Coulomb excitation of ^{157}Gd

D. C. Tayal,* K. P. Singh, and H. S. Hans
Department of Physics, Panjab University, Chandigarh, India
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The low-lying energy levels up to 814 keV in ^{157}Gd were Coulomb excited with 3.4–4.4 MeV protons. The branching ratios and the reduced quadrupole transition probabilities $B(E2)$ of energy levels at 434, 517, 702, 748, and 814 keV have been measured for the first time using direct Coulomb excitation technique.

The nucleus ^{157}Gd has been the subject of a number of theoretical and experimental investigations. The experimental information prior to 1983 has been summarized by Bunting and Reich in Nuclear Data Sheets.[1] The low-lying levels of ^{157}Gd have been studied experimentally through radioactive decay,[1–5] inelastic scattering,[6,7] and Coulomb excitation.[8–15] Only the 54 and 132 keV states were found to be Coulomb excited with protons earlier.[1] Stebra, Tjom, and Elbek[7] have measured $B(E2)\uparrow$ values from (d,d′) cross sections, and discussed in terms of collective vibrational excitations and the Coriolis coupling of single particle states. The values of reduced quadrupole transition probabilities reported by Stebra *et al.*[7] do not seem to be reliable, according to the authors themselves. Their values are derived on the basis of normalization at 90°, which for even nuclei are considered acceptable because the collective levels within each group are closely related. But in the case of odd nuclei, like ^{157}Gd one expects interference with other modes of excitation; hence the method may not be exactly applicable. It was, therefore, worthwhile to conduct the direct Coulomb excitation experiment with protons to obtain the $B(E2)$ values precisely.

In the present investigations, the low-lying levels of ^{157}Gd were excited with 3.4–4.4 MeV protons by using an enriched isotope of ^{157}Gd (93.5%), which was thick enough for incident protons. The gamma rays were observed with a 57 cm^3 Ge(Li) detector having 2.0 keV resolution at 1.332 MeV energy. The single gamma-ray spectra were recorded at 55° with respect to beam direction to eliminate the anisotropy effect, for all the incident proton energies. A typical gamma-ray spectrum obtained at 55° with 4.2 MeV protons is shown in Fig. 1. The experimental details are given in our previously reported work.[16] To find the gamma-ray intensities spectra were analyzed using the computer code SAMPO.[17,18] The branching ratios were established by taking the average of their values obtained with different incident energies. The thick-target gamma-ray yields were measured and compared with the direct $E2$ Coulomb excitation theory of Alder *et al.*[19] The $B(E2)\uparrow$ values for all the observed levels were obtained from the comparison of experimental

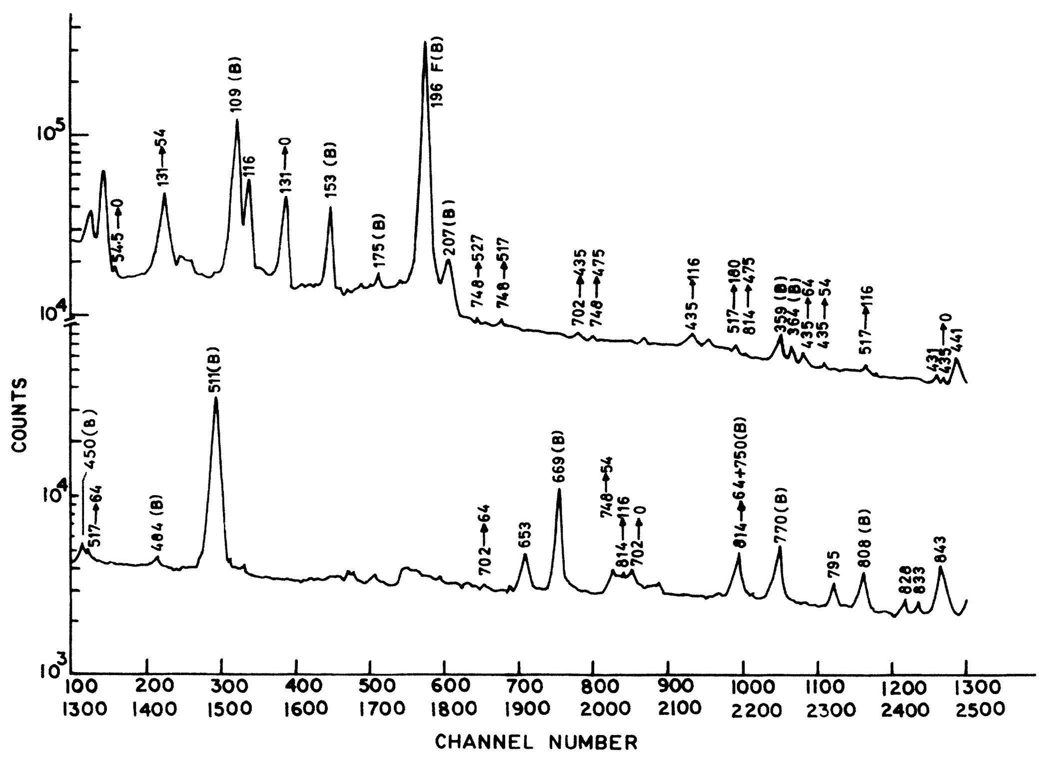

FIG. 1. Gamma-ray spectrum at 55° with 4.2 MeV protons.

TABLE I. Comparison of $B(E2)\uparrow$ values with previous results.

Level (keV)	J^{-*}	Transition	I_γ (%)	Measured $B(E2)\uparrow$ ($e^2\text{cm}^4\times10^{-50}$) Present	Stebra *et al.* (Ref. 7)	Ramsak, Olesen, and Elbek (Ref. 13)
55	$\frac{3}{2}^-$	55–0	100	175 ± 40	252	221 ± 10
132	$\frac{7}{2}^-$	132–0	18 ± 1.0	120 ± 9	136	121 ± 10
		132–55	82 ± 4.5	⋯	⋯	⋯
434	$\frac{5}{2}^-$	434–0	3 ± 0.4	0.39 ± 0.08	1.3	⋯
		434–55	5 ± 0.4	⋯	⋯	⋯
		434–64	32 ± 6.4	⋯	⋯	⋯
		434–116	60 ± 7.5	⋯	⋯	⋯
517	$\frac{7}{2}^-$	517–0	⋯	0.29 ± 0.07	1.4	⋯
		517–64	15 ± 3.8	⋯	⋯	⋯
		517–116	50 ± 6.5	⋯	⋯	⋯
		517–180	35 ± 6.7	⋯	⋯	⋯
702	$\frac{1}{2}^-$	702–0	70 ± 9.1	1.4 ± 0.3	0.7	⋯
		702–64	12 ± 2.5	⋯	⋯	⋯
		702–434	18 ± 3.5	⋯	⋯	⋯
748	$\frac{3}{2}^-$	748–0	⋯	1.25 ± 0.45	0.2	⋯
		748–55	77 ± 7.8	⋯	⋯	⋯
		748–475	6 ± 1.7	⋯	⋯	⋯
		748–517	11 ± 1.9	⋯	⋯	⋯
		748–527	6 ± 1.6	⋯	⋯	⋯
814	$\frac{3}{2}^-$	814–0	⋯	6.3 ± 2.0	0.7	⋯
		814–475	7[a]	⋯	⋯	⋯

[a]Reference 1.

and theoretical gamma-ray yields. The energy of the protons of 4.4 MeV is reasonably small for the effective penetration into the ^{157}Gd nucleus, hence no compound contribution was taken into account for the purpose of $B(E2)\uparrow$ measurements.

The summary of the branching ratios and reduced quadrupole transition probabilities along with their comparison with earlier results[7,13] for ^{157}Gd levels is shown in Table I. The assigned errors in the $B(E2)\uparrow$ values result mainly from the errors in the peak area, calibrated efficiency of the Ge(Li), and the stopping power for incident protons (3.4–4.4 MeV) in Gd. The values of $B(E2)$ obtained by us differ from the values as given by Stebra *et al.*[7] except for the first two rotational levels, i.e., 55 and 132 keV. According to Stebra *et al.*,[7] these are the only two levels for which such a comparison is possible. For other levels, ours are the only measurements based on Coulomb excitation.

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*Permanent address: Physics Department, N.R.E.C. College, Khurja-203131, India.

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