 1989Pi05 and their $\gamma$ branching.
2974 <i>I</i>	1 <sup>+</sup>	8.7 fs +13-11	24 4	B(M1)↑=0.34 4 B(M1)↑: Weighted average of 0.35 7 (1989Pi05) and 0.33 5 (1986Bo25), from ( $\gamma,\gamma'$ ), and 0.34 9 from 1986Bo25 (e,e').
3010 <i>I</i>	1 <sup>+</sup>	32 fs +12-7	5.9 14	B(M1)↑=0.09 2 B(M1)↑: Weighted average of 0.09 2 (1989Pi05) and 0.10 4 (1986Bo25), from ( $\gamma,\gamma'$ ). Other: 0.2 1, from 1986Bo25 (e,e').
3050 <i>I</i>	1 <sup>+</sup>	28 fs +11-6	8.1 18	B(M1)↑=0.11 3 B(M1)↑: From 1989Pi05.
3070 <i>I</i>	1 <sup>+</sup>	2.13 fs +19-16	80 15	J <sup>π</sup> : Positive parity assumed by 1989Pi05. B(M1)↑=1.22 9 Probable state of mixed n,p symmetry in the IBM-2 model. see, e.g., 1985Bo31. B(M1)↑: Weighted average of 1.21 23 (1989Pi05) and 1.20 12 (1986Bo25), from ( $\gamma,\gamma'$ ), and 1.3 2 from 1986Bo25 (e,e').
3096 <sup>a</sup>	2 <sup>+</sup>			B(E2)↑=0.0040 6 J <sup>π</sup> : 1985Bo31 propose that this is the 2 <sup>+</sup> member of $\alpha$ mixed-symmetry band based on the 1 <sup>+</sup> state at 3070 keV.
3122 <i>I</i>	1 <sup>+</sup>	26 fs +7-5	6.8 18	B(M1)↑=0.10 2 B(M1)↑: Weighted average of 0.09 3 (1989Pi05) and 0.10 4 (1986Bo25), from ( $\gamma,\gamma'$ ), and 0.11 5 from 1986Bo25 (e,e').
3150 <sup>a</sup>	(2 <sup>+</sup> )			
3158 <i>I</i>	1 <sup>+</sup>	7.4 fs +13-10	27 5	B(M1)↑=0.34 5 B(M1)↑: Weighted average of 0.34 7 (1989Pi05) and 0.36 15 (1986Bo25), from ( $\gamma,\gamma'$ ), and 0.32 10 from 1986Bo25 (e,e').
3218 <i>I</i>	1 <sup>+</sup>	7.5 fs +12-10	26 5	T <sub>1/2</sub> : $\gamma$ branching assumed for T <sub>1/2</sub> computation; only 1 $\gamma$ is reported. B(M1)↑=0.33 4 B(M1)↑: Weighted average of 0.31 6 (1989Pi05) and 0.33 6 (1986Bo25), from ( $\gamma,\gamma'$ ), and 0.38 10 from 1986Bo25 (e,e').
3314 <i>I</i>	1 <sup>-</sup>	9 fs +8-3	5.7 20	B(E1)↑=1.4×10 <sup>-5</sup> 6
3400 <sup>a</sup>	2 <sup>+</sup>	≤0.31 ps		B(E2)↑≈0.0020 B(E2)↑: Value estimated by the evaluator from figure in 1985Bo31. T <sub>1/2</sub> : Calculated from B(E2)≈2.0×10 <sup>-3</sup> from 1985Bo31, (e,e'). Value assumes the only deexciting $\gamma$ is that to the ground state; the existence of other $\gamma'$ s will reduce this computed value.

<sup>†</sup> From 1989Pi05 unless otherwise noted. Uncertainties are assigned by evaluator from a general statement of 1989Pi05. Other: 1986Bo25 for 1<sup>+</sup> levels.

<sup>‡</sup> Calculated by the evaluator from the listed B(M1)↑ and B(E1)↑ values and  $\gamma$  branching, unless noted otherwise.

# Label= $\Gamma_{\gamma 0}^2/\Gamma_{\gamma}$  (meV).

@ From adopted values.

& From 1989Pi05.

<sup>a</sup> From 1985Bo31.

<sup>b</sup> Nominal values from the Adopted Levels. The association of these levels with the graphical B(E2) data of 1985Bo31 is that of the evaluator.

$^{156}\text{Gd}(\gamma, \gamma'), (e, e')$  **1985Bo31, 1989Pi05, 1986Bo25** (continued)

$\gamma(^{156}\text{Gd})$							
$E_i(\text{level})$	$J_i^\pi$	$E_\gamma^\dagger$	$I_\gamma^\ddagger$	$E_f$	$J_f^\pi$	Mult.	Comments
1243	1 <sup>-</sup>	1154	121 <i>31</i>	89	2 <sup>+</sup>		
		1243	100	0	0 <sup>+</sup>		
1367	1 <sup>-</sup>	1278	203 <i>29</i>	89	2 <sup>+</sup>		
		1367	100	0	0 <sup>+</sup>		
1946	1 <sup>-</sup>	1857	1.8×10 <sup>2</sup> <i>6</i>	89	2 <sup>+</sup>		
		1946	100	0	0 <sup>+</sup>		
2027	1 <sup>+</sup>	1938	22 <i>21</i>	89	2 <sup>+</sup>		$I_\gamma$ : From <b>1989Pi05</b> . Note that this differs significantly from $I_\gamma=59$ as observed in the $^{156}\text{Eu}$ $\beta^-$ decay.
		2027	100	0	0 <sup>+</sup>		
2403	1 <sup>+</sup>	2314	53 <i>11</i>	89	2 <sup>+</sup>	[M1]	
		2403	100	0	0 <sup>+</sup>	[M1]	
2539	1 <sup>-</sup>	2450	134 <i>28</i>	89	2 <sup>+</sup>		
		2539	100	0	0 <sup>+</sup>		
2745	1 <sup>-</sup>	2656	178 <i>21</i>	89	2 <sup>+</sup>		
		2745	100	0	0 <sup>+</sup>		
2785	1 <sup>+</sup>	2696	55 <i>10</i>	89	2 <sup>+</sup>	[M1]	
		2785	100	0	0 <sup>+</sup>	[M1]	
2974	1 <sup>+</sup>	2885	52 <sup>#</sup> <i>10</i>	89	2 <sup>+</sup>		
		2974	100	0	0 <sup>+</sup>		
3010	1 <sup>+</sup>	2921	55 <sup>#</sup> <i>20</i>	89	2 <sup>+</sup>		
		3010	100	0	0 <sup>+</sup>		
3050	1 <sup>+</sup>	2961	36 <i>16</i>	89	2 <sup>+</sup>		
		3050	100	0	0 <sup>+</sup>		
3070	1 <sup>+</sup>	2981	57 <sup>#</sup> <i>5</i>	89	2 <sup>+</sup>		
		3070	100	0	0 <sup>+</sup>		
3096	2 <sup>+</sup>	3096		0	0 <sup>+</sup>		
3122	1 <sup>+</sup>	3033	50 <sup>#</sup> <i>20</i>	89	2 <sup>+</sup>		
		3122	100	0	0 <sup>+</sup>		
3150	(2 <sup>+</sup> )	3150		0	0 <sup>+</sup>		Mult.: Probable E2 transition, but assignment is not completely unambiguous ( <b>1985Bo31</b> ).
3158	1 <sup>+</sup>	3158		0	0 <sup>+</sup>		
3218	1 <sup>+</sup>	3129	44 <sup>#</sup> <i>10</i>	89	2 <sup>+</sup>		
		3218	100	0	0 <sup>+</sup>		
3314	1 <sup>-</sup>	3225	1.9×10 <sup>2</sup> <i>6</i>	89	2 <sup>+</sup>		
		3314	100	0	0 <sup>+</sup>		
3400	2 <sup>+</sup>	3400		0	0 <sup>+</sup>		

<sup>†</sup> Computed by evaluator from reported level energies.

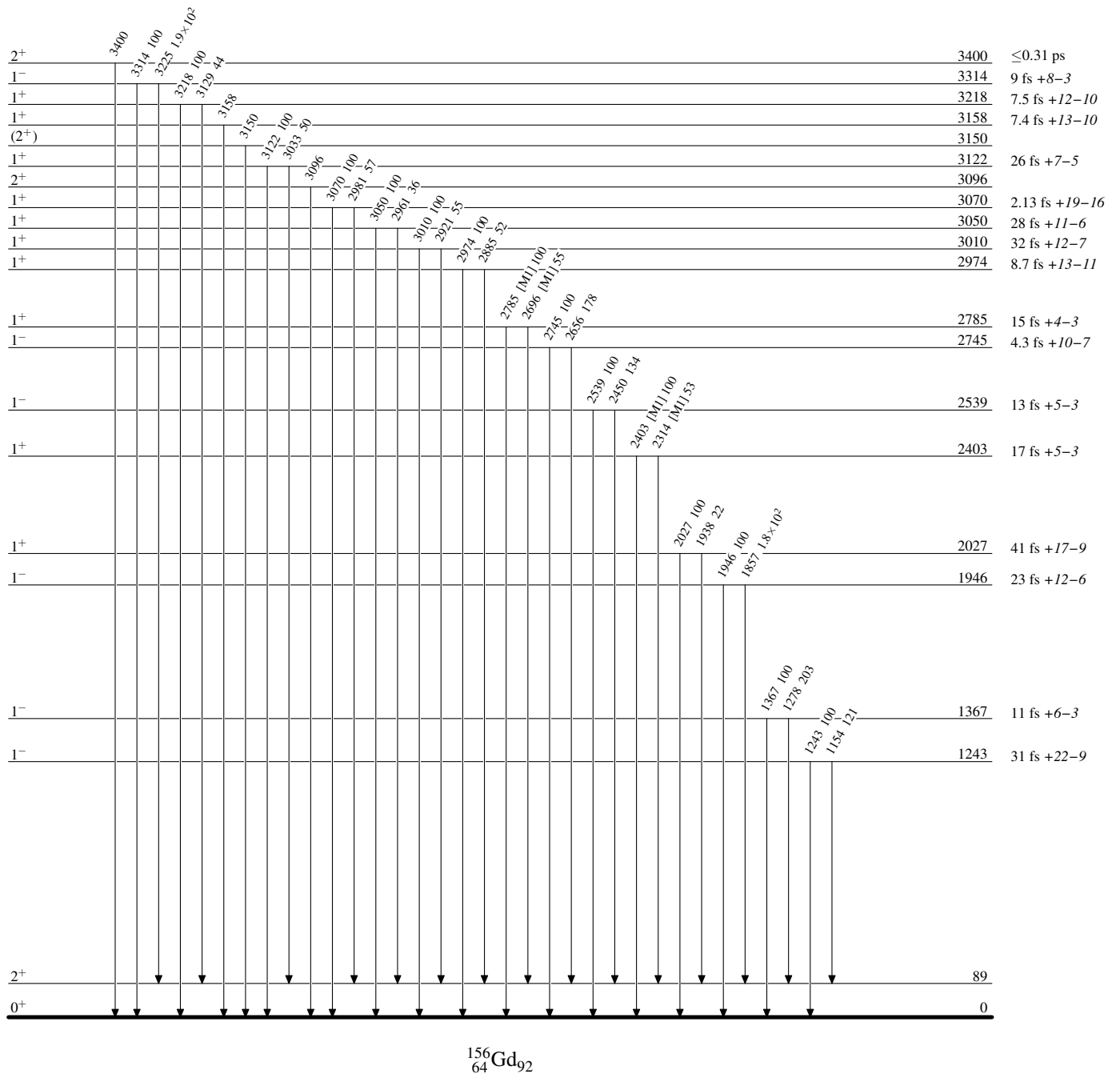
<sup>‡</sup> From **1989Pi05**, except where noted. Other: **1986Bo25**.

<sup>#</sup> Average of values of **1986Bo25** and **1989Pi05**.

$^{156}\text{Gd}(\gamma,\gamma'),(e,e')$  1985Bo31,1989Pi05,1986Bo25

## Level Scheme

Intensities: Relative photon branching from each level

 $^{156}_{64}\text{Gd}_{92}$