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7.2 Energy Dependence of the j-Effect in Radiative Capture of Polarized Nucleons

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It has recently been pointed out[1] that polarized nucleon capture data indicate a sensitivity to the $j_{\pm}$ value ($j_{\pm} = l \pm 1/2$) of the single particle final state for a given l value. Namely, it was shown that the b_k coefficients, in the absence of spin distortions, should obey the relationship

$$b_k\,(j_-)\,/\,b_k\,(j_+) = -\,(l+1)\,/\,l \tag{1}$$

and this conclusion (hereafter called j-effect) was found to be consistent with the signs of the b_2 coefficients known from (p ,γ) data at isolated energies where E1-capture is dominant.

In the present work the direct-semidirect (DSD) model is used to investigate the j-effect for all k and in the whole energy region of the giant multipole resonances. Here some results for radiative capture of 5-35 MeV neutrons by ^{40}Ca, are presented. Calculations are performed[2] taking into account the IS and IV GQR's and the ISGOR. The single particle final states (and binding energies) considered are : the ground state f 7/2 (8.36 MeV), the first excited state p 3/2 (6.42 MeV) and the j_- states p 1/2 (4.42 MeV), f 5/2 (3.48 MeV).

In Fig. 1 the function

$$B_{sum}\,(E,\theta) = \sum_{k=1}^{6} b_k\,(E)\,P_k^1\,(\cos\theta) \tag{2}$$

is plotted for capture to the $f_{\pm}$ states at 11 MeV (upper) and 15 MeV (lower) neutron incident energy and compared with the experimental points[3] for capture to the f 7/2 state. The opposite signs of the calculated functions B_{sum} are consistent with eq.(1). Due to the difference in the binding energies of the levels considered, E_n = 11 MeV is near the ISGQR peak for capture to the f 7/2 state and below it for f 5/2. Where E1 radiation dominates, the sum (2) reduces to its second term and the corresponding

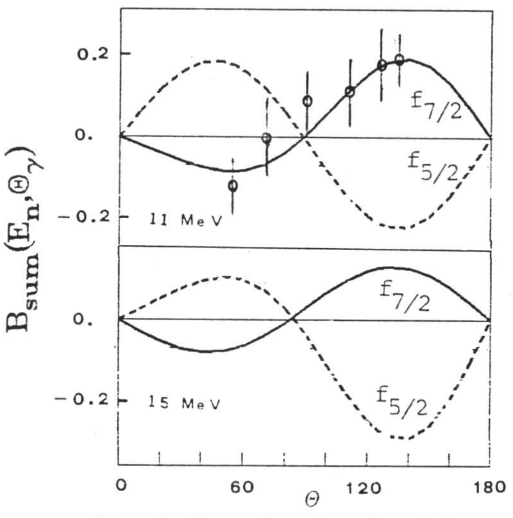

Fig. 1. B_{sum} for the $f_{\pm}$ states

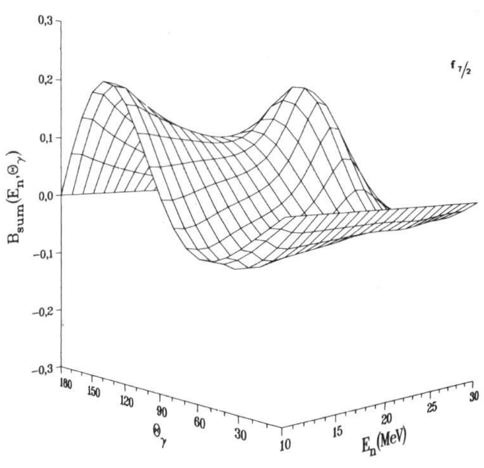

Fig. 2. B_{sum} for the f 7/2 state

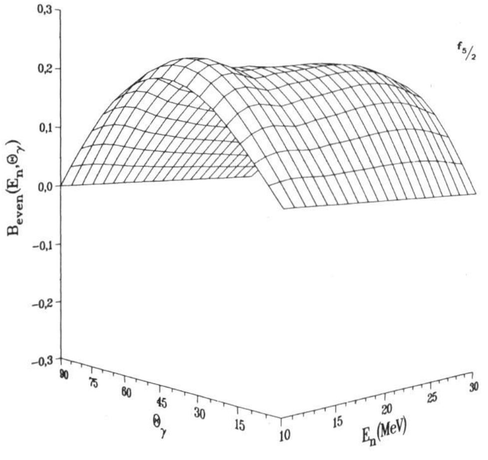

Fig. 3. B_{even} for the f 5/2 state

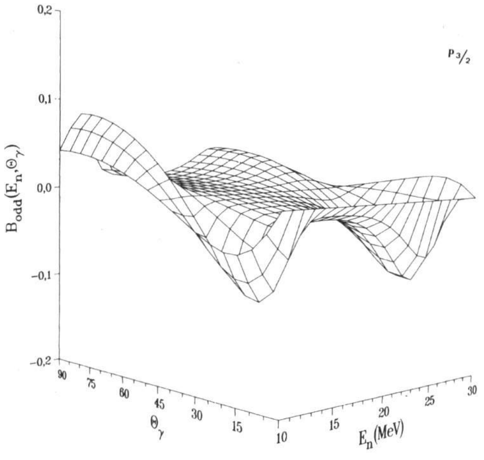

Fig. 4. B_{odd} for the p 3/2 state

curves are nearly symmetric. The asymmetry reveals the presence of E2 radiation. Qualitatively similar curves are obtained in the region of the IVGQR (25-30 MeV) as can be seen from Fig. 2. It should be noted however, that at ~ 25 MeV the positive values for B_{sum} (f 7/2) are pushed toward smaller angles. Similar results are obtained for capture to the $p_{\pm}$ states. Therefore, for angles between ~ 30^{o} and 90^{o} the model predicts positive values of B_{sum} both for capture to j_+ and j_- states.

The b-coefficients contain different multipole strength and this limits the possibility of using B_{sum} for studying the j-effect. Therefore two functions, which can be related to data from measurements at two supplemental angles, are here introduced :

$$B_{even}(E,\theta) = \sum_n b_n(E)\,P_n^1(\cos\theta)\,/\,[1+\sum_n a_n(E)\,P_n(\cos\theta)] \qquad (3)$$

$$B_{odd}(E,\theta) = \sum_m b_m(E)\,P_m^1(\cos\theta)\,/\,[1+\sum_n a_n(E)\,P_n(\cos\theta)] \qquad (4)$$

with n = 2,4,6 and m = 1,3,5. Calculations predict positive and negative values of B_{even} for capture to j_- and j_+ states respectively (see Fig. 3 for f 5/2). This rule holds in the whole energy-angle region for the 4 levels considered, except for the p 3/2 state where, at high energies, near zero-positive values of B_{even}, are obtained. The rule mentioned agrees with the sign, though values calculated here of the j-effect are greater than those of eq. (1). Figure 4 (p 3/2 state) shows greater variation from zero values at the peaks of IS and IV GQR's thus clearly indicating their positions. Taking into account the difference in binding energies the corresponding $j_{\pm}$ surfaces can be considered symmetric with respect to the zero plane. Calculated B_{odd} agree with the sign and indicate values of the j-effect close to those of eq.(1).

The present investigation shows that : 1) the energy-variation of the j-effect is closely related to the relative strength of different multipole contributions at a given energy; 2) the predictions of the DSD model together with measured values for the j-effect, can be useful as a tool both in assigning j-values to final states and in obtaining information about the strength and position of GMR's.

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