Effect of Level Structure on the Intensity of Partial Radiative Transitions in $^{155}Gd(n\gamma)^{156}Gd$ Resonances

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Submitted November 1, 1971
Zh. Eksp. Teor. Fiz. 62, 1228–1230 (April, 1972)

The intensities of partial radiative transitions in resonances of the reaction $^{155}Gd(n\gamma)^{156}Gd$ have been studied by means of a Ge(Li) spectrometer. The correlation observed between the widths for transitions to levels of the ground rotational band and the reduced neutron widths is discussed from the point of view of a semimicroscopic model of the nucleus.

A Ge(Li) spectrometer has been used to measure the spectra of capture γ rays in neutron resonances of the reaction $^{155}Gd(n\gamma)^{156}Gd$. In comparison with our earlier work,[1] we have studied the intensities of transitions to a larger number of final levels and have considered the question of correlation between the reduced neutron widths and partial radiation widths.

The measurements were made in the electron linear accelerator at the I. V. Kurchatov Institute of Atomic Energy. The γ-ray spectra were studied in the range 6.3–8.6 MeV in 23 resonances up to a neutron energy of 70 eV. On the basis of existence of transitions to final levels with characteristics 0^+, we have assigned to ten resonances a spin 1^- (69.7, 51.4, 43.97, 37.13, 34.83, 33.5, 27.56, 23.65, 11.52, 2.01 eV). In some cases we have determined the total intensities to vibrational levels and to levels of excitation above 1.9 MeV, including two transitions each. We have calculated the reduced partial radiation widths according to the statistical model

$$K_{E1}{}^{S} = (I_\gamma/E_\gamma{}^3)_{\text{av.}} \frac{10^{-2}\Gamma_\gamma}{A^{2/3}D},$$

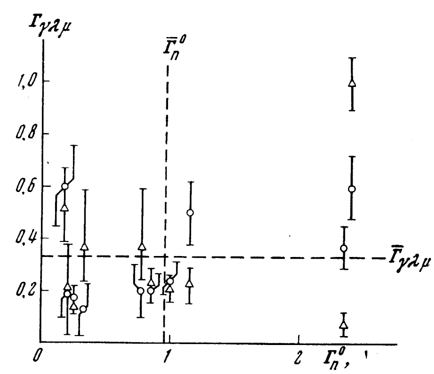
and according to the giant resonance model (Axel):

$$K_{E1}{}^{A} = (I_\gamma/E_\gamma{}^5)_{\text{av.}} \frac{10^{-2}\Gamma_\gamma}{A^{8/3}D},$$

where I_γ is the intensity of a partial transition with energy E_γ (MeV) in the number of photons per 100 captured neutrons, Γ_γ is the total radiation width (0.108 eV), A is the mass number, and D (eV) is the average distance between resonances with identical spins. The reduced widths, averaged over all initial and final levels studied, are: $K_{E1}^{S} = (3.8 \pm 1.2) \times 10^{-9}$ and $K_{E1}^{A} = (3.1 \pm 1.0) \times 10^{-15}$, which disagrees somewhat with the theoretical values but agrees with the values found by Carpenter.[2]

For transitions from $J = 1^-$ resonances to the 0^+ level (E_{γ_0} = 8530 keV) and the first excited level 2^+ (E_{γ_1} = 8441 keV) of the ground rotational band we have observed a correlation between the reduced radiation and neutron widths, and also between the radiation widths (see the figure and the table); the average correlation coefficient between $\Gamma_{\gamma\lambda\mu}$ and Γ_n^0 for transitions to levels of the rotational band is 0.4 ± 0.2 (20 cases), and the correlation coefficient between the radiation widths is 0.7. A correlation is also observed between transitions to vibrational levels.

	E_γ, keV	E_γ, keV: 8530	8441	7406 7375 7367	7261	Γ_n^0
Ground rotational band	8530	—	0.71	−0.15	−0.5	0.45
	8441	0.71	—	−0.13	−0.3	0.38
Vibrational levels	7406 7375 7367	−0.15	−0.13	—	0.62	−0.4
	7261	−0.5	−0.3	0.62	—	−0.4



Correlation between partial radiation widths and reduced neutron widths in resonances with $J = 1^-$, O–8535 keV, Δ–8441 keV.

According to the semimicroscopic description[3] the ^{155}Gd nucleus is among the cases favorable for observation of correlations. Correlations between two processes are observed in those cases in which these processes are determined mainly by the same few-quasiparticle components of the wave function of the highly excited capture state. Since the neutron width is determined by the two-quasiparticle components, correlations between the radiative transitions to the ground level and Γ_n^0 indicate that these radiative transitions are determined by a small number of quasiparticle excitations and mainly by the two-quasiparticle components. Existence of a positive correlation between transitions to one-phonon vibrational levels also argues in favor of common components for these transitions. Between transitions from 2^- resonances to the first excited level 2^+ (E_{γ_1} = 8441 keV) and Γ_n^0 and between transition to vibrational levels, a positive correlation is

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also observed: $C_{\gamma in}(J = 2^-) = 0.7$; $C_{\gamma\gamma}(J = 2^-) = 0.5$ (number of cases 13).

We will estimate the value of the coefficient b^{i2t} which determines the contribution of the two-quasiparticle components, from the reduced neutron width and the partial radiation width of the E1 transition to the ground level 0^+:[4] $\bar{\Gamma}_n^0 = \Gamma_{sp}^0(\bar{b}^{i2t})^2\bar{m}^2$, where Γ_{sp}^0 is the single-particle width, which is equal to $20/A^{2/3} = 0.7$ MeV, $\bar{\Gamma}_n^0(^{155}Gd) = 10^{-3}$ eV, $\bar{m}$ is the average number of states from which transitions are possible, which is equal to 2–4. Hence $(\bar{b}^{i2t})^2 \approx 10^{-10}$. The ratio of the partial radiation width to the single-particle width $\Gamma_{\gamma\lambda\mu}/\Gamma_W = 10K_{E1}^S D = 2\times10^{-7}$ (for ^{155}Gd $K_{E1}^S = 4\times10^{-9}$, D = 5.1 eV). The matrix element of the E1 transition is approximately equal to $\Gamma_{\gamma\lambda\mu} = (\bar{b}^{i2t})^2\Gamma_W\bar{n}_\gamma^2$,[4] where n_γ is the number of states of order 2–5, and hence $(\bar{b}^{i2t})^2 \approx 10^{-8}$. Thus, the quantity $(\bar{b}^{i2t})^2$ lies in the range 10^{-8}–10^{-10}.

According to the quasiparticle model the reduced intensity of transitions to levels of the vibrational band is determined by the greater number of components of excitation than to the ground level. The ratio of $(I_{\gamma vib})_{av}$ to $(I_{\gamma rot})_{av}$ in ^{155}Gd for resonances with J = 1^- is of the order 0.95, and for resonances with J = 2^- it is 2.5 ± 0.8 (according to the energy dependence E_γ^5 based on the giant resonance model[5]). Consequently, for resonances with J = 1^- two-quasiparticle excitations play a large role in transitions to rotational and vibrational levels, and in the case of resonances with J = 2^- a larger number of different multiquasiparticle excitations actually take part in transitions to vibrational levels.

It was shown previously[1] that the average reduced partial width (with inclusion of the distances between the source levels) to the 2^+ level of the ground rotational band from J = 1^- resonances is larger than from J = 2^- resonances. In the present work we have also obtained for the ratio of these transitions the value 2 ± 1. This may indicate a certain role of the quantum number K (the spin projection on the symmetry axis). The distributions of partial reduced widths have been investigated in resonances with J = 1^- for transitions to rotational levels (20 cases), and with addition of transitions to allowed vibrational levels (40 cases). The degree of freedom ν, determined by the method of maximum likelihood with inclusion of the limited sensitivity of the apparatus (intensities with a ratio to the average value of the order 0.15–0.2 are transmitted), turned out to be $\nu_{av} = 3^{+1.4}_{-0.8}$. It is possible that the difference from $\nu = 1$ is due to correlations between the partial widths. We note that, with an increase in the sample, in spite of the correlation between the radiation widths and Γ_n^0, agreement with the statistical theory ($\nu = 1$) will probably be observed in the limit, since the distribution of reduced neutron widths in ^{155}Gd agrees with $\nu = 1$.

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Translated by C. S. Robinson
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