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ON THE SHAPE OF ODD NUCLEI OF THE TRANSITION REGION

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In the transition region of nuclei with $N < 90$ neutrons, the energy of the deformation and the pairing energy have comparable values [1]. Therefore when nucleons are added or when the nucleus becomes excited, the shape of the latter may change.

The large values of log ft of β transitions, systematically observed in the transition region, speak in favor of the assumption that the odd-neutron and odd-proton nuclei of this region have different forms [2].

Direct measurements of the quadrupole moments of the odd-neutron nuclei ${}_{60}Nd^{145}_{85}$, ${}_{62}Sm^{147}_{85}$, ${}_{62}Sm^{149}_{87}$ (+0.02, -0.208, and +0.06 barns, respectively) show that they are spherical in shape; the quadrupole moments of the odd-proton nuclei ${}_{61}Pm^{147}_{86}$ and ${}_{63}Eu^{151}_{88}$, which are respectively equal to 0.7 and 1.16 barns, are much larger than the single-particle value (~0.16 b). We have calculated the equilibrium deformations of odd-proton nuclei by the method of Mottelson and Nilsson [3]. We did not include in the calculations the pairing forces, allowance for which leads to a sharp discrepancy with experiment near the limits of the large-deformation regions [4]. The agreement between the values calculated by us and the experimental ones for nuclei with $N = 90$ (Eu^{153}, Pm^{151}) and $N = 88$ (Eu^{151}) allows us to conclude that the role of pairing in the establishment of the equilibrium form becomes appreciable only when $n < 88$. Comparison of the experimental value of the deformation for Pm^{147} ($\delta = 0.075$) with the calculated value ($\delta = 0.13$) allows us to assess the influence of the pairing forces in other nuclei of the transition region. The approximate values assumed accordingly for the equilibrium deformations of the nuclei are listed in column 3 of the Table (the numbers without the parentheses are the experimental values).

The presence of small deformations should lead to large collectivization of the single-particle states. In terms of the Nilsson scheme, this denotes the existence in the of rotational admixtures. The collective properties of the levels are manifest most strongly in the rates of the electromagnetic transitions between them.

The Table lists the calculated delay factors for M1-transitions ($F_{M1} = B(M1)_{Nils}/B(M1)_{exp}$) and the acceleration factors for E2 transitions ($F_{E2} = B(E2)_{exp}/B(E2)_{Nils}$) between the first-excited and the ground levels of odd-proton nuclei of the transition region. The values for strongly deformed nuclei are included for comparison. The values of the matrix elements of the M1-transitions in the europium isotopes cannot be explained by the method of mixing of configurations with higher values of seniority [5] (the method of Arima et al. [6]).

Properties of M1 and E2 transitions

Nucleus	Transition	δ_{mix}	Delay M1: Moszkowski with stat. mult.	Delay M1: Nilsson	Accel. M2: Weisskopf with stat. mult.	Accel. M2: Nilsson
Pm^{145}	7/2 [404]→5/2 [402]	(0.05)	250	0,24	20	180
Pm^{147}	5/2 [402]→7/2 [404]	0.075	430	0.28	10	1600
Pm^{149}	" "	(0,12)	620	0.35	62	6800
Eu^{147}	7/2 [404]→5/2 [402]	(0,06)	140	0,064	⩽6	⩽60
Eu^{149}	" "	(0.09)	94	0,059	38	1400
Eu^{151}	" "	0,14	130	0,084	⩽38	⩽5800
	1/2 [411]→5/2 [402]	"	-	-	9	2600
Eu^{153}	3/2 [411]→5/2 [413]	0.29	740	0,05	5.2	27000
Lu^{175}	5/2 [402]→7/2 [404]	0.26	⩽1200	⩽0,94	⩽6,5	⩽4400

An essential feature of E2 transitions is that the large acceleration factors are in terms of the Nilsson unit; the M1 transitions are also accelerated in terms of Nilsson units. In the case of the strongly deformed nucleus Eu^{153}, the acceleration of the E2 and M1 transitions can be readily attributed to admixtures of the rotational transition. The reduced probability of the transition has then the form

$$B(\sigma L, I_i \to I_f)_{theor} = \{B(\sigma L, I_i \to I_f)^{1/2}_{Nils}$$

$$+ \alpha[(2I_f + 1)/(2I_i + 1)]^{1/2} B(\sigma L, I_f K_i \to I_i K_i)^{1/2}_{rot}\}^2$$

where I_i and I_f are the spins of the initial and final states, respectively, and α is the amplitude of the admixture. In the case of $Eu^{1\sigma3}$ with $\alpha = 0.12$ we obtain $F_{acc}(E2) = B(E2)_{exp}/B(E2)_{theor} = 0.7$ and $F_{del}(M1) = B(M1)_{theor}/B(M1)_{exp} = 1.7$.

The M2 transitions $11/2^- \to 7/2^+$ in europium isotopes are hindered, with the delay factor increasing with increasing deformation, from 50 for Eu^{147} to 230 for Eu^{151}. The hindrance may be connected with the fact that in the $11/2^-$ state the nuclei have spherical shape. The values of the lower limits of log ft of the β transitions from the spherical nuclei of gadolinium to the $11/2^{-1}$ level (10; ≥ 7.8; ≥ 9 for Eu^{147}, Eu^{149}, and Eu^{151}, respectively) likewise does not contradict the assumption that this state is spherical.

Thus, the odd-neutron nuclei of the transition region are spherical; only for N = 89 (Sm^{151}) does the shape become ellipsoidal. The properties of odd-neutron nuclei can be described by the phonon model with account of pairing [7]. To the contrary, from the aggregate of the considered properties of the odd-proton nuclei of the transition region it follows that these nuclei have small equilibrium deformations, which increase gradually with increasing number of neutrons, up to N = 88. On going from N = 88 to N = 90, the deformation increases more abruptly, and this increase is accompanied by change in the state of the unpaired proton in Eu^{153} and Pm^{151}). This deduction refutes the widespread opinion that the transition of the nuclear shape from spherical is always abrupt.

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ELECTROMAGNETIC FORM FACTORS OF BARYONS AND SU(6) SYMMETRY

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The breaking of SU(6) symmetry for vertex functions with arbitrary momentum transfer can be formally taken into account by adding to the main SU(6)-symmetry variant additional variants, in which some of the pairs of unit matrices are replaced by γ_5 matrices. Assuming that the relative weight of the different variants is determined by kinematic factors of the type $[q^2 - (m_1 + m_2)^2]^{1/2}$ for the unit matrix and $[q^2 - (m_1 - m_2)^2]^{1/2}$ for the γ_5 matrix, where m_1 and m_2 are the masses of the baryons whose wave functions frame the matrices I and γ_5, we have obtained by means of the standard procedure the following expression for the vertex describing the interaction of the baryon octet b with the electromagnetic field:

$$W = a\{[-q^2(1 + 3q^2)D + (1 + \tfrac{4}{3}q^2 - q^4)F]C + 2(1 + 2q^2)(D + \tfrac{2}{3}F)M\} \qquad (1)$$

where F and D are the types of coupling between the baryon octet and the electromagnetic field

$$F = Sp(b^+bQ - b^+Qb)$$
$$D = Sp(b^+bQ + b^+Qb) \qquad (2)$$

Q is the charge matrix

$$Q = \frac{1}{3}\begin{pmatrix} 2 & 0 & 0 \\ 0 & -1 & 0 \\ 0 & 0 & -1 \end{pmatrix} \qquad (3)$$

C and M are the usual matrix variants of the charge and magnetic-moment type, respectively, while q^2 is the square of the momentum transfer in units of $4m^2$ (m - average mass of the baryon 56-plet).

We note the following consequences of formula (1):

1. Formula (1) duplicates the well known relations for form factors when $q^2 = 0$ and $q^2 = -1$ (cf., e.g., [1]).