New levels in ^{160}Dy from the beta decay of ^{160}Tb

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Introduction

The radioactive even-even nucleus ^{160}Tb lies nestled between two stable odd-odd nuclei ^{160}Gd and ^{160}Dy in the A=160 mass chain. The ground state spin of ^{160}Tb is 3-. This unstable nucleus decays by β^- emission ($t_{½}$ = 72.3 d) to the excited levels of ^{160}Dy. Most recent beta decay studies [1,2,3] report that about five energy levels greater than 1300 keV are excited in the daughter ^{160}Dy in the decay. But as a result of the recent nuclear reaction studies leading to ^{160}Dy, many levels existing in the 1300 -1800 keV energy range with low spin-parity were observed and adopted [4] as shown in table 1.

Table 1: Excited levels (in keV) in ^{160}Dy observed in nuclear reaction studies

Study	Level Energy	Spin, Parity
^{160}Dy(d,d')	1349.76	2+
	1643.26	3-
	1654.99	3+/4+
	1694.36*	4+
Coulomb Excitation	1349.76	2+
	1643.26	3-
^{158}Dy(t,p)	1349.76	2+
	1518.42	2+
	1654.99	3+/4+
	1756.92	2+
	1650.873	4-,5-
^{162}Dy(p,t)	1349.76	2+
^{160}Dy(γ, γ')	1349.76	2+
	1489.50	1-
^{161}Dy(^{3}He,α)	1784.69	4-
	1607.86	4+
	1650.873	4-,5

*Also seen in other reactions

The total Q_{β^-} of the ^{160}Tb decay is 1835.1(13). By the simple beta decay selection rules, some of these energy levels with suitable Jπ ought to have some beta feeding too. However, no report of such beta feeding or of depopulating gamma rays from these levels was made so far. Few new γ rays of 53.51, 73.59, 97.82, 99.72, 148.75, 320.50, 707.54, 728.27, 1265.3, 1358.7 and 1556.6 keV were observed in some studies [5] for the first time in the decay of ^{160}Tb:. However with the exception of the 707.54 and 1556.6 keV gammas, these transitions were not incorporated into the current ^{160}Dy level scheme. Hence with an aim to look for the above transitions, as well as to search for gamma transitions from the other accessible levels identified in table 1, this study was undertaken.

Experiment

The radioisotope ^{160}Tb was obtained as Terbium Chloride in HCl from the Board of Radiation and Isotope Technology, BARC, Mumbai. Sources with an activity of ≈1000 cps were prepared for the gamma spectroscopy. The gamma spectra were acquired with the sources placed at 25 cm from the large volume, coaxial type HPGe detector (EG & G ORTEC-GMX series). The detector has an active volume of 60 cc and FWHM of 1.8 keV at 1.33 MeV and 665 eV at 5.9 keV. The detector was coupled to an 8K Multi Channel Analyzer. The unshielded detector's energy and efficiency calibration were performed with IAEA standard sources of point geometry, which were also placed at distance of 25 cm from the detector. Spectral acquisition and analysis was performed with MCA emulator and spectrum analysis software GammaVision-32 and the interactive computer program FIT [6]. The typical counting periods were about 5 x 10^5 seconds. The partial gamma spectrum of the decay of ^{160}Tb is shown in Fig. 1. The spectra were also examined for any impurity activity that may be present in the radioisotope. Some γ rays belonging to the decays of ^{153}Sm, ^{152}Eu and those due to the natural background radiation were observed in the spectra.

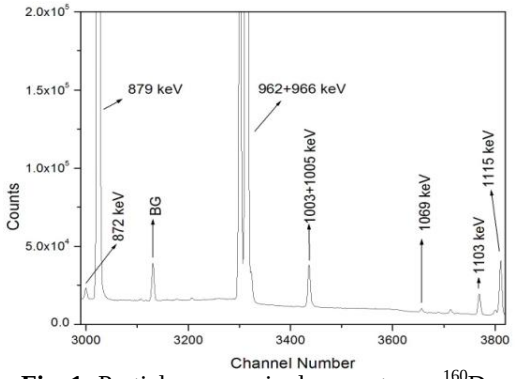

Fig. 1: Partial gamma singles spectrum: ^{160}Dy

Results and discussion

The gamma intensities were normalized with respect to the intense 879.4 keV transition taken as 100. Table 2 presents the relative gamma intensities of a few select transitions determined in the present study.

Table 2: Gamma energies and relative gamma intensities in ^{160}Tb beta decay (partial list)

Eγ (keV)	Rel. Iγ (present)	Rel. Iγ (adopted)	EL/ML
86.81	44.5(4)	43.7(4)	E2
298.54	86.4(8)	86.8(6)	E1
349.69	0.051(7)	0.048(3)	-
682.30	1.97(4)	1.98(3)	E2
707.53	0.044(16)	0.033(17)	E2
765.24	6.99(7)	7.11(4)	E2+M1
872.06	0.728(16)	0.723(12)	M1+E2
879.38	100.0(1)	100.0(2)	E2+M1
962.29	31.9(3)	32.6(3)	E2+M1
1251.27	0.353(11)	0.352(3)	E1(+M2)

The relative gamma intensities from the present study are in very good agreement with the adopted values, thus establishing the credibility of our measurements.

An extensive search for weak gamma transitions from levels of ^{160}Dy mentioned in Table 1 was also made in order to look for evidence of these being populated in the decay. The search led to the identification and analysis of a number of new gamma transitions. Their tentatively measured energies and relative intensities are given in Table 3. The uncertainties in I_γ vary from 15-60%. Detailed coincidence studies are however required for their confirmation.

Table 3: New gamma transitions: ^{160}Tb decay

E_{level} (keV)	Jπ	Eγ (keV)	Iγ	Probable ML/EL
1386.4	4-	99.7	0.003	M1
1286.7	3-	320.5	0.022	E1
1535.1	4-	148.7	0.0096	M1
1489.5	1-	1402.7 1489.5	0.009 0.017	E1 E1
1518.4	2+	232.8 1431.7	0.031 0.006	E2 M1
1643.3	3-	153.8 1556.5	0.039 0.031	E2 E1
1694.3	4+	645.2	0.039	M1
1784.7	4-	1500.7	0.09	E1

The assignment of the new gamma rays to the levels in ^{160}Dy is done here only on the basis of the gamma energy matching the energy difference between these established levels. The presence of weak gammas at 73.59, 97.82 320.50, 728.27, 1265.3 and 1358.7 keV proposed earlier [5] could not be verified due to their proximity to impurity peaks in the radioisotope and those due to background.

A tentative decay scheme of ^{160}Tb was constructed using the program GTOL by including the information about the new gammas and levels determined in the present study. This has resulted in a revised set of beta feedings to the levels of ^{160}Dy which are consistent.

References

[1] K. Chattopadhyay, J. M. Chatterjee, B. Sethi, Il Nuovo Cimento 82A, 403 (1984)
[2] D. Mehta et al., Nucl. Instrum. Meth. A245 447 (1986).
[3] K. Singh et al., Appl. Radiat. Isot. 43, 1521 (1992)
[4] C. W. Reich, Nucl. Data Sheets 105, 610 (2005).
[5] I. Adam et al, Proc.36th Ann. Conf. Nucl. Spectrosc. Struct. At. Nuclei, 119 (1986).
[6] V. Petkov and N. Bakaltchev, J. Appl. Crystallogr. 23, 138 (1990).