COMMENTS

Absolute Measurements of Anomalous ϵ/β^+-Decay Branching Ratios

R. B. Firestone, R. A. Warner, and Wm. C. McHarris*
Department of Chemistry,† Cyclotron Laboratory,‡ and Department of Physics, Michigan State University, East Lansing, Michigan 48824

and

W. H. Kelly
Cyclotron Laboratory‡ and Department of Physics, Michigan State University, East Lansing, Michigan 48824
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Absolute values of ϵ/β^+-decay branching ratios for decay of ^{145}Gd to twelve levels in ^{145}Eu have been measured. These measurements are all shown to deviate substantially from the calculated ϵ/β^+ ratios of Gove and Martin. Skew ratios (exp/theor) are found to range from 1.5 to 40. These "anomalies" are ascribed to second-order corrections to allowed decay which have not been included in the calculations.

In a previous Letter[1] we reported exciting evidence of large anomalous ϵ/β^+-decay branching ratios, relative to theoretical predictions,[2] for ^{145}Gd and ^{143}Sm decays. These were not absolute but relative measurements, and so we were forced to normalize our results to fast transitions where the ratio was assumed to be normal. The anomalies were proven, but this in itself made the normalization procedure somewhat suspect.

We have now completed absolute measurements of the ϵ/β^+-decay branching ratios for ^{145}Gd decay. Thin sources were prepared by depostion on Mylar tape at the nozzle of a helium-jet recoil transport system.[3] Annihilation radiation and K x rays were counted in a 7.6-cm×7.6-cm NaI detector, and coincident γ rays tagging the ϵ/β^+-fed levels in ^{145}Eu were detected in a large[4] Ge(Li) detector. The source was surrounded by a plastic annihilator to ensure total annihilaton at the source. The two energies were recorded along with the coincidence time on magnetic tape for off-line analysis. The NaI pulse-height spectra in coincidence with γ rays depopulating the 808.5- and 1757.8-keV levels in ^{145}Eu are presented in Fig. 1. The relative efficiency ratio between the x-ray region (45 keV) and 511 keV was measured, by use of internal γ-ray sources,[5] to be 2.00 ±0.14. This compares favorably with the predicted value[6] of 1.95, which is corrected for window thicknesses.[7] The ϵ/β^+ ratios were then determined for various transitions by incorporating well-known fluorescence yields[8] and $\epsilon(K)/\epsilon(\mathrm{tot})$ ratios[8] to obtain the total electron-capture intensities. The β^+ feedings were corrected for annihilation in flight in the plastic absorber, an ≈4% effect.[9] The transitions to the 1041.9-, 1757.8-, and 1880.6-keV levels in ^{145}Eu were measured sufficiently accurately to be used as primary absolute ϵ/β^+ ratios. Using the more extensive x-γ and β^+-γ coincidence data referred to in our earlier paper,[1] we then calculated the absolute ϵ/β^+ ratios to other levels. Total β-feeding intensities were calculated by use of our coincidence data; they compared favorably with γ-ray

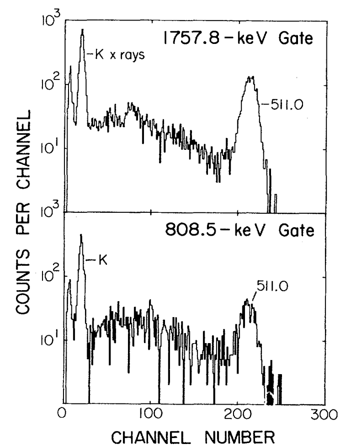

FIG. 1. NaI(Tl) coincidence spectra for the 1757.8- and 808.5-keV gates in the decay of ^{145}Gd to ^{145}Eu. Note that the $\gamma^\pm$ peak is severely depressed in the 808.5-keV gated spectrum, although normal decay-energy calculations would predict it to be much larger in that spectrum than in the 1757.8-keV gated spectrum. It should also be noted that β decay to states de-exciting through the 808.5-keV state accounts for nearly all of the $\gamma^\pm$ peak but only about half of the K x-ray peak.

TABLE I. Absolute ϵ/β^+-decay branching ratios for ^{145}Gd.

Level in ^{145}Eu	Allowed Transition	ε/β^+ Ratio Experiment	Calculated[a]	Skew Ratio (exp/theor)	Total % β Feedings Coincidence	Singles
808.5	Yes	18 ±8	0.45±0.04	40	2.8	3.2
1041.9	Yes	1.0 ±0.1	0.57±0.07	1.8	9.5	9.9
1567.3	b	37 ±18	0.95±0.10	39	1.0	0.9
1599.9	b	13 ±6	0.99±0.11	13	1.8	1.8
1757.8	Yes	1.87±0.09	1.18±0.14	1.6	36.6	36.4
1761.9	b	2.6 ±0.8	1.20±0.15	2.2	1.4	1.5
1845.4	b	43 ±21	1.31±0.17	33	0.6	0.5
1880.6	Yes	2.15±0.12	1.37±0.17	1.6	36.9	36.5
2048.9	b	4.2 ±1.0	1.72±0.24	2.4	1.1	1.0
2113.9	b	10 ±4	1.90±0.29	5.3	0.6	0.4
2494.8	b	4.8 ±0.5	3.41±0.61	1.4	1.2	1.3
2462.2	b	8.1 ±0.9	4.45±0.95	1.8	2.4	1.9

[a]N. B. Gove and M. J. Martin, Nucl. Data Tables 10, 205 (1971). Calculated for Q_ϵ = 5311 keV.

[b]These are most likely allowed transitions from log*ft* information, but we cannot yet make definite assignments.

singles intensities suggesting that no significant systematic errors entered our experiments. These results are presented in Table I.

Several new, weaker transitions are reported in Table I which were not discussed in our previous paper. These transitions were known at that time, but the decay scheme was not then certain enough to discuss them. The Q_ϵ value for ^{145}Gd decay has been measured as 5311 ± 120 kev,[10] and, with use of this value, theoretical ϵ/β^+ ratios were calculated[2] for the ^{145}Gd decays. These values are compared with the measured values in Table I and indicate that indeed all of the values are anomalous. A skew ratio (exp/theor) is defined to show the extent of the anomaly.

The extent to which these data differ from calculations is striking. Although some of the newly presented transitions might be first forbidden, such anomalies cannot be explained by the usual theoretical assumptions. Recently, we have found great success in explaining these anomalies in terms of second-order contributions to the allowed calculations. It appears that hindered transitions can have strong interference effects on the ϵ/β^+ ratio. Although these terms are second-order alone, they interfere with the allowed terms to yield first-forbidden corrections which are already important at log*ft* ≈ 6. These effects are most prominent in higher-Z nuclei where the nuclear raduis is large. Indeed, ϵ/β^+ skew ratios even larger than the ones discussed here are probable. The second-order effects may also explain a small, well-known anomaly in the ^{22}Na ϵ/β^+ ratio.[11] Detailed information on these calculations will appear in a forthcoming publication.

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[1]R. B. Firestone, R. A. Warner, Wm. C. McHarris, and W. H. Kelly, Phys. Rev. Lett. 33, 30 (1974).

[2]N. B. Gove and M. J. Martin, Nucl. Data Tables 10, 205 (1971).

[3]For a description of this system, see K. L. Kosanke, M. D. Edmiston, R. A. Warner, R. B. Firestone, Wm. C. McHarris, and W. H. Kelly, Nucl. Instrum. Methods 124, 365 (1975).

[4]18% efficiency at 1333 keV relative to that of the

NaI(Tl) detector at a source distance of 25 cm.

[5]A γ-ray source containing ^{109}Cd, ^{57}Co, ^{139}Ce, ^{137}Cs, and ^{60}Co supplied by the National Bureau of Standards and a separate thin ^{137}Cs source were used for this calibration.

[6]R. L. Heath, *Scintillation Spectrometry Gamma-Ray Spectrum Catalogue,* U. S. Atomic Energy Commission Research and Development Report No. IDO-16880-1, 1964 (unpublished), Vol. 1.

[7]I. Israel, Nucl. Data, Sect. A 7, 565 (1970).

[8]A. H. Wapstra, G. J. Nijgh, and R. van Lieshout, *Nuclear Spectroscopy Tables* (North-Holland, Amsterdam, 1959).

[9]J. Kantele and M. Valkonen, Nucl. Instrum. Methods 112, 501 (1973).

[10]T. W. Burrows, Nucl. Data Sheets 12, 203 (1974).

[11]E. Vatai, D. Varga, and J. Uchrin, Nucl. Phys. A116, 637 (1968).

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ANISOTROPIC COMPTON SCATTERING IN LiF. W. A. Reed, P. Eisenberger, F. Martino, and K.-F. Berggren [Phys. Rev. Lett. 35, 114 (1975)].

Reference 17 should read: W. H. Kleiner, J. Hanus, T. A. Kaplan, and H. E. Stanley, Bull. Am. Phys. Soc. 13, 483 (1968), and to be published.