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STRUCTURE OF THE GIANT RESONANCE IN PHOTONUCLEAR REACTIONS

E. V. INOPIN

Physico-Technical Institute, Academy of Sciences, U.S.S.R.

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IT was shown in the work of Danos[1] and Okamoto[2] that, in the case of nuclei having the shape of an ellipsoid of revolution, the cross section for photonuclear reactions should have two maxima, rather than one as in the case of spherical nuclei. These authors began from a two-fluid model of the nucleus, which leads to the equation and boundary condition

$$\nabla^2 \Psi + k^2 \Psi = 0, \qquad (\mathbf{n}\,\mathrm{grad}\,\Psi)_S = 0, \tag{1}$$

where Ψ is the deviation of the proton density from its equilibrium value, k is the wave vector connected with the frequency of vibration ω by the relation $k = \omega/u$ (u is the velocity of "sound" in the nucleus), n is the normal to the surface of the nucleus and S is the surface of the nucleus.

Solution of Eq. (1) in spheroidal functions, and subsequent calculation of eigenvalues k for dipole oscillations, showed that the eigenvalues could be approximately represented by the formula $k_i = 2.08/R_i$, where R_i is the corresponding axis of the ellipsoid. The question arises as to whether this result is still valid in the general case of an ellipsoid with three axes. This is of particular interest in connection with the theory of nonaxially symmetric nuclei, developed by Davydov and his collaborators.[3] In fact, the presence of three maxima in the region of the giant resonance would be the most direct demonstration of the existence of nonaxially symmetric nuclei.

In calculating the eigenvalues we use a variational principle,[4] according to which the eigenvalues of (1) are obtained from the minima of the corresponding functional

$$k^2 = \min \int (\nabla \Psi)^2 \, dV \Big/ \int \Psi^2 \, dV, \tag{2}$$

where the integration is carried out over the nuclear volume. In so far as (2) possesses a stationary property, we can choose as trial functions the functions Ψ_i^0 which are solutions to (1) for a spherical nucleus of equal volume:

$$\Psi_1^0 = j_1(k_0 r)\cos\vartheta, \qquad \Psi_2^0 = j_1(k_0 r)\sin\vartheta\cos\varphi,$$
$$\Psi_3^0 = j_1(k_0 r)\sin\vartheta\sin\varphi, \tag{3}$$

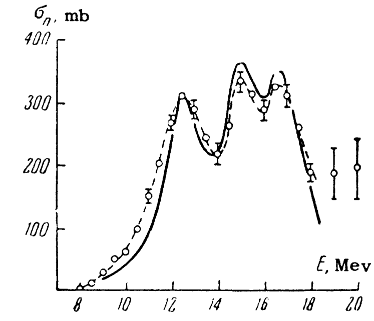
where $k_0 = 2.08/R_0$ (R_0 is the radius of the nucleus). Since the values k_0 are three-fold degenerate, then, in general, one should take linear combinations of the functions (3) as trial functions and then vary the coefficients in these linear combinations. However, there is no need for this in our case; the functions (3) are already the correct functions. This is connected with the fact that they transform according to different representations of the symmetry group of the ellipsoid (group D_{2h}).

Substitution of (3) into (2) and calculation of the integrals to within quantities of first order in the deformation of the nucleus leads to the result

$$k_i = \frac{2.08}{R_i}\left(1 + 0.08\frac{\Delta R_i}{R_0}\right), \qquad \Delta R_i = R_i - R_0. \tag{4}$$

Comparison of this formula in the axially symmetrical case with exact calculations of Danos[1] shows that the values of k_i are given, in the worst case, to an accuracy of 1%.

Splitting of the giant resonance into three maxima, as given by (4), appears to be shown in the experiments of Fuller and Weiss[5] in the nucleus Tb^{159} (see the figure), although this has not been noted by them. Approximating the experimental data by the sum of three resonance curves gives



Giant resonance in the (γ, n) reaction in Tb^{159}. The circles show the experimental points, and the dashed curve is drawn through these points. The solid curve represents the sum of three resonance curves within the parameters indicated in the text.

for the resonance energies $E_1 = 16.8$ Mev, $E_2 = 15.0$ Mev, $E_3 = 12.5$ Mev, and for the widths $\Gamma_1 = \Gamma_2 = \Gamma_3 = 1.9$ Mev (it is clear that even better agreement would be obtained if the widths were chosen to be somewhat different). Using these E_i ($E_i = \text{const} \cdot k_i$) in Eq. (4), calculation of the deformation gives $\beta = 0.30$ and $\gamma = 19°$. Calculation of β from $Q_0 = 6.9$ b (Coulomb excitation[6]) gives $\beta = 0.35$ (for $R_0 = r_0 A^{1/3}$ and $r_0 = 1.2 \times 10^{-13}$ cm).[7] The value of γ for Tb^{159} is not given from other sources; however, from the nearby nuclei[8] Gd^{154} and Dy^{160}, $\gamma = 14°$ and 12°, respectively.[8] Thus, the proposed interpretation of the (γ, n) data for Tb^{159} agrees satisfactorily with data obtained from other sources.

In conclusion, I would like to express my deep gratitude to A. K. Val'ter, who brought this problem to my notice, and also to S. P. Kamerdzhiev for help in carrying out the calculations.

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ANGULAR DISTRIBUTION OF Na^{24} *NUCLEI AND FISSION FRAGMENTS PRODUCED BY INTERACTIONS BETWEEN HIGH-ENERGY PROTONS AND* Au *AND* U *NUCLEI*

A. K. LAVRUKHINA, L. P. MOSKALEVA, V. A. MALYSHEV, L. M. SATAROVA, and SU HUNG-KUEI

Institute of Geochemistry and Analytical Chemistry, Academy of Sciences, U.S.S.R.

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In this communication we present the preliminary results on the angular distribution of Na^{24} nuclei and the fission fragments Sr^{91}, Br^{76}, I^{131}, $I^{130+133}$ from gold and uranium irradiated by 660-Mev protons. The experiment was carried out with the synchrocyclotron of the Joint Institute of Nuclear Studies. Sheets of metallic beryllium 50 μ thick were used as absorbing foils. The proton beam was monitored by the reaction $Al^{27}(p, 3pn)Na^{24}$. After irradiation, the beryllium sheets were dissolved in acid containing isotopic carriers of the produced elements, after which the elements were separated chemically and purified. The apparatus for measuring the activity and identifying the isotopes consisted of twin end-window counters of type T-25-BFL working in anti-coincidence with a ring of MS-9 counters to reduce the background. The geometric efficiency was about 70%.

Two series of experiments were made to determine the "forward-backward" ratio and to study the angular distribution from 0 to 180° in angular intervals of 30°.

1. An investigation of the "forward-backward" ratio was carried out for the isotopes Na, Sr, Br, and I emitted from plates of metallic uranium of size 20 × 15 × 1 mm. A second beryllium foil was placed as a shield between the aluminum foil-monitor and the absorbing sheet of beryllium. It was found that, in the laboratory system, the "forward-backward" ratio for the fission fragments Sr^{91} was 1.1; for Br^{76}, 1.0; for I^{131}, 0.6; for $I^{130+133}$, 1.0. The error in determining the ratio did not exceed 20%.

The calculation of the "forward-backward" ratio for Na^{24} was made more complicated by the presence of an impurity due to silicon in the beryllium sheets (1%). In order to introduce a correction for the production of Na^{24} from the silicon, a control experiment was made, in which the beryllium sheets were irradiated with 660-Mev protons, and the sodium was subsequently separated. Such an experiment made it possible to