RELATIVE γ TRANSITION PROBABILITIES IN STRONGLY DEFORMED NUCLEI

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The relative intensities of the γ transitions in Lu^{175} and Hf^{177} have been determined from the photoelectron spectra. The discrepancy between the experimental values for the relative γ transition probabilities and the theoretical values derived by the Alaga rules is confirmed. A similar disagreement between the experimental and theoretical values is also found to hold for the Ib^{173} and W^{183} nuclei.

ACCORDING to the collective model the internal wave functions of different states of the rotational band of strongly deformed nuclei can be assumed to be identical. In this case the ratio of the reduced probabilities of γ transitions going from some given state to various rotational states is found to depend only on geometrical factors, namely the Clebsch-Gordan coefficients (Alaga rules).[1]

We have considered two nuclei with large deformation parameters: Lu^{175} ($\delta = 0.28$) and Hf^{177} ($\delta = 0.26$) (see reference 2). The experimentally established level schemes[3] of Lu^{175} and Hf^{177} are in good agreement with the collective model of the nucleus of Bohr and Mottelson and with the Nilsson scheme.[4] The spins of the ground states and of the excited single particle levels correspond to the spins given by the Nilsson scheme with the corresponding δ. One observes rotational excitation of the ground states as well as single particle states. The deviation of the experimental values of the energy of the rotational levels from the values computed by the rotational formula is very small for both nuclei: $\Delta(E_2/E_1) = 0.5\%$.

However, the relative intensities of the γ lines obtained experimentally with scintillation[5,6] and crystal[7,8] spectrometers are very different from the values given by the Alaga rules. The data of references 5, 6 and 7, 8 are in slight disagreement. But it follows from either set of data that the γ transitions to excited states of the fundamental rotational band are much more intensive than is required by the intensity rules. In Lu^{175} the transitions from the 396 kev level to the first and second rotational states of the fundamental rotational band are faster by a factor of 7 and 55, respectively, than is predicted by the theory. In Hf^{177} the transitions from the 321 kev level to the first and second excited rotational states are faster by a factor of 1060 and 2200, respectively.

For a confirmation of this fact we have determined the relative intensities of the above-mentioned transitions by a different method. We took the photoelectron spectra of Yb^{175} and Lu^{177} with a magnetic lens spectrometer with a resolution of 0.5%. We used lead targets with the thickness 1.9 and 4.5 mg/cm^2 for Yb^{175} and 2.2 mg/cm^2 for Lu^{177}. The relative intensities were determined by the areas under the photoelectron lines with account of the experimentally established spectral sensitivity of the apparatus. The values of the relative intensities of the transitions under consideration are given in Table I.

It is seen from this table that our data are not in disagreement with the data obtained by other methods and, therefore, confirm the discrepancy between experiment and theory. In an effort to find analogous cases of disagreement between the experimental and theoretical values of the relative intensities we have investigated all nuclei with odd mass numbers in the region $150 < A < 192$. Owing to the insufficient amount of experimental data, we were able to choose only six nuclei for which it was possible to verify the above-mentioned intensity rules (we considered the ratio of the intensities of the competing transitions to the ground state and to the first two rotational levels from a level which does not belong to the basic rotational band E_0).

Some of the data relative to the nuclei under consideration are listed in Table II. It appears that only for two (Ta^{181}, Re^{187}) of the six nuclei do the relative intensities of the γ transitions conform to the Alaga rules. In the case of four nuclei (Yb^{173}, Lu^{175}, Hf^{177}, W^{183}) we observe considerable disagreement with the theory. It is interesting to note that the deviation from the theoretical values has uniform character: the transitions to the rotational states are faster than is predicted

TABLE I

Nucleus	E_γ, kev	Relative intensities of the lines: on the crystal spectrometer	on the scintillation spectrometer	on the magnetic spectrometer
		7, 8	5, 6	our data
Lu^{175}	396	100	100	100
	283	62	43	61
	145	5.9	2	13
Hf^{177}	321	100	100	100
	208	7300	1500	6000
	71	67	10	*

*Because of the x-radiation of Pb and Hf in the neighborhood of the photoelectron lines, it was impossible to separate the photoelectron L line for $E_\gamma = 71$ kev.

TABLE II

Nucleus	Deformation parameter, δ (reference 2)	Ratio of the intensities of the γ transitions $I_{\gamma_1} : I_{\gamma_2} : I_{\gamma_3}$*: theoretical by Alaga's rules	experimental**	E_0 kev	Enhancement coefficient of the transitions: f_2	f_3
$_{70}Yb^{173}_{103}$	0.29	100 : 14 : 0.43 (for $E1$)	100 : 1600 : 290 [11]	351	114	675
$_{71}Lu^{175}_{104}$	0.28	100 : 8,3 : 0.108 (for $E1$)	100 : 71 : 7.5 [7]	396	8.5	70
$_{72}Hf^{177}_{105}$	0.26	100 : 6,1 : 0.025 (for $E1$)	100 : 9700 : 83 [8]	321	1600	3300
$_{73}Ta^{181}_{108}$	0.23	100 : 15 (for $E2$)	100 : 17 [12]	482	1.1	
$_{74}W^{183}_{109}$	0.21	100 : 36.2 : 2.4 (for $M1$)	100 : 910 : 273 [12]	209	25	114
$_{75}Re^{187}_{112}$	0.19	100 : 21 (for $E1$)	100 : 21 [12]	686	1	

*$\gamma_1, \gamma_2, \gamma_3$ are the transitions to the ground, first excited rotational, and second excited rotational states, respectively.

**With account of conversion and the composition of the multipole mixture.

by the intensity rules, where the enhancement coefficent* of the transition to the second rotational level is greater than that for the transition to the first level. It may be noted that all transitions which violate the intensity rules are accompanied by a change of K by −1. We have been unable to detect regularities with respect to any other quantum numbers.

The fact that the transition rates to the rotational state in the nuclei Lu^{175} and Hf^{177} are enhanced was noted by Marmier and Boehm[8] and also by Chase and Wilets.[9] Attempts were made to explain this enhancement by the argument that the E1 transitions are forbidden by the asymptotic quantum numbers but that the rotational motion leads to a certain violation of this forbiddenness rule. However, we do not find this a convincing explanation. Apparently there is some other reason for the systematic violation of the intensity rules. It may be that the adiabatic approximation which has been used in the derivation of the intensity rules is not applicable for the nuclei under consideration. In particular, the violation of the adiabatic hypothesis may lead to the mixing of states with different K.[1] Similar instances of inaccurate theoretical values of the relative intensities of the γ transitions are also observed in a number of even-even nuclei. Davydov and Filippov[10] showed that the asymmetry of the equilibrium shape of the nucleus may lead to the violation of the Alaga intensity rules in even-even nuclei. Analogous calculations for nuclei with odd A are not available.

*By enhancement coefficient we mean the ratio of the experimental value of the relative intensity of a given γ transition to the theoretical value.

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