we expect this ratio to be ≈ 8, in rather good agreement with the measured value.

In conclusion, we find that the magnitude of the cross sections for the reaction $^{48}Ca(^{16}O, ^{15}C)^{49}Ti$ leading to several levels in ^{49}Ti are comparable to the ones observed for few-nucleon transfers. The experimental results seem to imply that, in general, it may not be possible to ignore the contributions to cross sections originating from the more complex transfer processes. It is hoped that the present data will be used to test reaction calculations which include such processes.

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Blocking Effect of the $M1$ Core Polarization Studied from the g Factor of the 8^+ State in ^{214}Ra

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The g factor of the 8^+ state of ^{214}Ra ($T_{1/2}=67$ μsec) has been determined to be $g=0.88\pm0.01$ by the in-beam γ-ray NMR method. The blocking effect of the $[\pi_{11/2}^{-1}\pi h_{9/2}]$-$1^+$-type core polarization on g factors of $\pi h_{9/2}^{\,n}$ states is investigated. The observed blocking effect is much less than the theoretical expectation, implying that the correction to the g factor of the $\pi h_{9/2}$ state because of $[\pi h_{11/2}^{-1}\pi h_{9/2}]$ 1^+ excitation is comparable with that because of $[\nu i_{13/2}^{-1}\nu i_{11/2}]$ 1^+.

Until a few years ago it had been one of the shell-model puzzles why the magnetic moment of the $\pi h_{9/2}$ state of ^{209}Bi deviates largely from the Schmidt value. Recently it was found[1] that half the deviation is due to the anomaly in the proton orbital g factor ($\delta g_l \simeq 0.1$). With this anomaly the puzzle seemed to be solved, since the other half of the deviation had already been explained by the $M1$ core polarization theory.[2-4] From the experimental point of view, however, questions still remain as to the mechanism of the $M1$ core polarization.

The $M1$ spin polarization of the ^{208}Pb core arises mainly from the following one-particle, one-hole excitations: $[\pi h_{11/2}{}^{-1}\pi h_{9/2}]\ 1^+$ and $[\nu i_{13/2}{}^{-1}\nu i_{11/2}]\ 1^+$. One way to study quantitatively the effect of these excitations on the g factor is to measure their blocking effect.[5] The probability of making such particle-hole pairs is proportional to the number of vacancy sites in the $\pi h_{9/2}$ orbital (or $\nu i_{11/2}$ orbital). Therefore, the g factor for the $\pi h_{9/2}{}^n$ state is expressed as

$$g(\pi h_{9/2}{}^n) = g_{\text{Schmidt}}(\pi h_{9/2}) + \tfrac{12}{11}\delta g_l + [(9-n)/8]\,\delta g_{\text{core}}(\pi h) + \delta g_{\text{core}}(\nu i), \tag{1}$$

where $\delta g_{\text{core}}(\pi h)$ is the effect of the $[\pi h_{11/2}{}^{-1}\pi h_{9/2}]\ 1^+$ excitation on the g factor of ^{209}Bi and so on. If we look at the variation of the g factors for the $\pi h_{9/2}{}^n$ states as a function of n, we will be able to deduce $\delta g(\pi h)$.

Recently Maier *et al.*[6] found a 67-μsec 8^+ isomeric state in $^{214}_{88}\text{Ra}_{126}$. The main configuration of this state is $\pi h_{9/2}{}^6$ which is suitable to study the blocking effect. In this Letter we report the g-factor determination of this state and discuss the mechanism of the $M1$ core polarization in the ^{208}Pb region.

The method employed was the in-beam γ-ray NMR method.[7] The 8^+ isomeric state was populated via the reaction ^{206}Pb(^{12}C, $4n$)^{214}Ra with the 90-MeV ^{12}C beam from the Institute of Physical and Chemical Research cyclotron. A metallic foil of enriched ^{206}Pb was used as the target. A preliminary spectroscopic study, using a 30-cm^3 Ge(Li) detector, revealed a clean peak of the 1381-keV $2^+\to0^+$ transition. Therefore, the g-factor measurement was carried out with 4.5 cm $\times$4.5 cm NaI(Tl) detectors placed at 0° and 90° with respect to the beam direction. A static external magnetic field (H_0) was applied parallel to the beam direction, and an rf field ($2H_1$) with fixed frequency was applied perpendicular to H_0. The measurements were done at two different temperatures, 270°C and room temperature.

Typical NMR patterns at room temperature are shown in Fig. 1. Solid curves are those fitted by the theoretical function of Matthias *et al.*[7] At the beginning of the experiment it was anticipated that the electric field gradients due to radiation damage might cause an appreciable relaxation of the spin orientation of the 8^+ state during the period of the lifetime.[8] To avoid such a relaxation we first tried to heat the target up to 270°C (just below the melting point). However, it turned out that the observed NMR patterns at room temperature were cleaner than those at 270°C. This implies that the quadrupole relaxation due to radiation damage is negligible in the present case, and a possible relaxation is only the magnetic relaxation due to conduction electrons (Korringa type).[9] One of the reasons may be that the quadrupole moment of the 8^+ state is expected to be very small [in fact, $B(E2;\ 8^+\to6^+)$ is very small], since the protons in ^{214}Ra fill half the $h_{9/2}$ orbital.

At room temperature the NMR pattern disappeared at $H_1=2.7$ G (but not at $H_1=5.5$ G). From this fact the effective relaxation time, $\tau_{\text{eff}}=1/\omega_1=\hbar/g\mu_N H_1$, was estimated to be $\tau_{\text{eff}}\simeq44\pm14$ μsec. This τ_{eff} is related both to the lifetime of the state, τ, and to the conventional longitudinal relaxation time T_1 through the equation[10]

$$\frac{1}{\tau_{\text{eff}}}=\frac{1}{\tau}+\frac{3}{T_1}. \tag{2}$$

Thus, we obtain $T_1\simeq240^{+220}_{-80}$ μsec at room temperature. Detailed discussions of the relaxation process will be given elsewhere.

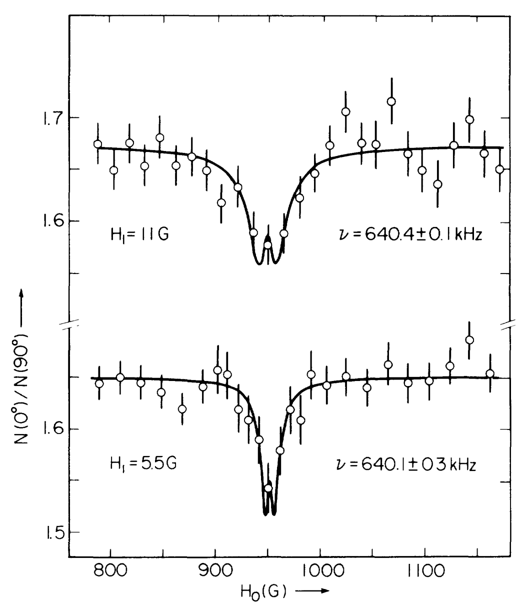

FIG. 1. Typical NMR patterns for the 67-μsec 8^+ state of ^{214}Ra populated via the reaction ^{206}Pb(^{12}C, $4n$)^{214}Ra in a metallic lead target at room temperature. The ratio of the counting rates of two detectors placed at 0° and 90° was taken as a function of the longitudinal external field. The solid curves are the theoretical curves (Ref. 7) best fitted to the experimental points.

The g factor (uncorrected value) obtained is

$$g_{\text{uncorr}}(8^+;\,^{214}\text{Ra}) = 0.881 \pm 0.003. \tag{3}$$

The diamagnetic correction for a Ra atom estimated from the calculation by Feiock and Johnson[11] is $\sigma = -2.0\%$, while the Knight shift (Δ_K) of Ra in Pb has not been known. We have estimated Δ_K by the following two ways. One is from the observed relaxation time. If the observed T_1 is mainly due to conduction electrons, we have $\Delta_K \simeq 1.2\%$ from the Korringa relation.[9] The other way is from the extrapolation of the known Δ_K data for alkali and alkali-earth metals.[12] This yields $\Delta_K \simeq 2.8\%$.[13] Therefore, the reasonable value is $\Delta_K \simeq (2\pm1)\%$ which nearly cancels the diamagnetic correction. After the corrections for the Knight shift and diamagnetism we obtain

$$g_{\text{corr}}(8^+;\,^{214}\text{Ra}) = 0.88 \pm 0.01. \tag{4}$$

The g factors of n-proton states outside the ^{208}Pb core (where main configurations are believed to be $\pi h_{9/2}{}^n$) are summarized in Fig. 2. The g factor of the 8^+ state of ^{214}Ra is 3% smaller than those of the $\frac{9}{2}^-$ state of ^{209}Bi and of the 8^+ state of ^{210}Po, clearly showing the blocking effect of the $[\pi h_{11/2}{}^{-1}\pi h_{9/2}]$-$1^+$-type core polarization. If all the states in Fig. 2 have pure configurations of $\pi h_{9/2}{}^n$, then the observed gradient readily gives $\delta g_{\text{core}}(\pi h) = 0.05 \pm 0.01$ from Eq. (1). This value is only one third of the theoretical value, $[\delta g_{\text{core}}(\pi h)]_{\text{theory}} = 0.12$–$0.16$.[2-4]

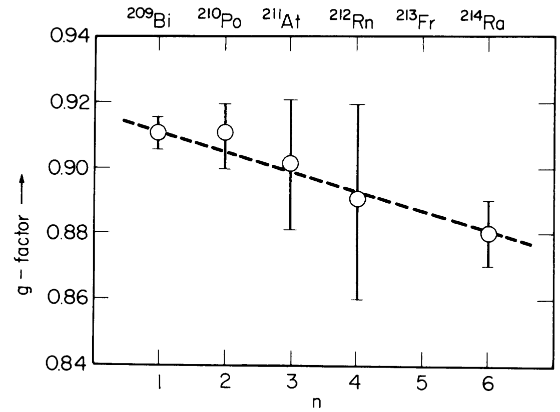

FIG. 2. The observed g factors of the n-proton states of $h_{9/2}{}^n I$ character outside of the ^{208}Pb core. The previous data (the $\frac{9}{2}^-$ state of ^{209}Bi, the 8^+ state of ^{210}Po, the $\frac{21}{2}^-$ state of ^{211}At, and the 8^+ state of ^{212}Rn) are taken from Ref. 14. The dotted line represents the experimental points.

The above treatment to deduce $\delta g_{\text{core}}(\pi h)$ is too crude, since it is expected that the 8^+ state of ^{214}Ra involves the $\pi f_{7/2}$ and $\pi i_{13/2}$ components because these orbitals lie just above the $\pi h_{9/2}$ orbital. The wave function of the state may be written as

$$|8^+;\,^{214}\text{Ra}) = (1-\textstyle\sum|\alpha_i|^2)^{1/2}|h_{9/2}{}^6;\,8^+) + \alpha_1|[h_{9/2}{}^4]8^+\otimes[j^2]0^+;\,8^+) + \alpha_2|h_{9/2}{}^5 f_{7/2};\,8^+) + \alpha_3|[h_{9/2}{}^4]J_1\otimes[j^2]J_2;\,8^+), \tag{5}$$

where $j = f_{7/2}$ or $i_{13/2}$. Among the three terms added to the $\pi h_{9/2}{}^6$ component, the first term (α_1 component), which is the $n=4$ component, makes the occupation number of protons in the $\pi h_{9/2}$ orbital smaller than 6. Using the pairing energy of $G = 0.11$–0.15 MeV, we estimated that the effective occupation number, n_{eff}, of protons in the $\pi h_{9/2}$ orbital for the 8^+ state of ^{214}Ra is ~4.3–4.9. Using the notion of n_{eff}, we can write down the g factor of the 8^+ state of ^{214}Ra as

$$g(8^+;\,^{214}\text{Ra}) = g(\pi h_{9/2}{}^{n_{\text{eff}}}) + |\alpha_2|^2\Delta g_2 + |\alpha_3|^2\Delta g_3, \tag{6}$$

where $\Delta g_2 = g([\pi h_{9/2}{}^5\pi f_{7/2}]\ 8^+) - g(\pi h_{9/2}{}^{n_{\text{eff}}})$ and so on. Because the g factors of the $\pi f_{7/2}$ and $\pi i_{13/2}$ states are larger than that of the $\pi h_{9/2}$ state, Δg_2 and Δg_3 are always positive. Arita[15] calculated the coefficients α_2 and α_3, and obtained $|\alpha_2|^2\Delta g_2 + |\alpha_3|^2\Delta g_3 = 0.011$. Thus we obtain,

$$g(\pi h_{9/2}{}^{n_{\text{eff}}}) = 0.87 \pm 0.01 \quad (n_{\text{eff}} \cong 5). \tag{7}$$

Using this value in Eq. (1) leads to

$$\delta g_{\text{core}}(\pi h) \simeq 0.09, \tag{8}$$

where to deduce this value the present result (7) together with the g factors of the $\frac{9}{2}^-$ state of ^{209}Bi and the 8^+ state of ^{210}Po have been used. This value of $\delta g_{\text{core}}(\pi h)$ is, however, still smaller than the theoretical value.[2-4]

Since the value of δg_l is known to be 0.1–0.15,[1] Eq. (1) gives $\delta g_{\text{core}}(\nu i) = 0.13$–$0.07$. This means that

$$\delta g_{\text{core}}(\pi h) \simeq \delta g_{\text{core}}(\nu i) \simeq 0.1. \tag{9}$$

So far the theoretical calculations[2-4] always showed that $\delta g_{\text{core}}(\pi h)$ plays a dominant role for the magnetic moment of the $\pi h_{9/2}$ state of ^{209}Bi, while $\delta g_{\text{core}}(\nu i)$ does not. Contrary to this prediction, our conclusion is that the effect of the like-particle excitation, $\delta g_{\rm core}(\pi h)$, is comparable with that of the unlike-particle excitation, $\delta g_{\rm core}(\nu i)$. In other words, the $(\sigma\cdot\sigma)$ $(\tau\cdot\tau)$ force plays an essential role in the magnetic core polarization. Arita[15] made calculations using various forces and showed that the Rosenfeld force reproduces the experiment when the force range becomes long.

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10-μm Heterodyne Stellar Interferometer*

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A spatial interferometer for 10-μm wavelength which uses two independent telescopes separated by 5.5 m, heterodyne detection of the infrared radiation, and path equalization by a variable-length rf cable, has given interference fringes from radiation of the planet Mercury. Continuous fringe observations during 4000 sec indicate remarkable stability in the optical-path difference through the atmosphere and the two telescopes, fluctuations between 20-sec averages being about $\frac{1}{6}$ of the 10-μm wavelength.

A two-element spatial interferometer, operating with two 10-μm-wavelength heterodyne receivers on a baseline of 5.5 m, has been constructed and successfully tested on an astronomical source. In purpose, the apparatus is similar to Michelson's stellar interferometer in that it provides very high angular resolution of infrared stars and other localized sources; in construction, however, the instrument more closely resembles a long-baseline microwave interferometer.[1,2]

Presently, the interferometer uses the two in-