Analogous Gamow-Teller and $M1$ transitions in ^{26}Mg and ^{26}Al

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In the so-called "$T = 1$ system," a variety of analogous transitions can be compared. The GT transitions from the $J^\pi = 0^+$ ground state of the $T_z = 1$ even-even nucleus to 1^+ states (GT states) in the $T_z = 0$ odd-odd nucleus can be studied via CE reactions. From Fig. 1, we notice that the $M1$ transitions from these excited GT states with $J^\pi = 1^+$ to the lowest $T = 1$, $J^\pi = 0^+$ state in the $T_z = 0$ nucleus (IAS) are also analogous to the GT transitions. The B(GT) values from ^{26}Mg(^{3}He, t)^{26}Al reaction at 0° were compared with the $B(M1)$ values of the analogous $M1$ γ transitions in ^{26}Al from the excited 1^+ GT states to the IAS in order to study the spin and orbital contributions in these $M1$ transitions.

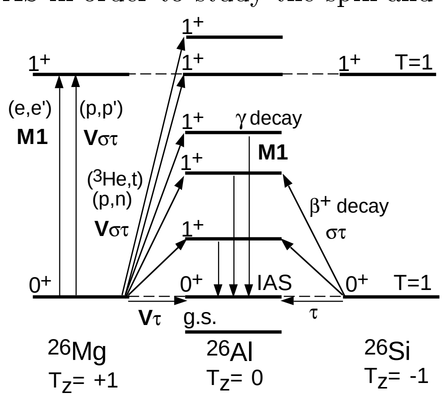

Figure 1: Isospin analogous transitions in $A = 26$, $T_z = \pm 1$ and 0 isobar system are schematically shown. The Coulomb displacement energies are removed so that the isospin symmetry of the system and that of transitions become clearer. Analog states with $T = 1$ are connected by broken lines.

The $M1$ γ-transition strengths $B(M1)\downarrow$ (in μ_N^2) for these transitions are calculated by using the measured lifetime (mean life) τ_m, γ-ray branching ratio b_γ to the IAS, and the γ-ray energy E_γ by using the data compiled in Ref. [1]. The $B(M1)\uparrow$ value that would be obtained in an (e, e')-type transition from the ground state with spin-value J_0 to the excited state with J_j is obtained by correcting the $2J + 1$ factors as $B(M1)\uparrow = (2J_j + 1)/(2J_0 + 1)B(M1)\downarrow$.

In addition to the IV spin term that is common with the GT operator, the $M1$ operator contains the IV orbital ($\ell\tau$) term. This additional term can contribute either constructively or destructively with the IV spin term. Under the assumption that isospin T is a good quantum number, such contributions can be studied by comparing the strength of an $M1$ transition with that of the analogous GT transition representing the contribution only from the IV spin term. If the $\sigma\tau$ term that is common in both GT and $M1$ transitions is the main term, then there is a simple relationship between $B(M1)$ and B(GT) [2].

$$B(M1) \approx \frac{3}{8\pi}(g_s^{\rm IV})^2 \mu_N^2 R_{\rm MEC} B({\rm GT}) = 2.644 \mu_N^2 R_{\rm MEC} B({\rm GT}), \quad (1)$$

where $R_{\rm MEC}$ represents the different reduction factor of the $\sigma\tau$ term in τ_0-type $M1$ transitions and $\tau_\pm$-type GT transitions due to the different contributions of meson exchange currents (MEC) [3, 4]. The most probable value $R_{\rm MEC} = 1.25$ is deduced for nuclei in the middle of sd shell [2]. From Eq. (1), we find that by introducing renormalized $B(M1)$ values

Table 1: Values of $B^R(M1)$, $B(\mathrm{GT})$, and R_{OC} for the five low-lying 1^+ states in ^{26}Al. The GT and $M1$ transitions are from the ground state of ^{26}Mg and the isobaric analog state of it in ^{26}Al (IAS), respectively. The $B(\mathrm{GT})$ values are from $^{26}\mathrm{Mg}(^3\mathrm{He}, t)$ reaction. The ratio $R_{\mathrm{OC}} > 1$ (< 1) shows the constructive (destructive) interference of orbital and spin contributions in a $M1$ transition.

E_x	$B^R(M1)$	$B(\mathrm{GT})$	R_{OC}
1.058	3.1 ± 0.6	1.081 ± 0.029	2.3 ± 0.4
1.851	0.33 ± 0.04	0.527 ± 0.015	0.50 ± 0.05
2.072	0.017 ± 0.003	0.112 ± 0.004	0.12 ± 0.02
2.740	0.094 ± 0.011	0.117 ± 0.004	0.64 ± 0.06
3.724	0.25 ± 0.08	0.106 ± 0.004	1.9 ± 0.5

$B^R(M1) = B(M1)/(2.644\mu_N^2)$, the $M1$ transition strengths can be comared directly with the GT transition strengths $B(\mathrm{GT})$. Using these values, the interference of IV orbital term with the IV spin term in an $M1$ transition can be shown by the ratio

$$R_{\mathrm{OC}} = \frac{1}{R_{\mathrm{MEC}}} \frac{B^R(M1)}{B(\mathrm{GT})}, \tag{2}$$

where the effects of MEC are also taken into account. The ratio is usually larger (smaller) than unity if the contribution of the IV orbital ($\ell\tau$) term is constructive (destructive) with the IV spin ($\sigma\tau$) term [2].

The $B^R(M1)$ values for the transitions from the $J^\pi = 0^+$ IAS at 0.228 MeV to the excited 1^+ states were calculated using the $B(M1)$ [$= B(M1)\uparrow$] values. These are given in column 2 of Table 1. It can be seen that the $B^R(M1)$ values for the 1.06 MeV and 3.72 MeV states in ^{26}Al are larger than the corresponding $B(\mathrm{GT})$ values. On the other hand, $B^R(M1)$ values are smaller for the 1.85 MeV, 2.07 MeV, and 2.74 MeV states. In particular, the $B^R(M1)$ value for the first 1^+ state at 1.06 MeV is almost three times larger than the corresponding $B(\mathrm{GT})$ value, while that for the 2.07 MeV state is almost one order of magnitude smaller.

The $B^R(M1)$ and $B(\mathrm{GT})$ values should be similar under the assumption that the $\sigma\tau$ term in the $M1$ transition is dominant. The difference comes from the $\ell\tau$ term existing only in the $M1$ transition. By using Eq. (2), the ratios R_{OC} were calculated from the $B^R(M1)$ and $B(\mathrm{GT})$ values assuming $R_{\mathrm{MEC}} = 1.25$. These are given in column 4 of Table 1. It is interesting to see that a clear correlation exists between R_{OC} and the excitation energy. A large R_{OC} of 2.3 is obtained for the $M1$ transition to the lowest 1^+ state at 1.06 MeV. The ratios are smaller than unity for the states between 1.5 and 3 MeV, and then the ratio becomes large again for the 3.72 MeV state. A similar E_x dependence of the R_{OC} has been reported for the IV $M1$ transitions observed in ^{24}Mg [5] and in ^{28}Si [6].

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