Quenched M1 Transitions Between Nilsson States in ^{235}U.

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From the ^{235}U data set discussed in earlier annual reports we have extracted for the first time reliable absolute B(M1)-values for transitions between rotational bands belonging to different Nilsson states of the same j-multiplet. There are no comparable measurements in the literature for any nucleus. For the [752]5/2 to [743]7/2 bands, gamma-ray branching ratios were calibrated to the in-band [752]5/2 cascade strength, which is reliably predicted. For the [734]9/2 to [743]7/2 bands, branching ratios were calibrated to the stretched E2 transition strengths between the bands measured in our earlier Coulomb excitation experiments. We will show below that the experimental B(M1)-values are much smaller than expected.

The results were compared to three models: 1) a Woods-Saxon calculation by Chasman et.al.[1], 2) a standard Nilsson model [2], and 3) a particle-rotor calculation with the Semmes-Ragnarsson code both with and without Coriolis mixing. In all cases, a simple pairing correction was applied [2]. For bands differing by 1 in their K-values, (K_i, $K_f \neq ½$) the B(M1;$K_i \rightarrow K_f$) is proportional to a Clebsch-Gordon coefficient (squared) times the reduced matrix element, G_{M1} (squared), where [1]

$$G_{M1}(K_i \rightarrow K_f) = (g_s - g_R) \langle s_+ \rangle + (g_l - g_R) \langle l_+ \rangle$$

Here, g_s, g_R and g_l are the usual gyromagnetic ratios, which for neutron states we took to be –2.30, 0.30 and 0.0 respectively. In general, the matrix elements $\langle s_+ \rangle$ and $\langle l_+ \rangle$ can vary widely, depending on the specific orbitals involved: but for orbitals belonging to the same high-j intruder multiplet the calculated values are rather constant, and very large. This comes about because the intruders do not mix appreciably with orbitals of the shell, and they remember their spherical shell-model heritage, namely j=15/2. If one examines the calculations of ref [1], and [2] for the j15/2 intruders, then over the whole multiplet K=1/2 to K=15/2, one finds $\langle l_+ \rangle$-values in the range 5.5 to 6.5 and $\langle s_+ \rangle$-values in the range 0.35 to 0.50. The predicted G_{M1}-values are therefore robust, and lie in the range –2.0 to –3.0, insensitive to the deformation, or to the model parameters

For the K= 5/2 to 7/2 bands in the spin range 25/2 to 39/2, the measured B(M1)-values are attenuated by a factor between 10 and 25 in comparison to the different calculations. The K= 9/2 to 7/2 bands in the spin range 13/2 to 19/2 are attenuated by factors between 10 and 100. The one exception is the I → I transitions from K = 5/2 to 7/2, where the particle-rotor calculation with Coriolis mixing yields a very small B(M1) that reproduces the experimental values. This must be accidental, since in the I → I±1 cases, Coriolis mixing increases the calculated B(M1), and makes the overall attenuation larger.

We have conducted a literature search for nuclei where at least one gamma transition connects rotational states based on intruders differing by ΔK=1 in the same multiplet. We considered all odd-neutron, and odd-proton deformed nuclei from Sm to Es isotopes, examining neutron intruders $j_{15/2}$ and $i_{13/2}$, and proton intruders $i_{13/2}$ and $h_{11/2}$. Including ^{235}U, there are nine nuclides in the odd-neutron list. For ^{183}Pt and ^{187}Os the gamma-ray branch relative to the predictable in-band transition has been measured: in the other nuclides the strength of the calibrating E2 transition has to be estimated from the particle-rotor code with the Coriolis mixing derived from a crude fit to the moments of inertia and rotational energy staggering. Relative to the particle rotor code, the attenuations vary from a factor of 3 to several hundred. There are seven nuclides on the odd-proton list and once again the attenuations vary from 3 to several hundred.

This attenuation of the B(M1)-values between members of the j multiplet appears to be a serious problem. Coupling to octupole excitations, which goes some way to explaining the attenuated Coriolis interactions (cf. Annual Report 2004.) can not account for the effect. The BCS treatment of the pairing may be too simple, but in the ^{235}U case if we calculate the occupation numbers blocking each quasi-particle separately, the pairing attenuation factor for the K = 5/2 to 7/2 bands goes from 0.81 to 0.72, which implies that pairing is unlikely to be the central cause of the discrepancy. A possible scenario that may explain this effect involves the coupling to the $K=1^+$ scissors mode known to exist in the deformed rare earth and actinide regions. A priori, a cancellation of the single particle strength with that of the 1^+ phonon could lead to a systematic quenching of the B(M1). Definitely, more theoretical work is required to confirm this conjecture.

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