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VI.c. M1 Core Polarizabilities of the 8^+ and 6^+ States in ^{210}Po

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(Presented by K. Harada)

M1 core polarizabilities of the low-lying excited states of ^{210}Po are studied on the basis of the first order perturbed calculation in the framework of the shell model. It is shown that the M1 core polarization of the type of $(h_{9/2}\, h_{11/2}^{-1})1^+$ in ^{210}Po is more blocked than in ^{209}Bi, and this blocking effect has a large J-dependence.

The nuclear magnetic moments and the M1 transition rates have been successfully calculated by taking into account the M1 core polarization.[1]

If one assumes the wave function of ^{210}Po to be a pure $(h_{9/2})^2$ configuration, the shell model additivity

$$g[^{210}\mathrm{Po}(h_{9/2})^2 J] = g[^{209}\mathrm{Bi}(h_{9/2})] \tag{1}$$

holds for $J = 8$, 6, 4 and 2. However, it is expected that the low-lying excited states of ^{210}Po will have different M1 core polarizabilities from that of the ground state of ^{209}Bi, because, in ^{210}Po the core polarization of the type of $(h_{9/2}\, h_{11/2}^{-1})1^+$ will be blocked to some extent by the presence of two protons in the $h_{9/2}$ orbit. Therefore, the above additivity seems not to hold strictly. The neutron $(i_{11/2}\, i_{13/2}^{-1})1^+$ polarization affects ^{209}Bi and ^{210}Po equally, and then the additivity is not disturbed by this type of the polarization.

In order to examine the magnitude of the blocking effect, we have calculated the first order corrections induced by the core polarization to the g-factors of the excited states of ^{210}Po.

Calculations were made by using the δ-interaction with $V_s(p-p) = -94.3$ MeVfm^3, $V_s(n-p) = -53.7$ MeVfm^3, and CAL, COP of Gillet *et al.*[2] as the central two-body force. In the δ-interaction, the potential values are determined from the following consideration. $V_s(p-p)$ is taken so as to give the best fit to the experimental data of the low-lying 2^+, 4^+, 6^+ and 8^+ levels of ^{210}Po by assumming the pure $(h_{9/2})^2$ configuration. The quantity $V_s(n-p)$ is fixed to reproduce the multiplet states $1^-, 2^-, \ldots, 10^-$ of ^{210}Bi under the $(h_{9/2})_\pi(i_{11/2})_\nu$ configuration, and the ratio of $V_t/V_s = 1.5$ is assummed. The single particle energy differences are taken as $\Delta E(h_{9/2} - h_{11/2}) = 5.6$ MeV, $\Delta E(i_{11/2} - i_{13/2}) = 5.86$ MeV, and g_l, g_s factors for the free nucleons are used.

Besides the $(h_{9/2})^2$ configuration, the $(h_{9/2}\, f_{7/2})$ proton configuration is also able to give the first order correction to the g-factor. Taking the mixing amplitudes given by ref. 3, we have calculated the corrections induced by the $(h_{9/2}\, f_{7/2})$ mixture.

The results obtained by the use of the δ-interaction are shown in Table I. Similar results were obtained for CAL and COP forces. The g-factor correction for the $J = 8^+$ state is very

Table I. First order corrections to the g-factors. Δg_p and Δg_n are the corrections caused by the excitations of protons and neutrons, respectively. Δg means the sum of Δg_p and Δg_n. δg is the correction calculated by taking into account the $(h_{9/2})^2$ and $(h_{9/2}\, f_{7/2})$ configurations.

		Δg_p	Δg_n	$\Delta g \equiv \Delta g_p + \Delta g_n$	δg
^{209}Bi	$(9/2^-)$	0.115	0.014	0.129	
^{210}Po	8^+	0.106	0.014	0.120	0.121
	6^+	0.098	0.014	0.112	0.115
	4^+	0.087	0.014	0.101	0.105
	2^+	0.061	0.014	0.075	0.084

close to that of ^{209}Bi. This is consistent with the fact that the blocking effect has not been observed experimentally for that state,[4] because of the large anomaly of the g_l-factor. However, it is found that the state with a lower spin has a larger blocking effect. In order to see the blocking effect more clearly we have calculated the quantity $P(J)$ defined by

$$P(J) \equiv \frac{g[^{210}\mathrm{Po}(8^+)] - g[^{210}\mathrm{Po}(J)]}{g[^{210}\mathrm{Po}(8^+)]}, \qquad (2)$$

since the effect of the anomaly of g_l may be canceled out in the numerator of eq. (2). The calculated J-dependence of the blocking effects are shown in Figs. 1 and 2. As seen from Table I and Fig. 2, the mixing of the $(h_{9/2}\, f_{7/2})$ configuration acts to reduce the blocking effect, but the mixing amplitude is not large enough to cancel out this effect.

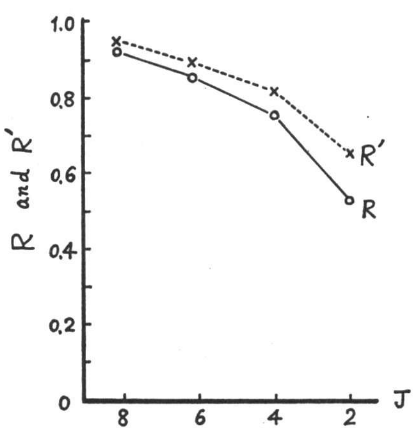

Fig. 1. The J-dependence of the ratio of $\Delta g(^{209}\mathrm{Bi}(J))$ to $\Delta g(^{210}\mathrm{Po}(J))$. Circular and cross points stand for R and R', respectively, where $R = \Delta g_p(^{210}\mathrm{Po})/\Delta g_p(^{209}\mathrm{Bi})$ and $R' = \delta g(^{210}\mathrm{Po})/\Delta g(^{209}\mathrm{Bi})$.

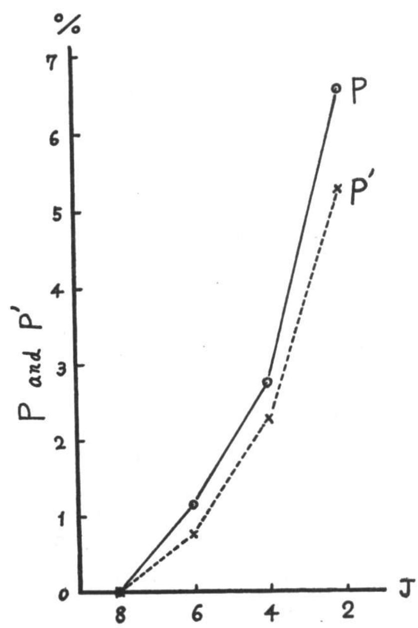

Fig. 2. The J-dependence of the $P(J)$ defined in eq. (2). In the calculation of $P'(J)$, $(h_{9/2})^2$ and $(h_{9/2}f_{7/2})$ configurations are taken into account.

The experimental value of the $P(J)$ has been reported in this conference[5)] and it is

$$P^{exp}(J = 6^+) = -2.2 \pm 0 7\% .$$

Unfortunatly, our result for ($J = 6^+$) disagrees with the experiment. It is supposed that this descrepancy may be resolved by taking into account the effects of the second order perturbation correction, of a possible J-dependence in the g_l-anomaly and further of the two-body L-S force.

For the purpose of a more close examination of the blocking effects, the following investigation was made. Under the assumption of the pure $(h_{9/2})^2$ configuration, the deviation of the g-factor from the Schmidt value can be written as follows.

$$\Delta g[^{210}\text{Po}(h_{9/2})^2, J] = \Delta g[^{209}\text{Bi}(h_{9/2})] + \Delta g_1(J) + \Delta g_2(J) . \tag{3}$$

The first term of the right hand side is the deviation from the Schmidt value of ^{209}Bi and this term is illustrated graphically by (a) + (b) in Fig. 3. The second term represents the blocking effect, and has the opposite sign to the first term. This second term graphically corresponds to (c) + (d) − (a) − (b) in Fig. 3.

The diagram (e) in Fig. 3 represents a characteristic process in the two particle system, which gives rise to the third term $\Delta g_2(J)$ in the eq. (3).

In the state $|J = M = 8\rangle$, the two protons are in the unique magnetic substate ($m_1 = 9/2$, $m_2 = 7/2$) in the $h_{9/2}$ orbit, and $\Delta g_2(J = 8)$ does not exist. The state $|J = M = 6\rangle$ has two possibilities, namely ($m_1 = 9/2$, $m_2 = 3/2$) and ($m_1 = 7/2$, $m_2 = 5/2$), and the matrix elements between these two states provide a finite $\Delta g_2(J = 6)$ correction.

Three terms in the eq. (3) are evaluated separately in term of the m-scheme. The results for the proton part are as follows in the case of the δ-interaction.

$$\begin{aligned}\Delta g[^{210}\text{Po}(h_{9/2})^2, J = 8] &= \Delta g[^{209}\text{Bi}(h_{9/2})] + \Delta g_1(8) + \Delta g_2(8)\\ &= 0.1146 - 0.0095 + 0.0000\\ &= 0.1051,\end{aligned}$$

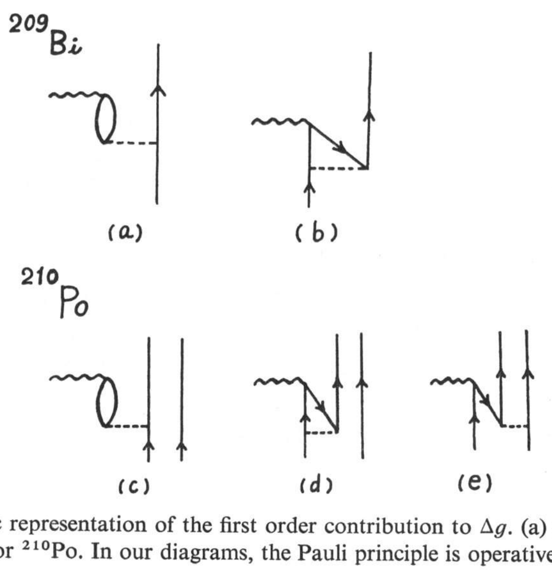

Fig. 3. Diagrammatic representation of the first order contribution to Δg. (a) and (b) are for ^{209}Bi, (c), (d) and (e) are for ^{210}Po. In our diagrams, the Pauli principle is operative in every stage.

Table II. The J-dependence of Δg, Δg_1, and Δg_2 expressed in eq. (3) for the δ-interaction.

$\Delta g[^{209}\mathrm{Bi}(\mathrm{h}_{9/2})] = 0.115$

J	$\Delta g[^{210}\mathrm{Po}(J)]$	$\Delta g(J)$	$\Delta g_1(J)$	$\Delta g_2(J)$
8	0.105	−0.010	−0.010	0.000
6	0.097	−0.018	−0.014	−0.003
4	0.085	−0.030	−0.020	−0.010
2	0.057	−0.057	−0.029	−0.028

$$\begin{aligned}\Delta g[^{210}\mathrm{Po}(\mathrm{h}_{9/2})^2, J = 6] &= \Delta g[^{209}\mathrm{Bi}(\mathrm{h}_{9/2})] + \Delta g_1(6) + \Delta g_2(6) \\ &= 0.1146 - 0.0142 - 0.0034 \\ &= 0.0970.\end{aligned}$$

The absolute value of $\Delta g_1(6)$ is larger than that of $\Delta g_1(8)$. This result suggests that the particle which occupies the substate with a smaller magnetic quantum number will lead to a larger blocking effect. It is ascertained that $\Delta g_2(6)$ acts to enhance the blocking effect. In the states $J = 4$ and 2, Δg_1 and Δg_2 have further large effects as seen from Table II.

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Discussion

M. NOMURA (Univ. of Tokyo): I have a comment concerning the g factors of Po and At. Using effective one- and two-body operators for the magnetic moment operator, we get a certain simple identity among the g factor of the ground state in ^{209}Bi, the g factors of the 6^+ and 8^+ states in ^{210}Po, and the g factor of the $21/2^-$ state in ^{211}At. If observed g factors are used, the identity, however, is not satisfied.

L. ZAMICK (Rutgers Univ.): I noticed that your Δg, as you point out, increases with J. Now the condition I set on my two body operator $U(12)$ $\boldsymbol{J}$ (see paper by L. Zamick, this conference) is that U_{12} is a constant; this means that Δg should be proportional to J. This seems to be very closely realized, as far as I can see, in your numbers. If what I say is true, then if you go to the three particle system $A = 211$ the M1 rate should very nearly vanish. It might be a good alternate test.