Suppression of the strength of spin-isospin excitations in β^+ decay

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A clearly defined resonance of the Gamow-Teller type has been found in the β^+ decay of ^{147m}Dy. The strength function for the β^+ decay of this nucleus is calculated. The experimental probability for the β^+ decay is only 36% of the calculated value.

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Observations of the Gamow-Teller resonance in the (p,n) reaction for several heavy and intermediate-weight nuclei[1] have revealed that the total strength observed experimentally for the Gamow-Teller excitations is 0.3–0.5 of the theoretical sum-rule prediction. This resonance is known to be a collective state constructed from particle-hole excitations of the (pn^{-1}) type, which are associated with an angular momentum of 1^+ and have an isospin projection $\mu_\tau = -1$. Several theoretical papers (see Ref. 2, for example) have attributed the suppression of Gamow-Teller excitations to an admixture of (Δ-isobar)–(nucleon hole) states in nucleon–(nucleon hole) states.

It is clearly worthwhile to experimentally study the behavior of charge-coupled states, i.e., excitations of the $(p^{-1}n)$ type with an isospin projection $\mu_\tau = +1$. Such states may be excited in the (n,p) reaction and in β^+ decay. A study[3] of the strength functions of β^+ decay has shown that in nuclei far from the stability band (with a relatively small neutron excess and a large decay energy) the Gamow-Teller excitations are largely concentrated in a narrow energy interval below the decay energy. Studying these nuclei is the easiest way to study a Gamow-Teller resonance with an isospin projection $\mu_\tau = +1$. Calculations on the excitation of this resonance in the β^+ decay of several thulium nuclei were reported in Ref. 3. These calculations were carried out in the random-phase approximation with a $G_{\tau\sigma}(\tau\tau)(\sigma\sigma)$ residual interaction. The experimental values of the probability for β^+ decay turned out to be about three times lower than the calculated values. In the thulium nuclei, however, the resonances in the strength functions for β^+ decay lie near the decay energy. The filling of these resonances by $\beta^+(\epsilon)$ transitions is slight, and several components of the resonance may lie outside the measurement interval. As a result, it was not possible to correctly evaluate the error in the results in Ref. 3, so that the estimate of the suppression of Gamow-Teller excitations found there was strictly qualitative.

In this letter we report a study of the strength function of the $\beta^+(\epsilon)$ decay of the nucleus ^{147m}Dy. The measurements were made by a total-γ-absorption spectrometer working on line with the IRIS mass separator. The experimental procedure is described in detail in Ref. 4. We determined the decay half-life $T_{1/2} = 55.7(5)$ s and the decay energy $Q_\epsilon = 7.18(10)$ MeV, and we constructed the strength function for the

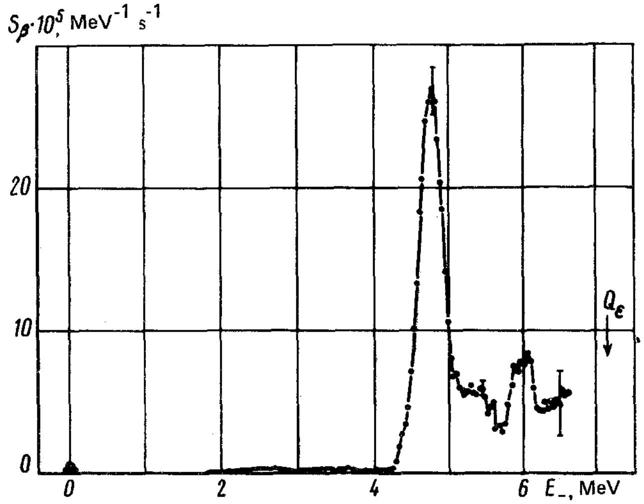

FIG. 1. Strength function of the $\beta^+(\epsilon)$ decay of ^{147m}Dy.

$\beta^+(\epsilon)$ decay (Fig. 1). In the strength function we see a narrow peak at 4.84 MeV, flanked on the high-energy side by some fainter peaks. The low position of this resonance (with respect to Q_ϵ), the high probability for its occurrence (42% of the decay events), and the rather accurate measurements of $T_{1/2}$ and Q_ϵ here make it possible to reliably determine the probability for the excitation of this resonance in β^+ decay. This probability corresponds to the value $\log ft = 3.67(7)$.

We have also calculated the strength function for the β^+ decay of this nucleus, using the random-phase approximation. Pairing correlations in the proton system were taken into account in the BCS approximation with a constant $G_{\text{pair}} = 27/A$ MeV. The single-particle energies were taken from Ref. 5. As usual, the spin-isospin interaction constant was taken to be 50/A MeV. From these calculations we found the entire strength of the Gamow-Teller excitations to be concentrated in a single peak. The probability for its excitation corresponds to the value $\log ft = 3.22(10)$ if the axial vector constant is assumed to have the same value as for the free nucleon ($g_A = 1.23 g_V$). The error in this calculated value is determined by a possible change in the parameters of the average field. Comparison reveals that the excitation probability for Gamow-Teller states with $\mu_\tau = +1$ observed experimentally for the nucleus ^{147m}Dy is only 0.36(12) of the theoretical value.

Comparison of this result with data from the (p,n) reaction[1] shows that the suppression of the Gamow-Teller excitations in the low-energy region is approximately the same for the isospin projections $\mu_\tau = -1$ and $\mu_\tau = +1$. It should be noted that a similar suppression has been found[6] for the M1 resonance corresponding to $\mu_\tau = 0$.

The probability for β decay is related to the matrix element M_{GT} by

$$\frac{1}{ft} = \left(\frac{G_A}{g_V}\right)^2 |M_{\text{GT}}|^2 D^{-1}; \quad D = 6250 \text{ s}.$$

The experimental and theoretical values of *ft* can be reconciled by assuming that for a complex nucleus the axial vector constant of the weak interaction, G_A, is not the same as that for the free nucleon, G_A; i.e., this constant is renormalized in a nucleus. For the nucleus ^{147m}Dy in this case we find $|G_A/g_V| = 0.74(11)$, so that G_A is smaller than g_A by a factor of nearly two.

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