g factor of the 3.830 MeV $(\frac{15}{2}^+)$ level in ^{41}Ca*

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The g factor of the 3.830 MeV level of ^{41}Ca has been measured by the time-differential perturbed-angular-distribution method to be $g=+0.29\pm0.02$. The reaction ^{27}Al(^{16}O, p, n)^{41}Ca was used to populate the state in a magnetic field of 58 kG. The measured g factor can be understood within the configuration $(d_{3/2}^{-1}f_{7/2}^2)^{15/2^+}$. The calculated g factor depends sensitively on the isospin character of the particle-hole interaction.

[NUCLEAR REACTIONS ^{27}Al(^{16}O, $pn\gamma$), $E=48$ MeV; measured $\gamma(\theta, B, t)B=58$ kG deduced g(3.830 MeV).]

Recently, many high-spin levels in ^{41}Ca have been populated by utilizing the large angular momentum transfer inherent in heavy-ion fusion evaporation reactions.[1,2] Many of these levels have also been observed in (^{3}He, d) and (d, n) reactions[3] on ^{40}K. The 3.830-MeV level in ^{41}Ca has been assigned $(\frac{15}{2}^+)$ both from the γ decay[1,2] and from the $l=3$ transfer[3] in (^{3}He, d). A $\frac{15}{2}^+$ level can be made in $d_{3/2}^{-1}f_{7/2}^2$ by coupling the isospin of the two $f_{7/2}$ particles to either $T_p=0$ or $T_p=1$. The composition of the $(\frac{15}{2}^+)$ level is probably some mixture of these two levels, and a g-factor measurement can determine the relative amounts of the two isospin components.

The short lifetime (4.7 nsec) of the isomeric 3.830-MeV level requires a large field in order to utilize the time-differential perturbed-angular-distribution technique. The superconducting magnet[4] at the Stony Brook FN tandem Van de Graaff was used for the measurement. A pulsed beam of 48-MeV ^{16}O ions was incident on a thick ^{27}Al target which was placed in a transverse field of 58 kG. The decay of the $(\frac{15}{2}^+)$ level includes a γ ray of either 3369 keV or 3201 keV, and fortunately these γ rays have very large anisotropies[1] of opposite sign [$A_2(3369)=+0.67$, $A_2(3201)=-0.34$]. Delayed-time spectra of both γ rays were taken in Ge(Li) counters at ±45° to the beam direction at the target. The time resolution for both γ rays was 3.5 nsec full width at half maximum (FWHM). The following double ratio was formed:

$$R(t)=\frac{[N_+(3369)-N_+(3201)]-[N_-(3369)-N_-(3201)]}{N_+(3369)+N_+(3201)+N_-(3369)+N_-(3201)}.$$

By expressing the data in this way, many possible systematic distortions of the time spectra are eliminated in first order. The $R(t)$ obtained is shown in Fig. 1, along with a least-squares fit with $\omega_L=0.082(5)$ nsec^{-1} corresponding to $g=+0.29\pm0.02$. Knight-shift and diamagnetism corrections were not applied as they were very small compared to other uncertainties. The amplitude of the $R(t)$ is consistent with the measured A_2 coefficients, indicating that there is no additional loss of the nuclear alignment for calcium in aluminum compared to calcium in tungsten.[1] After this work was completed, another less-precise measurement of the g factor with the time-integral perturbed-angular-distribution method was reported[5] and is in agreement with our result.

To interpret the g factor, shell-model calculations were performed in a complete model space of all 1s 0d and 1p 0f orbits. These calculations demonstrate that the wave function of the lowest $\frac{15}{2}^+$ level is

$$|\tfrac{15}{2}^+\rangle=\alpha\,|d_{3/2}^{-1}(f_{7/2}^2)^{T_p=1}_{J_p=6}\rangle-\beta\,|d_{3/2}^{-1}(f_{7/2}^2)^{T_p=0}_{J_p=7}\rangle+\ldots$$

with $\alpha^2+\beta^2\approx0.99$, $\alpha,\beta>0$. The magnitudes of α and β depend sensitively on the interaction used. To a good approximation one may disregard all orbits except for the $1d_{3/2}$ and $1f_{7/2}$ orbits. In

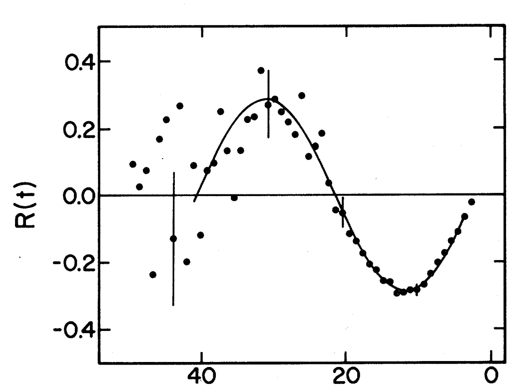

FIG. 1. Double ratio (defined in text) vs time. The smooth curve is a least-squares fit to the data.

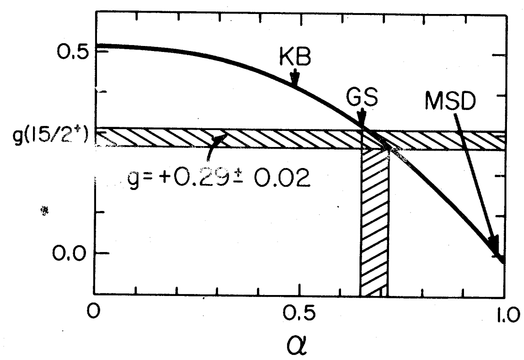

FIG. 2. $g(\frac{15}{2}^+)$ as a function of the amplitude of the component of the wave function with $T_p=1$.

Fig. 2 is plotted the g factor of the $\frac{15}{2}^+$ state as a function of α, including only these two states. Free nucleon g factors were used, since the configuration-mixing contributions were calculated to be very small and the mesonic effects are expected to be small in this mass region. Also shown in the figure are the values of α obtained from calculations employing bare Kuo-Brown (KB),[6] Gillet-Sanderson (GS),[7] and modified surface δ (MSD)[8] matrix elements for the particle-hole interaction.

A feature which emerges is the sensitivity of the calculated g factor to the relative admixtures of the states in which the $f_{7/2}$ pair is coupled to $T_p=1$ or $T_p=0$ as the two basis states have significantly different g factors. Although $d_{3/2}^{-1}(f_{7/2}^2)^{T_p=0}$ has an unperturbed energy 3 MeV lower than $d_{3/2}^{-1}(f_{7/2}^2)^{T_p=1}$, the particle-hole interaction is more attractive for those states in which the intermediate isospin is largest, and the $T_p=1$ state is lowered more. The isospin dependence of the particle-hole interaction is usually parametrized[9-11] by the constant b, which is the average separation of the $T_p=1$ and $T_p=0$ particle-hole centroids. The modified surface δ interaction (the parameters of which were chosen to fit levels in ^{40}Ca) has $b=2.84$ MeV. Thus one expects the MSD interaction to give a large admixture of the $d_{3/2}^{-1}(f_{7/2}^2)^{T_p=1}$ state into the lowest $\frac{15}{2}^+$ state. Indeed, one obtains $\alpha=0.982$, resulting in a g factor in disagreement with experiment. On the other hand, values of b of 1.42 and 1.54 MeV are obtained from the KB and GS interactions, respectively, and these give values of g much closer to the experiment. The nature of the wave function, and therefore the calculated magnetic moment, depends on the energies of the two $f_{7/2}^2$ states; the calculations above used the renormalized Kuo-Brown matrix elements[6] which underestimate the energy separation between the 7^+ $T_p=0$ and the 6^+ $T_p=1$ states by 0.3 MeV. If the experimental energies are used, the value of b necessary to reproduce the experimental g factor increases to about 1.85 MeV, still short of the usually quoted value.

The large value of b obtained from the ^{40}Ca spectra[12] and from stripping and pickup reactions may not be realistic because of the influence of configuration mixing and many-particle–many-hole states. The results presented here indicate that the g factor of the lowest $\frac{15}{2}^+$ level in ^{41}Ca provides a more sensitive test for the isospin character of the particle-hole interaction, and that interactions with $b=1.5$ to 1.8 can reproduce the measured g factor.

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[1]P. Gorodetsky, J. J. Kolata, J. W. Olness, A. R. Poletti, and E. K. Warburton, Phys. Rev. Lett. 31, 1067 (1973).

[2]K. P. Lieb, M. Uhrmacher, J. Dank, and A. M. Kleinfeld, Nucl. Phys. A223, 445 (1974).

[3]W. Bohne, H. Fuchs, K. Grabisch, H. Kluge, H. Morgenstern, H. Oeschler, and W. Schlegel, Nucl. Phys. A240, 171 (1975).

[4]L. E. Young, R. Brenn, and G. D. Sprouse, Nucl. Instrum. Methods 12, 87 (1974).

[5]M. Uhrmacher, A. Geldberg, F. Brandolini, A. M. Kleinfeld, and K. P. Lieb, Phys. Lett. 56B, 247 (1975).

[6]T. T. S. Kuo and G. E. Brown, Nucl. Phys. A114, 241 (1968).

[7]V. Gillet and E. A. Sanderson, Nucl. Phys. 54, 472 (1964).

[8]A. E. L. Dieperink, H. P. Leenhouts, and P. J. Brussard, Nucl. Phys. A116, 556 (1968).

[9]R. K. Bansal and J. B. French, Phys. Lett. 11, 145 (1964).

[10]L. Zamick, Phys. Lett. 19, 580 (1965).

[11]E. Osnes and T. T. S. Kuo, Phys. Lett. 47B, 430 (1973).

[12]D. Cline, M. J. A. deVoigt, P. Vold, O. Hansen, O. Nathan, and D. Sinclair, in *Proceedings of the International Conference on Nuclear Physics, Munich, 1973*, edited by J. de Boer and H. J. Mang (North-Holland, Amsterdam/American Elsevier, New York, 1973), p. 446; Nucl. Phys. A233, 91 (1974).