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III.h. $g(\pi h_{9/2}^2, J)$ Difference for 6_1^+ and 8_1^+ States in ^{210}Po

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(Presented by C. Signorini)

Some experimental data concerning the additivity of magnetic moments will be presented. For pure single particle states and $j-j$ coupling the magnetic moments of several nucleons add as their angular momenta. In terms of g-factors this can be written as follows:

$$g(j^n, J) = g(j) \tag{1}$$

$$g(j^n, J) = g(j^n, J') \tag{2}$$

Equation (1) has been checked in several regions. It holds fairly well around the closed core ^{208}Pb as summarized in the previous talk from Dr. Nagamiya.[1] However, in the Ca region deviations have been discussed by Dr. Nomura.[2] The aim of the present experiment was to check eq. (2) in the ^{210}Po nucleus where the 8^+ ($E_x = 1558$ keV, $T_{1/2} = 110$ ns) and the 6^+ ($E_x = 1473$ keV, $T_{1/2} = 41.4$ ns) states are expected to have fairly pure $(\pi 1h_{9/2})^2$ configurations. The two lifetimes are well suited to DPAC measurements. Moreover, the g-factors of the configurations $(\pi 1h_{9/2})^n$ with $n = 1, 2, 3, 4$ (see for example ref. 1) are eqaul within experimental errors ($\pm 1\%$). Before presenting the experimental results, the classical DPAC experiment that was used to measure the difference in g-factors will be discussed. If one assumes that only the 8^+ state is populated and aligned by a suitable nuclear reaction, the γ-ray angular correlation pattern in a magnetic field of the $4^+ - 2^+$ (246 keV), or $2^+ - 0^+$ (1181 keV) transitions (the $6^+ - 4^+$ transition could not be observed in the present experiment) is given by the relation:

$$W(\theta, t_8, t_6) = 1 + b_2 \cos 2(\theta - \omega_8 t_8 - \omega_6 t_6) \quad \text{with } t = t_8 + t_6 \,.$$

The quantities ω_8 and ω_6 (t_8 and t_6) are the Larmor frequencies (occupation times) for the 8^+ and 6^+ levels, respectively. The time dependent correlation is given by

$$\begin{aligned} N(\theta, t) &= N_0 \int_0^t \lambda_8 e^{-\lambda_8 t_8} \lambda_6 e^{-\lambda_6 (t-t_8)} W(\theta, t_8, t - t^8)\, dt_8. \qquad (3) \\ &= N_0(\lambda_6 \lambda_8/\Delta\lambda)[e^{-\lambda_8 t}\{1 + b_2 \cos\alpha \cos[2(\theta - \omega_8 t) - \alpha] \\ &\quad - e^{-\lambda_6 t}\{1 + b_2 \cos\alpha \cos[2(\theta - \omega_6 t) - \alpha]\}] \,, \end{aligned}$$

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where
$$\alpha = \mathrm{tg}^{-1}\frac{2\Delta\omega}{\Delta\lambda},\ \Delta\lambda = \lambda_6 - \lambda_8 \text{ and } \Delta\omega = \omega_6 - \omega_8 .$$

The measurement was performed at $E_\alpha = 24$ MeV with the reaction ^{208}Pb(α, 2n) ^{210}Po. The target was thick metallic ^{208}Pb placed in a field of 13.76 ± 0.07 kG (calibrated by the g-factor of ^{19}F $5/2^+$ state excited via the (α, α') reaction). Both the 1181 keV and 246 keV γ-rays were observed at $\pm 45°$ to the beam directions and the usual quantity

$$R(t) = \frac{N(-45°, t) - N(+45°, t)}{N(-45°, t) + N(+45°, t)}$$

has been extracted from the experimental data for each γ ray. From eq. (3) one gets:

$$R(t) = -b_2 \cos\alpha \left[\frac{\sin(\alpha + 2\omega_8 t)}{(1 - e^{-\Delta\lambda t})} + \frac{\sin(\alpha + 2\omega_6 t)}{(1 - e^{\Delta\lambda t})}\right]. \tag{4}$$

This expression shows a significant sensitivity to the Larmor frequency difference $\Delta\omega$ (or to the difference $g_6 - g_8$) through the phase α. In the measurement one has to take into account the direct feeding of the 6^+ state (47%) which is straight forward; it makes the formula only slightly more complex. A small beam bending correction was also made. The experimental data for the 1181-keV γ ray (background subtracted) are shown in the upper part of the figure. Several exploratory fittings procedures were carried out. (i) The population of the 8^+ and 6^+ states was varied within reasonable limits. (ii) An experimental amplitude damping was included. (iii) The decay curves were fit in different time regions. All of the values extracted for α (*i.e.* $\Delta\omega$) and ω_8 were found consistent. The Knight shift and diamagnetic correction have been estimated to total 0.0 ± 1.0%. The accepted results are:

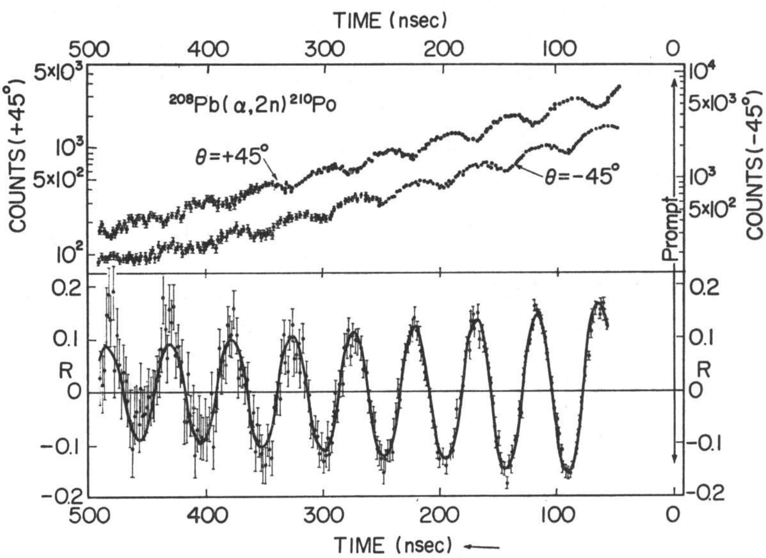

Fig. 1. The data $N(\theta, t)$ observed at $\theta_\gamma = \pm 45°$ are plotted after background substraction. In the lower part of the ratio $R(t)$ is shown along with a fit to the complete theoretical expression that included $\Delta\omega$ and ω_8 as variables.

$$\frac{g_6 - g_8}{g_8} = +(2.0 \pm 0.7)\%$$

$$g_8(\text{uncorrected}) = 0.909 \pm 0.007, \quad g_8(\text{corrected}) = 0.909 \pm 0.011$$

(see Table of Magnetic Moments in the Lead Region, S. Nagamiya)

$$g_8(\text{adopted value}) = 0.910 \pm 0.010$$

which lead to a $g_6 = 0.93 \pm 0.02.$

The experimental results cannot be explained only in terms of configuration mixing. From the wave functions of Kuo and Herling,[3] one gets a percentage difference in g factors of $+0.05\%$. On the other hand, the calculation based on core polarization reported in this conference[4] which gave-0.6%, and Migdal theory[5] with results between-0.5% and 0.0% were also unable to explain the experimental value. These measurements therefore give evidence that small violations to the additivity principle of a few percent can be expected. These results are not yet well understood theoretically.

References

1) S. Nagamiya, presented at this conference III.g.
2) T. Nomura, presented at this conference IV.e.
3) G. H. Herling and T. T. S. Kuo: Nuclear Phys. **A181** (1972) 113; T. T. S. Kuo and G. H. Herling: U. S. Naval Research Laboratory Report No. 2258, 1971.
4) I. Tonozuka, K. Sasaki and K. Harada, presented at this conference VI.c.
5) J. Speth, presented at this conference VI.d.

Discussion

S. Nagamiya (Tokyo): Can you say conclusively that the pattern shows an interference between the 6^+ and 8^+ state? Couldn't the effects be due to relaxation?

Signorini: We have analyzed the data with and without relaxation and the results are exactly the same.

Nagamiya: What is the relaxation time you obtained?

Signorini: I do not remember the exact figure, but it is something like several microseconds. During the analysis of the experimental data we tried to explore all possible fitting procedures and this has made our experimental error slightly bigger than quoted.

D. Riegel (Freie Univ., Berlin): Can you exclude contributions from higher excited states which also have comparable lifetime?

Signorini: The only canditate which can cause trouble is the 11^- state at 2.85 MeV ($t_{1/2}$=24 nsec). The population of this state at 25 MeV is small compared to the 8^+ state, as shown also by the early Yamazaki work. The best proof that it can be neglected is that the fit to the best part of the spin rotation pattern gives results consistent with the fit to the complete pattern. Among other higher excited states only the level at 4.37 MeV ($t_{1/2}$=93 nsec) is a possible candidate, for trouble, but its population at this energy can definitely be neglected.

R. M. STEFFEN (Purdue Univ.): Can the results be explained by assuming equal g factors and the presence of a weak electric quadrupole interaction? What worries me is that the effect looks like a strong magnetic interaction superimposed on a weak electric quadrupole interaction.

SIGNORINI: We have tried to put this relaxation time into our calculation.

D. A. SHIRLEY (Berkeley): I think that Professor Steffen is referring to static quadrupole interactions, which would give a frequency shift.

P. KIENLE (Munich): The essential information concerning the difference of the g factors is contained in the phase shift of the spin rotation pattern, which should not be changed directly by relaxation or quadrupole effects. Only differences in these effects in both states can affect the results.