CORE POLARIZATION EFFECT ON THE MAGNETIC MOMENT OF THE $(h_{9/2}{}^2)$ 8^+ STATE OF ^{210}Po†

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The g factor of the $(h_{9/2}{}^2)$ 8^+ state of ^{210}Po has been determined to be 0.911 ± 0.010 by the pulsed generation of the aligned isomeric state in the reaction ^{208}Pb$(\alpha, 2n)$. This g factor agrees within 1 % with that of the $h_{9/2}$ ground state of ^{209}Bi, indicating that the $h_{9/2}$ proton carries the same renormalized anomalous magnetic moment both in ^{209}Bi and in ^{210}Po.

Recently an 8^+ isomeric state of the $h_{9/2}{}^2$ configuration has been identified in ^{210}Po (see the level structure in Fig. 1).[1,2] Owing to its almost pure shell-model configuration, one can examine how well the core polarization of ^{208}Pb by the $h_{9/2}$ proton persists from the one-particle state (^{209}Bi) to the two-particle state (^{210}Po). The $E2$ effective charge deduced from the observed $B(E2)$ values has already been discussed in Ref. 2. In this note we report on a g-factor measurement of the $(h_{9/2}{}^2)$ 8^+ state and discuss the effect of core polarizability by two protons in order to elucidate the nature of the anomalous magnetic moment of the $h_{9/2}$ state of ^{209}Bi. The experimental method is the same as that employed by Yamazaki and Matthias,[3] who determined the g factor of a three-particle isomer of ^{209}Po from the time-differential perturbed angular distribution in (α, xn) reactions. This work showed that a thick metallic target of Pb provides a perfect environment for the Po isomers populated in (α, xn) reactions. Preliminary measurements applied to ^{210}Po were reported earlier.[4]

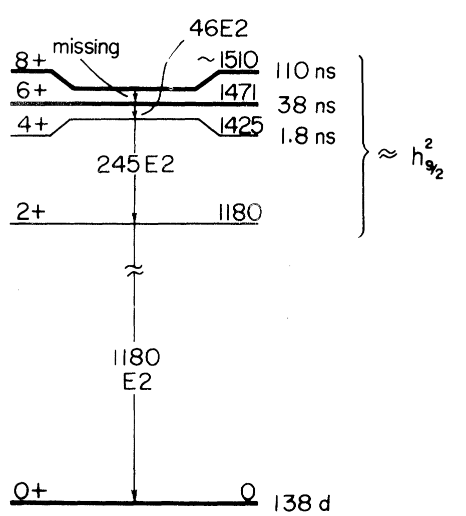

FIG. 1. The partial level scheme of $^{210}\mathrm{Po}_{126}$, as established in Refs. 1 and 2.

A ^{208}Pb target of 30-mg/cm^2-thick metallic foil was bombarded with 25-MeV α particles from the Institute of Physical and Chemical Research cyclotron. Gamma rays were detected with a $1\frac{1}{2}$-in.$\times 1\frac{1}{2}$-in.-diam NaI(Tl) counter placed at 135° to the beam direction. The time distributions of gamma rays were measured with use of the natural beam bursts of 132-nsec interval. Delayed gamma-ray spectra at this bombarding energy taken with a Ge(Li) detector exhibited only 245-keV ($4^+ \to 2^+$), 511-keV, and 1180-keV ($2^+ \to 0^+$) peaks. This demonstrated that a scintillation counter could be used in the present experiments. The population of the 24-nsec 11^- state is negligible at $E_\alpha = 25$ MeV, and therefore the delayed 245- and 1180-keV transitions are perturbed only through the 110-nsec 8^+ state and the 38-nsec 6^+ state. An external magnetic field of 10.93 kG (±0.5 %) was applied up and down perpendicularly to the beam-detector plane. The time spectra and the normalized differences for the 245-keV peak are shown in Fig. 2, from which a Larmor frequency of 48.44 ± 0.04 MHz was obtained. The Knight shift at the Po nucleus in metallic Pb is not known, but we can assume that it is not far from the Knight shift (1.47 %) observed for Pb nuclei in metallic Pb.[5] We thus obtain

$$g = 0.911 \pm 0.010.$$

The assigned error (1 %) includes possible experimental uncertainties. Because of the missing $8^+ \to 6^+$ and $6^+ \to 4^+$ gamma rays it was impossible to separate the Larmor precessions at the 8^+ and the 6^+ states. However, it can be assumed that both states have the same g factor, since they are of the same $h_{9/2}{}^2$ configuration. The

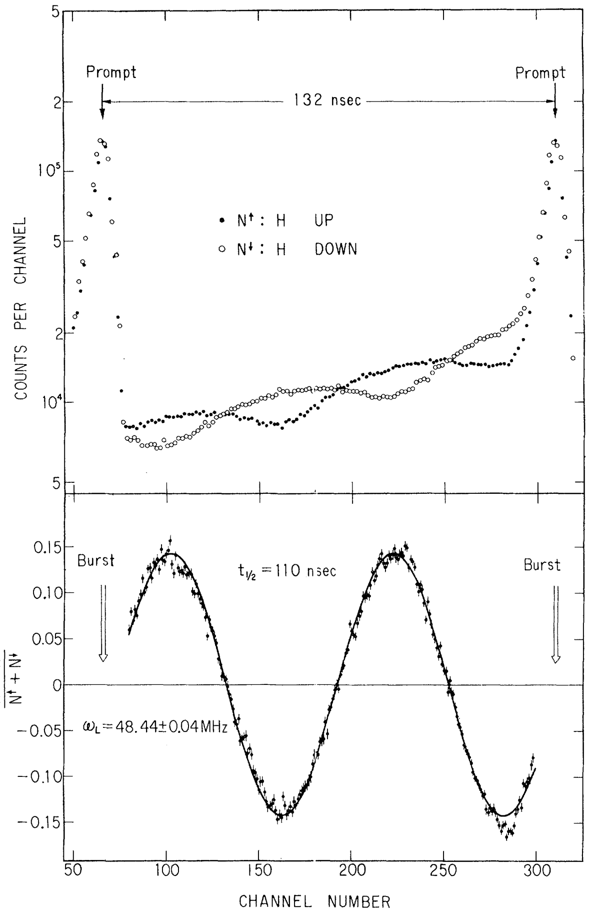

FIG. 2. Time spectra of the 245-keV γ radiation of ^{210}Po in the reaction $^{208}Pb(\alpha,2n)^{210}Po$ at $E_\alpha = 25$ MeV in the presence of an external magnetic field of 10.93 kG. The data were taken for opposite field directions applied perpendicularly to the beam-detector plane, showing the opposite direction of the Larmor precession. Normalized differences are plotted in the lower part of the figure including the result of a least-squares fit.

contribution of configurations other than $h_{9/2}{}^2$ is evaluated to be negligible.

It is well known that the $h_{9/2}$ ground state of ^{209}Bi exhibits an extremely anomalous magnetic moment.[6] A theoretical interpretation of this anomaly was given by Arima and Horie,[7] who took into account the particle($j = l - \frac{1}{2}$)-hole($j = l + \frac{1}{2}$) excitation of the ^{208}Pb core. This effect arises from a polarization of like particles in the core. A recent calculation of Blomqvist, Freed, and Zetterstrom[8] as well as that of Arima and Horie[7] could, however, account for only half of the observed anomaly by such a core polarization. The understanding of the real nature of this anomaly does not seem to be settled. It is therefore worthwhile to examine how the anomaly appears in the two-particle state.

Table I summarizes the present result together with that of ^{209}Bi. The single-particle estimate, g_{sp}, with the free-nucleon g_s factor of 5.5856 is given in column 4 and $\Delta g_{expt} \equiv g_{expt} - g_{sp}$ in column 5. If the same renormalization is associated with a state $|j\rangle$, then the shell-model additivity for one- and two-particle states, i.e.,

$$g(|j^2, J\rangle) = g(|j\rangle),$$

holds even for anomalous magnetic moments. The nearly equal g_{expt} in both ^{209}Bi and ^{210}Po indicates validity of the above identity within one percent.

It is suggested by Arima[9] that the core polarization can be blocked out by the presence of particles in the $h_{9/2}$ orbit. If the $(h_{11/2}{}^{-1}h_{9/2})\ 1^+$ polarization is assumed to be fully responsible for the anomalous magnetic moment of ^{209}Bi, then we would expect some blocking of such a core polarization by the presence of particles in the $h_{9/2}$ orbit. Out of ten states in the $h_{9/2}$ orbital, the number of vacancies is nine in ^{209}Bi and eight in ^{210}Po. Therefore, we would obtain

$$\Delta g(^{210}Po)/\Delta g(^{209}Bi) \sim 0.90,$$

while

$$\Delta g_{expt}(^{210}Po)/\Delta g_{expt}(^{209}Bi) = 1.01 \pm 0.03.$$

This comparison implies that the $(h_{11/2}{}^{-1}h_{9/2})\ 1^+$ excitation may not be the sole contributor to the anomalous magnetic moment of ^{209}Bi. This is compatible with the shell-model calculations[7,8] which could account for only half of the total anomaly. The remainder is unexplained. This raises a question as to whether g_l is really equal

Table I. Summary of the anomalous magnetic moments in ^{209}Bi and ^{210}Po.

Nucleus	State	g_{expt}	g_{sp}	Δg_{expt}	$(\Delta g_s{}^{eff}/g_s{}^{free})_{expt}$
$_{83}{}^{209}Bi_{126}$	$h_{9/2}$	0.907	0.583	0.323	−0.637
$_{84}{}^{210}Po_{126}$	$(h_{9/2}{}^2)\ 8^+$	0.911 ± 0.010	0.583	0.328 ± 0.010	−0.646 ± 0.020

to 1 or not. The possibility was discussed in Ref. 4 that g_l could be determined from the g factor of the $(h_{9/2}i_{13/2})$ 11^- state of ^{210}Po, but a precise determination to elucidate this problem is yet to be done.

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THRESHOLD PHOTONEUTRON CROSS SECTION FOR Mg^{25} AND ISOBARIC ANALOGS OF Na^{25} †

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The photoneutron cross section for Mg^{25} has been measured from 30 to 2000 keV above threshold. The locations of the isobaric analogs of the ground and first excited states of Na^{25} have been assigned and lower limits for their neutron-decay widths have been determined.

In many nuclei, the region of excitation just above the photoneutron threshold contains the isobaric analogs of low-lying states in the nucleus whose ground-state isospin is one unit higher than that of the nucleus under study. In such cases, the threshold photoneutron technique[1,2] is a useful tool for (1) locating precisely the excitation energies of the analog states, (2) helping to identify their spins and parities, and (3) measuring their neutron or ground-state radiative transition widths. The first of these items results from the precise energy resolution of neutron time-of-flight spectroscopy; the second from use of the electromagnetic selection rules; and the third from the cross-section measurements themselves. When the width for neutron emission is large compared with the width for proton and gamma-ray decay, then the radiative width is determined, independent of the experimental resolution, from the area under the resonance. When it is not, then in general the level will not be resolved completely; in this case, a prior knowledge of the radiative width, together with the threshold photoneutron cross section, yields a lower limit for the neutron width. The excitation energies of the analog levels give a direct measure of the Coulomb-energy radius of the nucleus, and can be used, in the case of isospin quartets, to predict nuclear masses. The radiative transition widths can be compared with theoretical predictions of the radiation width computed from a knowledge of both the target and parent ground-state wave functions, and also can be used to deduce the beta-decay matrix elements of the parent states. The neutron widths can be compared with the corresponding neutron widths for ordinary states (states with the same isospin as the ground state) to give the isospin mixing, or isospin purity, of the analog states.

This paper reports a measurement of the threshold photoneutron cross section for Mg^{25}. The data presented here were taken at an angle of 135° between the neutron-flight tube and the incident-photon beam. The bremsstrahlung target was yttrium, and the incident electron-beam energy was 11.0 MeV. The sample consisted of