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THE K QUANTUM NUMBER AND THE γ–DECAY OF NEUTRON RESONANCES*

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The energy-corrected intensities of the primary γ-transitions in ^{168}Er, ^{178}Hf, ^{166}Ho, ^{176}Lu, ^{182}Ta and ^{177}Lu following thermal and average resonance neutron capture are calculated from data available in the literature. The data reveal a significantly lower average transition rate for K-forbidden than for K-allowed primary transitions. The effect is more pronounced in the data from thermal neutron capture than in the data from 2 keV neutron capture.

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The order-chaos transition predicted in heated nuclei is believed to imply complete mixing of quantum numbers related to the mean-field picture and the intrinsic nuclear coordinate system, such as the spin projection K on the nuclear symmetry axis. The degree of K mixing may be utilized as a probe for investigating the amount of disorder in the system: In the case of limited configuration mixing and approximate K conservation, the γ-decay from a given eigenstate will essentially obey the selection rule $\Delta K \leq \lambda$, with λ being the multipolarity of the transition. Transitions to final states with K-values fulfilling this criterion, so-called "allowed" transitions, are expected to be far more intense than "forbidden" transitions. On the other hand, an initial state with extensive configuration mixing is composed by a large variety of components with different K values through which γ-decay

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may take place, and a wide range of final state K values will be equally "allowed".

We have studied the primary decay pattern of neutron resonance states in the following deformed nuclei: ^{168}Er, ^{178}Hf (even-even) ^{166}Ho, ^{176}Lu, ^{182}Ta (odd-odd) and ^{177}Lu (odd-Z), populated by means of thermal and 2 keV (ARC) neutrons. Tables of primary γ-lines and level schemes are taken from Refs [1–6].

The dominance of s-neutrons leads to well-defined capture states with spin values $I_i = I_{\mathrm{target}} \pm 1/2$ and parity equal to π_{target}. According to the usual spin selection rules, the K values of the capture states should be restricted to $K_i = K_{\mathrm{target}} \pm 1/2$ in the absence of K mixing. Correspondingly, the final states accessible through dipole transitions should have K values ranging from $K_{\mathrm{target}} - 3/2$ to $K_{\mathrm{target}} + 3/2$.

The intensities of the high-energy transitions connecting the capture states and the various low-lying final states with known quantum numbers $I^{\pi}K$ have been investigated. Since the transition intensities depend on the spin and parity of the final state, only transitions within the same spin and parity group can be compared directly. Dimensionless relative reduced transition probabilities x_i have been extracted by dividing out the dependence on γ-energy and final-state spin and parity, as described in detail in Ref. [7]. The quantities x_i can then be grouped according to final-state K value, and eventually compiled into one forbidden and one allowed ensemble. Average relative reduced transition probabilities $\langle x \rangle_F$ and $\langle x \rangle_A$ can then be calculated for the two ensembles, together with an effective hindrance factor $R = \langle x \rangle_F / \langle x \rangle_A$. Results for the nuclei studied so far are listed in Table I. The numbers given for ^{176}Lu and ^{182}Ta must be considered as highly preliminary.

TABLE I

Average reduced relative transition probabilities $\langle x \rangle_F$ and $\langle x \rangle_A$ for forbidden and allowed transitions, respectively, and effective hindrance factors $R = \langle x \rangle_F / \langle x \rangle_A$. The numbers of transitions in the various ensembles are listed in parentheses.

Nucleus	$\langle x \rangle_F$ (thermal)	$\langle x \rangle_A$ (thermal)	Ratio R (thermal)	$\langle x \rangle_F$ (2 keV)	$\langle x \rangle_A$ (2 keV)	Ratio R (2 keV)
^{168}Er	0.69 (17)	1.10 (47)	0.63	0.93 (16)	1.03 (30)	0.90
^{178}Hf	0.38 (8)	1.07 (9)	0.36	0.81 (9)	1.10 (14)	0.74
^{166}Ho	0.49 (10)	1.46 (11)	0.34	0.95 (10)	1.07 (12)	0.89
^{176}Lu	0.82 (17)	1.28 (11)	0.64	0.98 (17)	1.03 (11)	0.95
^{182}Ta	0.71 (6)	1.14 (13)	0.62	0.82 (6)	1.07 (11)	0.77
^{177}Lu	0.59 (10)	1.31 (13)	0.45			
All nuclei	0.64 (68)	1.19 (104)	0.54	0.92 (58)	1.05 (78)	0.87

The x distributions for forbidden and allowed transitions, obtained by adding the ensembles for all nuclei studied, are displayed in Fig. 1 (upper subframes). The average x values measured for different final-state K quantum numbers, $\langle x \rangle_K$, are shown in the two lower subframes.

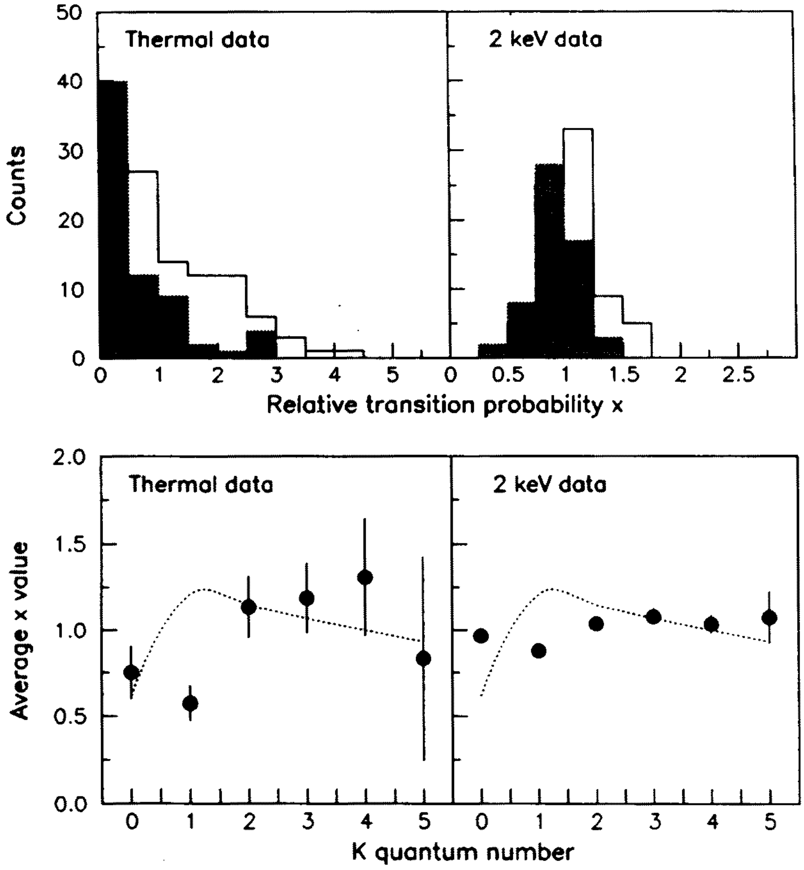

Fig. 1. Distributions of relative reduced transition probabilities x for all nuclei studied (upper subframes) and average x-values for different final-state K-values (lower subframes)

The experimental results can be summarized as follows: The primary γ-decay after low-energy neutron capture shows a significant suppression of so-called K-forbidden transitions, which may indicate partial K conservation. The effect is systematically weaker for ARC than for thermal neutron capture.

Due to the K-dependent density of available single-particle basis states, a small forbidden-allowed difference might be expected also in the case of complete K-mixing. However, a simple estimate assuming a resonance state K composition proportional to the level density $\rho(K) \propto (2 - \delta_{K,0})$ gives a $\langle x \rangle_K$ distribution (dashed lines in lower subframes of Fig. 1) peaking at $K = 1$ and thus inconsistent with the experimental data.

The difference between the results for thermal and ARC neutron energies remains unexplained so far. The two groups of resonance states are expected to be quite equivalent with respect to quantal structure, showing the same degree of configuration mixing. One relevant factor could be the different neutron widths of the thermal and ARC neutron capture states. In the ARC case, the high-K entrance component would decay much faster by neutron emission and to a larger extent be rendered unavailable for γ-decay to high-K final states. However, for this mechanism to explain the observations adequately, the entrance component would have to play a very important role with respect to the decay pattern. In case of a dynamic effect, where a significant part of the γ-decay takes place via the entrance component before thermalization, only limited information could be obtained about the composition of the full resonance state wave function and the associated degree of K mixing. On the other hand, a systematic occurrence of large static entrance component amplitudes would imply incomplete configuration mixing. Further research is needed in order to illuminate these questions.

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