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GROSS STRUCTURE OF GIANT DIPOLE RESONANCE ON NUCLEI OF THE TRANSITION REGION N ≈ 90

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Nuclei with N ≈ 90 neutrons are noted for the instability of their form. Thus, as a result of a small increase of N from 88 to 90, the mean-square deformation of the ground state $\bar{\beta} = (01\ \beta^2\ 10)^{1/2}$ increases (e.g., $\beta = 0.167$ for Gd^{152} and $\beta = 0.304$ for Gd^{154} [1]), and the energy of the first excited level decreases (from $E_{2+} = 0.33$ to $E_{2+} = 0.12$ MeV); the approximate equidistant arrangement of the lowest excited levels is replaced by a characteristic rotational spectrum [2].

There are also experimental indications [3, 4] that the form of nuclei with N ≈ 90 can be noticeably altered upon excitation.

The internal structure of such nuclei is determined by the intersection of two groups of Nelsson levels (β) with positive and negative directions [5, 6].

Mottelson and Nilsson, who first called attention to this circumstance, have shown by means of simple calculations that in this case the same nucleus can have states with both small and large (positive) equilibrium deformations [5]. In this connection it is sometimes stated that these nuclei have two different self-consistent fields, one weakly deformed and the other strongly deformed [4, 7].

The purpose of our experiment was to ascertain how such an instability of the form can affect the properties of the dipole spectrum of a nucleus.

We present here the results of the measurement of the photoneutron cross sections of the isotopes $Gd^{152,\ 154,\ 156,\ 158}$ and $Eu^{151,\ 153}$ in the photon energy range $E_\gamma = 8 - 22$ MeV.

The measurement and analysis of the results were performed by the standard procedure used in experiments with a bremsstrahlung spectrum [8. 9]. The photoabsorption cross section σ_t, at photon energies below the threshold of the reaction (γ, 2n), was identified with the photoneutron cross section; at energies above threshold, σ_t was determined from the photoneutron cross section in accordance with the statistical theory.

The photoabsorption cross sections and the photoneutron cross sections for the isotopes Gd and Eu are shown in Figs. 1 and 2 respectively.

The most interesting results is the clear-cut splitting of the giant resonance (the Okamoto-Danos effect) on the Gd^{152} nucleus (N = 88). This phenomenon indicates that Gd^{152} is not (as was proposed relatively recently) a spherical nucleus executing harmonic quadrupole oscillations, since, in accord with

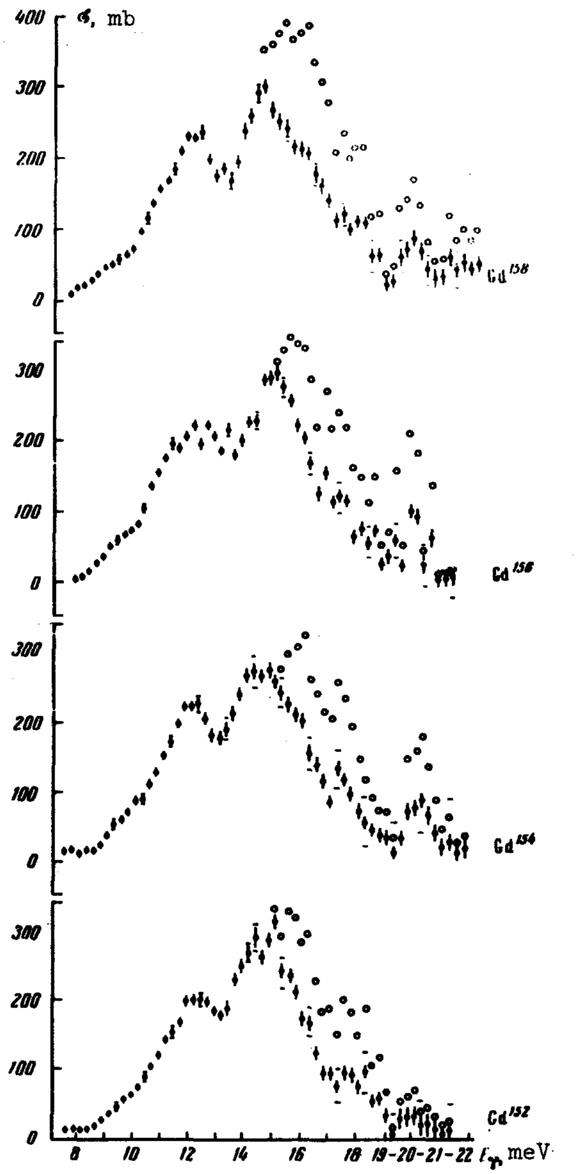

Fig. 1. Photoneutron cross sections and cross sections for the photoabsorption by the gadolinium isotopes Gd^{152}, ^{154}, ^{156}, ^{158} (reading upward). The statistical and mean-square errors of the photoabsorption cross sections are given. (The latter are denoted by horizontal strokes at the points 9.42 MeV, 10.42 MeV, etc.) At photon energies above the threshold of the (γ, 2n) reaction, the photoneutron cross sections, unlike the absorption cross sections, are denoted by circles.

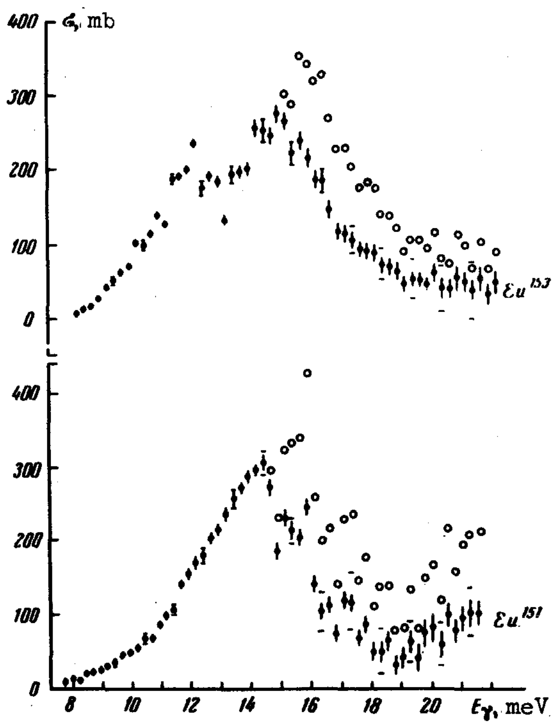

Fig. 2. Photoneutron cross sections and photoabsorption cross sections for Eu^{151} and Eu^{153}. The graphic symbols are the same as in Fig. 1.

the model of the coupling of dipole and quadrupole oscillations [10, 12], the photoabsorption curve should have in this case the form of a smooth maximum. An analogous conclusion concerning the form of nuclei with N = 88 follows from an analysis of the spectra of the sequence of nuclei N = 86 - 92 with the aid of the Davydov-Chaban model [13] and the Kumar and Baranger calculations [14], and also from measurements of the quadrupole moment of the 2^+ state [15].

At the same time, Gd^{152} has a relatively small mean-square deformation; therefore the surprising similarity of the form of its giant resonance to the curve of photoabsorption by Gd^{154}, which is strongly deformed in the ground state, can be regarded as a manifestation of the already mentioned dual character of the form of transition nuclei.

When giant resonance is described within the framework of collective models, such a duality of form may be a reflection of the presence of two minima at $\gamma = 0$ in the potential of the unified model [14], and also of the assumed possibility of change of deformation of the average field [16] in dipole transitions. As shown in [16], owing to the small amplitude of the zero-point β oscillations, the transitions with sufficiently strong change of deformation ($\Delta\beta = 0.15$) are not forbidden in this case by the Franck-Condon law [17].

In the case of odd Eu nuclei, an increase of N from 88 to 90 is accompanied by a sharp change in the form of the giant resonance, the Okamoto-Danos effect is observed in Eu^{153} ($\beta = 0.31$ [18]), and no such effect is observed in Eu^{151} ($\beta = 0.13$ [18]).

The deviation from the situation that takes place in even nuclei can be explained in this case in the same manner as it is customary to explain [19] the existence of an anomalously large spontaneous-fission barrier for odd nuclei. Nonradiative transitions ("slipping" [20]) between terms of odd nuclei are forbidden by the need for spin and parity conservation, whereas in the case of even nuclei the transitions are effected by paired nucleons, and there is no such forbiddenness. Therefore the deformation potential of odd nuclei should be steeper than that of even-even nuclei. As a result, dipole transitions to states with a deformation different from β should be forbidden in the case of odd nuclei in accordance with the Franck-Condon principle.

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