Suppression of Gamow-Teller Transitions in Deformed Mirror Nuclei ^{25}Mg and ^{25}Al

Y. Fujita[a], Y. Shimbara[a,b], I. Hamamoto[c], T. Adachi[a], G.P.A. Berg[b,d], H. Fujita[b], K. Fujita[b], K. Hatanaka[b], J. Kamiya[b], K. Nakanishi[b], Y. Sakemi[b], Y. Shimizu[b], M. Uchida[e], T. Wakasa[f] and M. Yosoi[e]

[a]*Dept. Phys., Osaka University, Toyonaka, Osaka 560-0043*
[b]*RCNP, Osaka University, Ibaraki, Osaka 567-0047*
[c]*Div. Mathematical Physics, LTH, Univ. Lund, S-22100, Lund, Sweden*
[d]*KVI, Zernikelaan 25, 9747 AA Groningen, The Netherlands*
[e]*Dept. Phys., Kyoto University, Sakyo, Kyoto 606-8224*
[f]*Dept. Phys., Kyushu University, Higashi, Fukuoka 812-8581*

In a deformed nucleus with z-axis symmetry, the z component K of the total spin J is a good quantum number. Each single nucleon is in a Nilsson orbit labeled by the asymptotic quantum numbers $[Nn_z\Lambda\Omega]$ [1], where N is the total oscillator quantum number, n_z the number of quanta along the z axis, and Λ and Ω are z-axis projections of the orbital and total angular momenta. Low-lying states of an odd-mass deformed nucleus are well described in terms of the particle-rotor model assuming both a single quasi-particle in various Nilsson orbits as the intrinsic configuration and the collective rotation induced by the core. Since the rotation of the core is perpendicular to the z axis, $K = \Omega$ holds. Therefore, each rotational band is specified by the quantum numbers of the single particle orbit $K^\pi[Nn_z\Lambda]$.

In the middle of the sd shell, nuclei with mass number $19 \leq A \leq 25$ are strongly deformed [1]. Low-lying states in the $A = 23$, $T_z = \pm 1/2$ mirror nuclei ^{23}Na and ^{23}Mg and those in the $A = 25$ system ^{25}Mg and ^{25}Al are well described in terms of the particle-rotor model [1, 2], where T_z is the z component of isospin T. The GT excitations in the $A = 23$ system were studied previously in the $^{23}\mathrm{Na}(^3\mathrm{He}, t)^{23}\mathrm{Mg}$ reaction at 0° [3]. With the high resolution of the measurement, many prominent peaks of GT excitations were observed, as shown in Fig. 1(a). The study is extended to the $A = 25$ system by the same reaction on a ^{25}Mg target. Although the mass-number difference of these two systems is only two, we found that the measured ^{25}Al spectrum, selectively showing GT excitations, is completely different at excitation energies (E_x) below 6 MeV. In the $A = 25$ system most of the GT excitations are very much suppressed except for the transitions to the ground and 1.61 MeV states.

In intra-band transitions, quantum numbers specifying the intrinsic motion do not change. The matrix element for the σ_z operator is given by

$$\langle N\, n_z\, \Lambda\, K|\sigma_z|N\, n_z\, \Lambda\, K\rangle = 2\Sigma, \tag{1}$$

where Σ is the z component of the spin. In intra-band transitions, where K does not change, the transitions by the GT operator are allowed.

The inter-band transitions are caused by $\sigma_\pm$ operators. By applying $\sigma_\pm$, we get

$$\sigma_\pm|N\, n_z\, \Lambda\, K\,\rangle \propto \delta(K, \Lambda \mp 1/2)\, |N\, n_z\, \Lambda\, K \pm 1\rangle, \tag{2}$$

showing that $\sigma_\pm$ operators cause transitions changing the asymptotic quantum number Σ, and thus K by one unit. It should be noted that the asymptotic quantum numbers n_z and Λ are not constants of the motion, but K is. Therefore, the selection rules $\Delta K = \pm 1$ are

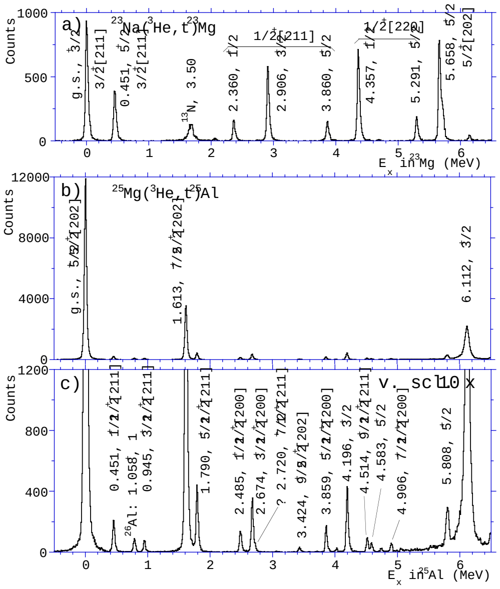

Figure 1: Comparison of (a) ^{23}Na(^{3}He, t)^{23}Mg spectrum and (b) ^{25}Mg(^{3}He, t)^{25}Al spectrum. The ordinates of figs. a) and b) are scaled so that states with similar B(GT) values have similar peak heights. The spectrum shown in Fig. (b) is repeated in Fig. (c) with the vertical scale expanded by a factor of ten (v. scl. ×10) in order to show weakly excited states more clearly.

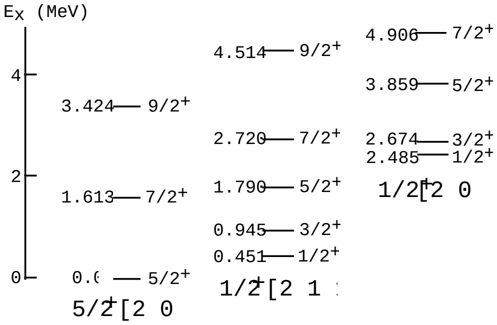

Figure 2: Proposed band structure for the low-lying positive-parity states of ^{25}Al based on the Nilsson-orbit classification [1]. Each band is identified by the combination of quantum numbers $K^\pi[Nn_z\Lambda]$. Each state is denoted by the excitation energy (in MeV) and J^π values.

important results from Eq. (2). In addition, it is expected that the transitions are much favored if the asymptotic quantum numbers n_z and Λ do not change in the transitions.

On the basis of various experimental data [4], a band structure for ^{25}Al shown in Fig. 2 and a very similar one for ^{25}Mg are proposed [1]. With our resolution of $\Delta E = 35$ keV, many weakly excited ^{25}Al states having J^π values of either $3/2^+$, $5/2^+$, or $7/2^+$ [see Fig. 1(c)] could be identified in the $E_x < 6$ MeV region. These states are allowed in terms of the $\Delta J^\pi = 1^+$ selection rule. In such cases, the selections by the K quantum number should be examined. As shown in Fig. 2, the 0.945 MeV, $3/2^+$, 1.790 MeV, $5/2^+$, and 2.720 MeV, $7/2^+$ states are members of the rotational band $1/2^+[2\,1\,1]$. The transitions from the $J^\pi = 5/2^+$ ground state of the $5/2^+[2\,0\,2]$ band to the members of the $1/2^+[2\,1\,1]$ band require a change of the K quantum number by 2 units. These transitions are not allowed by the $\sigma_\pm$ operators, as seen from Eq. (2), and thus GT transitions are not allowed. The same is true for the transitions to the 2.674 MeV, $3/2^+$, 3.859 MeV, $5/2^+$, and 4.906 MeV, $7/2^+$ states that are members of the $1/2^+[2\,0\,0]$ deformed band.

More details are discussed in Ref. [5].

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