Nuclear magnetic moments of 44.3 s $^{107}Ag^m$ and 39.8 s $^{109}Ag^m$

R. Eder, E. Hagn, and E. Zech
Physik-Department, Technische Universität München, D-8046 Garching, Federal Republic of Germany
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The magnetic hyperfine splitting frequencies $\nu_M = |g\mu_N B_{hf}/h|$ of $^{107}Ag^m$ ($E=93$ keV; $I^\pi=\frac{7}{2}^+$; $T_{1/2}=44.3$ s) and $^{109}Ag^m$ ($E=88$ keV; $I^\pi=\frac{7}{2}^+$; $T_{1/2}=39.8$ s) as dilute impurities in Fe and Ni have been measured with nuclear magnetic resonance on oriented nuclei at temperatures of ~ 10 mK as $\nu_M(^{107}Ag^m Fe)=428.09(9)$ MHz, $\nu_M(^{107}Ag^m Ni)=103.19(12)$ MHz, and $\nu_M(^{109}Ag^m Ni)=103.26(4)$ MHz. With the magnetic hyperfine fields, $B_{hf}(AgFe)=-446.9(5)$ kG, $B_{hf}(AgNi)=-107.8(2)$ kG, the magnetic moments of $^{107}Ag^m$ and $^{109}Ag^m$ are deduced to be $(+)4.398(5)\ \mu_N$ and $(+)4.400(6)\ \mu_N$, respectively. The reorientation of short-lived nuclear states due to spin lattice relaxation is discussed.

I. INTRODUCTION

In the odd-A isotopes ^{107}Ag and ^{109}Ag, isomeric states with $I^\pi=\frac{7}{2}^+$ and half-lives of 44.3 and 39.8 s exist which are populated in the decays of 6.5 h ^{107}Cd and 13.4 h ^{109}Pd.[1] The magnetic moment of $^{109}Ag^m$ has already been known from an atomic beam magnetic resonance (ABMR) measurement,[2] $\mu=(+)4.27(13)\ \mu_N$, the accuracy being limited because of the short half-life. For $^{107}Ag^m$ no data could be found in the literature. The nuclear magnetic resonance on oriented nuclei (NMR-ON) technique (nuclear magnetic resonance detected via the anisotropy of radiation[3]) is well suited for a precise measurement of the magnetic hyperfine splitting of isomers with such half-lives, if they are populated in the decay of longer lived isotopes. Moreover, the absolute values of the γ anisotropies following the decay of reorienting intermediate states are of interest, as they provide independent information on the spin-lattice relaxation mechanism. This had already been proposed by Stone *et al.*,[4] who studied the γ anisotropy of $^{109}Ag^m Fe$ at temperatures down to ~ 10 mK. Because of the lack of knowledge on the magnetic hyperfine splitting, Stone *et al.*[4] could not draw unique conclusions on the spin-lattice relaxation. Meanwhile, however, the spin-lattice relaxation of $^{110}Ag^m$ in Fe and Ni was studied extensively by Rueter *et al.*[5] The Korringa constants C_K of Ag*Fe* and Ag*Ni* derived by Rueter *et al.*[5] from time-dependent NMR-ON measurements can be compared with the Korringa constants derived in the present work from the absolute values of γ anisotropies. Thus the results of two independent methods can be used as a test of whether the present understanding of the spin-lattice relaxation of dilute impurities in ferromagnetic metals is complete.

In this paper we report on NMR-ON measurements on $^{107}Ag^m Fe$, $^{107}Ag^m Ni$, and $^{109}Ag^m Ni$, from which precise values for the magnetic moments of $^{107}Ag^m$ and $^{109}Ag^m$ are derived. In addition, the γ anisotropies are interpreted as due to incomplete reorientation in the isomeric states, from which Korringa constants for the spin-lattice relaxation are deduced.

II. EXPERIMENTAL PROCEDURE

A. The decay schemes

The decay schemes of $^{107}Ag^m$ (Ref. 6) and $^{109}Ag^m$ (Ref. 7) are shown in Fig. 1. In both decays the $\frac{7}{2}^+ \rightarrow \frac{1}{2}^-$ $E3$ transition is highly converted, the absolute γ intensities being 4.6% and 3.6% for $^{107}Ag^m$ and $^{109}Ag^m$, respectively. $^{109}Ag^m$ is populated in the decay of ^{109}Pd and ^{109}Cd. Stone *et al.*[4] performed their nuclear orientation experiment on $^{109}Ag^m Fe$ with ^{109}Cd as the parent state, while for the present work ^{109}Pd has been used. $^{107}Ag^m$ is populated only via the EC β^+ decay of ^{107}Cd.

B. Nuclear orientation (NO) and nuclear magnetic resonance (NMR) on oriented nuclei (NMR-ON)

The angular distribution of γ rays emitted in the decay of oriented nuclei is given by[8]

$$W(\theta)=1+\sum_k B_k A_k P_k(\cos\theta) Q_k \ . \qquad (1)$$

The parameters A_k are products of the normally used angular correlation coefficients U_k and F_k, which depend on spins and multipolarities of the decay cascade. The

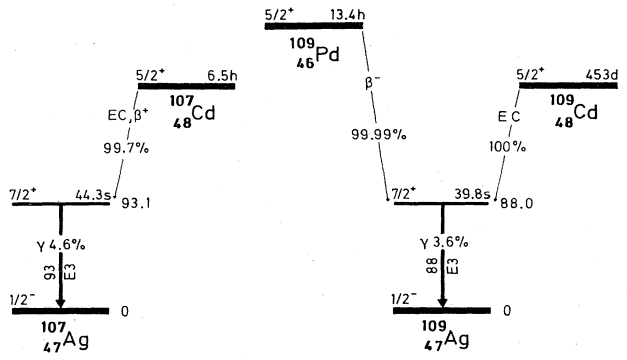

FIG. 1. Simplified decay schemes according to Ref. 1.

$P_k(\cos\theta)$ are Legendre polynomials, θ being the angle between the quantization axis and the direction of observation, and Q_k are solid angle correction coefficients. The B_k describe the degree of orientation; they depend on the sublevel population probabilities a_m, which for the case of thermal equilibrium are given by a Boltzmann distribution. It is convenient to introduce the often used ratio

$$\epsilon(T)=\frac{W(0,T)}{W(90,T)}-1 . \tag{2}$$

In the present case, the sublevel populations of the isomeric $\frac{7}{2}^+$ states cannot be described by a Boltzmann distribution, as the half-lives are of the same order of magnitude as the spin-lattice relaxation time T_1', which means that the isomeric states decay before they reach equilibrium. The effect of an incomplete reorientation in an intermediate state on the sublevel populations and thus on the γ anisotropy can be calculated as follows: The starting point is the set of rate equations for the time-dependent sublevel population probabilities $a_m(t)$ of the nuclei in the isomeric $\frac{7}{2}^+$ state:

$$\frac{d}{dt}a_m(t)=\sum_n \{W_{nm}a_n(t)-W_{mn}a_m(t)\} . \tag{3}$$

Here W_{mn} are the transition probabilities from state $|\, m\,\rangle$ to state $|\, n\,\rangle$. The W_{mn} for magnetic spin-lattice relaxation are given explicitly in Ref. 9; they depend on the Korringa constant C_K and on the temperature T. The solution of Eq. (3) can be written as

$$a_m(t)=\sum_{nl} C_{mnl}\exp(-\lambda_l t)a_n(0) , \tag{4}$$

where C_{mnl} and λ_l are constants which are found by diagonalization of the matrix of Eq. (3), and which depend on C_K and T. The $a_n(0)$ represent the initial condition for the relaxation. They are calculated easily from the sublevel populations of the parent state given by a Boltzmann distribution. (There is no ambiguity in the β decays, which are of allowed Gamow-Teller type.) Average population probabilities $\bar{a}_m$ are calculated by integration over the lifetime τ of the isomeric state,

$$\begin{aligned}\bar{a}_m&=\frac{1}{\tau}\int_0^\infty a_m(t)\exp(-t/\tau)dt\\&=\sum_{nl} C_{mnl}\frac{1}{1+\lambda_l\tau}a_n(0) ,\end{aligned} \tag{5}$$

from which effective orientation parameters B_k and effective γ anisotropies $\overline{W(\theta)}$ are found, which depend on the temperature T of the lattice and on the Korringa constant C_K. Such model calculations can be used to deduce C_K from the measured γ anisotropies. A simultaneous determination of C_K and the magnetic hyperfine splitting frequency

$$\nu_M=|\, g\mu_N B_{hf}/h\,| \tag{6}$$

from the temperature dependence of the γ anisotropy will contain severe uncertainties. Therefore it is more appropriate to determine ν_M with the NMR-ON method, which is independent of the degree of reorientation in the intermediate state, as a radio-frequency-induced change of the sublevel populations is detected via the corresponding change of the γ anisotropy, as long as the absolute value of the γ anisotropy is sufficiently large that the resonant change can be detected with statistical significance. For a pure magnetic hyperfine interaction the resonance condition is given by

$$\begin{aligned}&\nu=\nu_M+b(1+K)B_0 ,\\&b=|\, g\mu_N/h\,|\,\mathrm{sgn}(B_{hf}) ,\end{aligned} \tag{7}$$

where B_{hf} is the magnetic hyperfine field, K is the Knight shift parameter, and B_0 is the external magnetic field.

III. EXPERIMENTAL DETAILS

Samples of ^{107}Cd in Fe and Ni were prepared with the recoil-implantation technique. A sandwich target consisting of 16 ^{106}Pd foils (isotopic enrichment 98.5%; thickness 1.7 mg/cm^2), each followed by a 1.6 mg/cm^2 Fe (or Ni) foil (purity 99.999%), was irradiated with 43 MeV α particles at the cyclotron in Karlsruhe for 6—8 h with an average current of 2 μA. The ^{107}Cd nuclei which are produced via the ^{106}Pd(α,3n) compound reaction (estimated cross section $\sim$1000 mb) have a kinetic energy of $\sim$1.5 MeV, which has the consequence that the ^{107}Cd nuclei which are produced in the rear $\sim$0.15 μm surface layers of the Pd foils leave the target foils. These nuclei are implanted homogeneously into the Fe/Ni catcher foils within a thickness of $\sim$0.15 μm. The homogeneous distribution of the impurity nuclei in the catcher foils is a decisive advantage in comparison to mass-separator implantation, where the implantation depth is in general smaller by a factor of $\sim$10, and, in addition, the implanted nuclei are not distributed homogeneously. After the irradiations, the most active parts (2×3 mm^2) of the Fe/Ni foils were cut out and soldered to the Cu coldfinger of an adiabatic demagnetization cryostat. These foils had not been annealed after the irradiations, first, because of the small half-life of ^{107}Cd, second, as the annealing properties of Cd in Fe and Ni are not well known, and third, as the NMR-ON technique has been shown to be very applicable to unannealed recoil-implantation-prepared samples for most elements.

Samples of ^{109}Cd in Fe and Ni could in principle be prepared in the same way by using enriched ^{108}Pd as the target. However, the activity which can be obtained for a given irradiation time is inversely proportional to the half-life of the isotope. Thus the activity of ^{109}Cd ($T_{1/2}$=453 d) obtained with an irradiation time of 8 h was expected to be too small to perform an NMR-ON experiment within a reasonable measurement time. Therefore ^{109}Pd, which can easily be prepared by irradiation with thermal neutrons, was chosen as the mother isotope for $^{109}Ag^m$. As the solubility of Pd in Fe is limited to $\lesssim10^{-2}$, while Pd is soluble in Ni between 0 and 80 at. % Pd,[10] Ni was chosen as the host lattice.

Samples of ^{109}Pd*Ni* were prepared in the following way: ^{108}Pd (isotopic enrichment 98.9%) was melted with highly pure Ni (purity 99.999%) in an electron beam furnace, with a Pd concentration of 0.5 at. %. In a further melting step the alloy was diluted with pure Ni to a final Pd con-

centration of 0.1 at. %. Foils with a thickness of 1.6 mg/cm^2 were obtained by coldrolling. Four foils with an area of 4×6 mm^2 were neutron-irradiated at the Munich research reactor FRM for 20 h in a neutron flux of 2×10^{13} n/cm^2 s. After the irradiation the foils were annealed for ~3 h at ~650 °C in a vacuum ($<10^{-7}$ Torr), cooled down to room temperature in ~3 h, and GaIn-soldered to the coldfinger of the cryostat.

All samples were cooled down to $T\sim10$ mK and polarized with an external magnetic field $B_0\leq4$ kG. The radio frequency (rf) field was applied with a one-turn rf coil; it was 1 kHz frequency modulated with a total band width of 0.2—2 MHz. The center frequency was varied in steps of 0.05—1 MHz over the resonance region. The γ radiation was detected with two 80 cm^3 coaxial Ge(Li) detectors placed at 0° and 90° with respect to B_0. γ-ray spectra were accumulated for 200 s at fixed frequencies. After the accumulation the intensities of the 88- and 93-keV transitions and of some thermometer lines were determined with least-squares fitting routines. Always an even number of single resonance spectra were added which had been measured with increasing and decreasing center frequency, in order to avoid possible shifts of the (effective) resonance centers due to the finite spin-lattice relaxation time.

IV. RESULTS

A. γ anisotropies

As mentioned in Sec. II B, the γ anisotropies of the 88 and 93 keV γ rays depend strongly on the reorientation process in the isomeric states, i.e., on the Korringa constant C_K, which is defined by $T_1\cdot T=C_K$, where T_1 is the high-temperature spin-lattice relaxation time of a tensor rank 1 quantity such as the magnetization,[11] and T is the temperature of the lattice. The Korringa constants of two different isotopes in the same host lattice are expected to vary as

$$C_K^{(1)}/C_K^{(2)}=[\nu_M^{(2)}/\nu_M^{(1)}]^2\,, \tag{8}$$

where $\nu_M^{(1,2)}$ are the respective hyperfine splitting frequencies. As the high-field Korringa constants of ^{110}Ag^m in Fe and Ni are known experimentally,[5] $C_K(^{110}\mathrm{Ag}^m Fe)=2.57(11)$ s K, $C_K(^{110}\mathrm{Ag}^m Ni)=7.5(5)$ s K, as well as the ratio of g factors, $g(^{109}\mathrm{Ag}^m)/g(^{110}\mathrm{Ag}^m)=2.0904(9)$ and $g(^{107}\mathrm{Ag}^m)/g(^{110}\mathrm{Ag}^m)=2.0910(16)$ (see Sec. V), the high-field Korringa constants for ^{107,109}Ag^m in Fe and Ni are estimated to be 0.59(3) and 1.7(1) s K, respectively, which means that the 88- and 93-keV γ anisotropies can be predicted.

Because of the high solubility of Pd in Ni, for the annealed ^{109}Pd*Ni* it is expected that almost 100% of the impurity nuclei are substituted onto regular lattice sites and are thus subject to the full undisturbed hyperfine field. In external magnetic fields 0.16, 0.32, 0.48, and 0.64 kG, γ anisotropies $\epsilon=-0.126(15)$, $-0.141(14)$, $-0.155(14)$, and $-0.149(14)$, respectively, were observed immediately after the demagnetization. [During the NMR-ON experiments external magnetic fields up to 3.84(8) kG were applied; the γ anisotropies remained constant.] Figure 2 shows the γ anisotropy $W(0,T)$ calculated for different values of the Korringa constant C_K. For the hyperfine splitting of $^{109}\mathrm{Ag}^m Ni$ $\nu_M=103.26$ MHz has been taken (see Sec. IV B). Taking into account the systematics of magnetic moments of $\nu\frac{5}{2}^+$ states and the known hyperfine field of Pd*Ni*, the hyperfine splitting of the parent state ^{109}Pd*Ni* was estimated to be -43 MHz. Because of the different sign of the magnetic moments of the parent and the isomeric state—the signs of the hyperfine fields of Pd and Ag in Ni are both negative—the energetically higher substates of the isomer are populated immediately after the β decay, which would correspond to a negative temperature at the beginning of the relaxation process. Curve *a* in Fig. 2 represents no reorientation ($C_K=\infty$); curve *d* represents complete reorientation ($C_K=0$) in the isomeric state. Curve *b* has been calculated with $C_K=1.7$ s K, which would be expected taking into account the high-field Korringa constant of $^{110}\mathrm{Ag}^m Ni$ (Ref. 5) and scaling according to Eq. (8). The measured γ anisotropy (shaded area in Fig. 2) indicates that the Korringa constant is smaller, i.e., the relaxation is faster. Curve *c* was calculated with $C_K=0.8$ s K, with which the experimental values can be explained.

For $^{107}\mathrm{Ag}^m Ni$ slightly larger γ anisotropies were expected, as the hyperfine splitting of the parent state ^{107}Cd*Ni* is smaller than that of ^{109}Pd*Ni* and the hyperfine splittings of ^{107}Ag^m and ^{109}Ag^m are nearly equal (see Sec. IV C). However, the observed γ anisotropies were found to be slightly smaller, $\epsilon=-0.100(33)$, $-0.120(13)$, $-0.114(13)$, and $-0.138(13)$ in external magnetic fields of 0.16, 0.32, 0.48, and 0.64 kG, respectively. This can be caused by two effects: (1) The fraction of impurity nuclei being subject to the full undisturbed hyperfine field is less

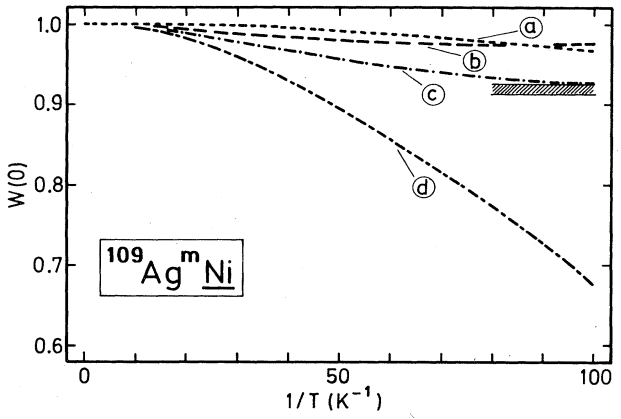

FIG. 2. 0° γ anisotropy of the 88 keV transition emitted in the decay of ^{109}Pd*Ni* vs reciprocal temperature. In the intermediate state ^{109}Ag^m a reorientation may take place during the half-life of 39.8 s, depending on the strength of the spin-lattice relaxation matrix element, which is most conveniently described by the Korringa constant C_K. The different curves represent calculations with different values for C_K: *a*, $C_K=\infty$ (no reorientation); *b* and *c*, $C_K=1.7$ and 0.8 s K, respectively (partial reorientation); *d*, $C_K=0$ (complete reorientation). The shaded area represents the experimental γ anisotropy, which indicates that a partial reorientation takes place.

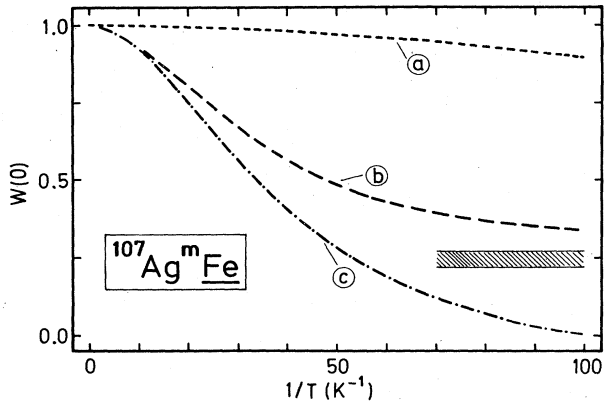

FIG. 3. 0° γ anisotropy of the 93 keV transition emitted in the decay of ^{107}Cd*Fe* vs reciprocal temperature. The different curves have been calculated with different values for the Korringa constant C_K: *a*, $C_K=\infty$ (no reorientation); *b*, $C_K=0.6$ s K (partial reorientation); *c*, $C_K=0$ (complete reorientation). The shaded area represents the experimental γ anisotropy, which indicates that a partial reorientation takes place, too.

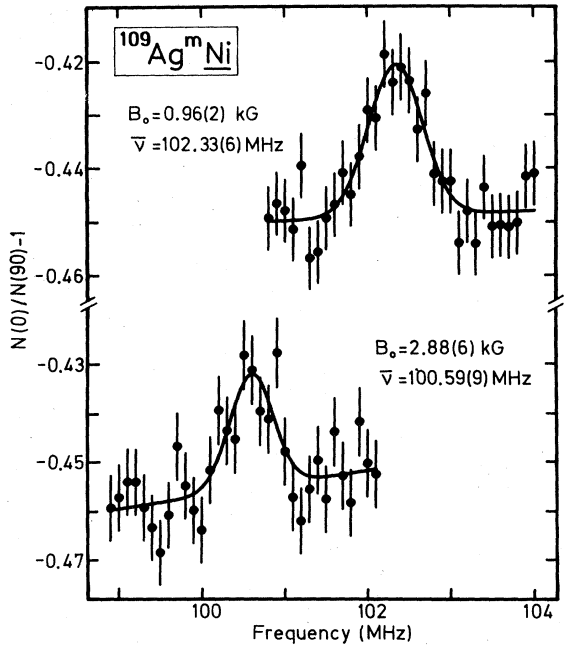

FIG. 4. $^{109}Ag^m$*Ni* NMR-ON resonances measured with a total modulation band width of 0.4 MHz for two different external fields.

than 1. This could be understood as the solubility of Cd in Ni is worse than the solubility of Pd in Ni.[10] Furthermore, the sample had not been annealed after the irradiation, as it could not be excluded that Cd would diffuse out of the Ni matrix. (2) The Korringa constants C_K for the samples are slightly different because of the different surrounding, namely pure Ni in one case and Ni containing 0.1 at. % Pd in the other. This would be supported by the experimental fact that the γ anisotropy of 4.9 s $^{191}Ir^m$ in Ni—this is also a reorienting intermediate state—was found to depend on the impurity concentration (in this case ^{190}Os), even if the samples had been annealed carefully, but with different annealing parameters. Thus we cannot draw definite conclusions on the origin of the too small γ anisotropy of $^{107}Ag^m$*Ni* at present.

For $^{107}Ag^m$*Fe*, in external magnetic fields of 0.16, 0.32, 0.48, 0.64, and 0.80 kG, the observed γ anisotropies at $1/T=90(10)$ K^{-1}—the temperature during the anisotropy measurements was rather constant, but the absolute value was determined only to $\sim 10\%$, as a precise knowledge of the temperature is not necessary for NMR-ON experiments, which were the main aim of this work—were found to be $\epsilon=-0.571(9)$, $-0.701(6)$, $-0.775(5)$, $-0.804(5)$, and $-0.826(4)$, respectively. Figure 3 shows model calculations for $^{107}Ag^m$*Fe*: curves *a*, *b*, and *c* represent $C_K=\infty$ (no reorientation), $C_K=0.6$ s K [as expected according to Ref. 5, again with the proper scaling according to Eq. (8)], and $C_K=0$ (complete reorientation). The shaded area represents our experimental value. Here again, the relaxation is faster than expected according to the known high-field Korringa constant from $^{110}Ag^m$*Fe*.[5] Taking into account that the fraction of $^{107}Ag^m$ nuclei subject to the full undisturbed hyperfine field is less than 100%, $C_K<0.5$ s K can be inferred from the present experiment.

B. NMR-ON on $^{109}Ag^m$*Ni*

With an external magnetic field $B_0=0.80(2)$ kG, the resonance was searched with the following parameters: frequency range 80—120 MHz; frequency resolution 1 MHz; modulation width ±1 MHz; counting time 100 s/spectrum. After a resonance signal had been detected at ~102 MHz, the frequency region was reduced, and the further measurements were performed with a resolution of 0.1 MHz and a frequency modulation band width of ±0.2 MHz. An attempt was made to perform measurements with a modulation band width of ±0.1 MHz; the resonance amplitude was, however, too small to obtain reasonable statistical accuracy within a time interval of several hours. Further measurements were performed with external magnetic fields of 0.96(2), 1.92(4), 2.88(6), and 3.84(8) kG. Figure 4 shows NMR-ON resonances of the 88 keV transition. The total resonance line widths (including the broadening due to the frequency modulation band width of ±0.2 MHz) were found to be 0.77(12), 0.73(14),

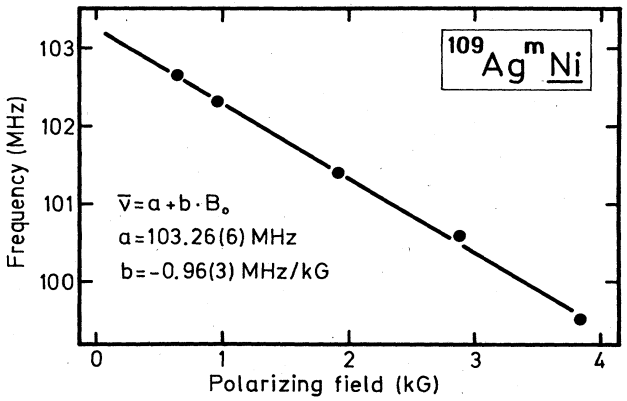

FIG. 5. Shift of the NMR-ON resonances of $^{109}Ag^m$*Ni* with the external magnetic field B_0.

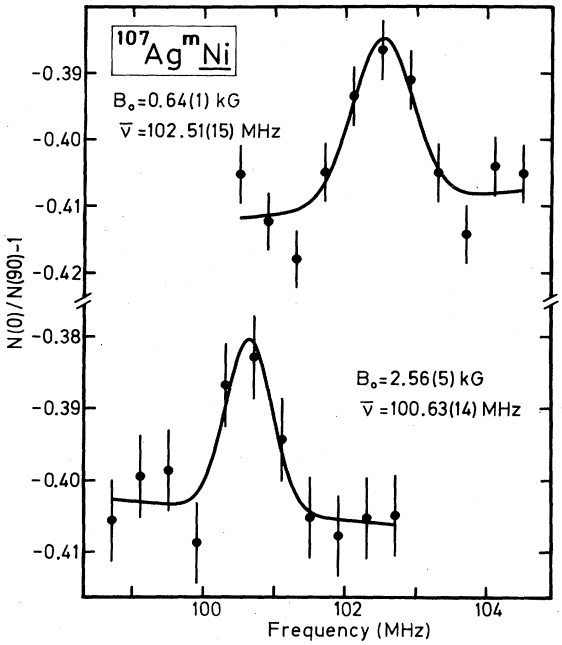

FIG. 6. ^{107}Ag^m*Ni* NMR-ON resonances measured with a total modulation band width of 0.8 MHz for two different external fields.

0.62(15), and 0.58(17) MHz for the measurements in the magnetic fields of 0.96(2), 1.92(4), 2.88(6), and 3.84(8) kG, respectively. This shows that no artificial broadening is introduced by the finite measurement time. The resonance centers versus polarizing field are shown in Fig. 5. The least squares fit yields

$$\bar{\nu}(B_0=0)=103.26(6)\ \text{MHz}\ ,$$

$$d\bar{\nu}/dB_0=-0.96(3)\ \text{MHz/kG}\ .$$

We have also tried to find the NMR-ON resonance of the parent state ^{109}Pd*Ni* in the frequency range 30—55 MHz. Although a resonance amplitude of several percent was expected according to model calculations as outlined in Sec. II B, together with the experimentally known resonance effect of ^{109}Ag^m*Ni*, from which the fraction of "good-site" nuclei was estimated, no resonance signal from the parent state could be detected with statistical significance.

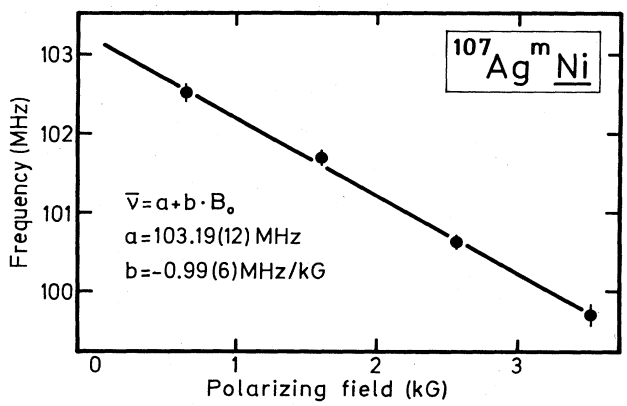

FIG. 7. Shift of the NMR-ON resonances of ^{107}Ag^m*Ni* with the external magnetic field B_0.

C. NMR-ON on ^{107}Ag^m*Ni*

Two NMR-ON resonances of ^{107}Ag^m*Ni* are shown in Fig. 6. In comparison to ^{109}Ag^m*Ni*, the resonance effect was found to be smaller by a factor of ~ 2. Therefore, in order to get a significant statistical accuracy in a reasonable measurement time, the measurements were performed with the larger frequency modulation band width of ± 0.4 MHz and a frequency resolution of 0.4 MHz. Measurements were performed in external magnetic fields 0.64(2), 1.60(3), 2.56(5), and 3.52(7) kG. The dependence of the center frequencies on B_0 is illustrated in Fig. 7. The least-squares fit yields

$$\bar{\nu}(B_0=0)=103.19(12)\ \text{MHz}\ ,$$

$$d\bar{\nu}/dB_0=-0.99(6)\ \text{MHz/kG}\ .$$

D. NMR-ON on ^{107}Ag^m*Fe*

Figure 8 shows two NMR-ON resonances of ^{107}Ag^m*Fe*, measured in external fields $B_0=0.80(2)$ and 1.60(3) kG. Additional measurements were made for $B_0=2.40(5)$ kG. The resonance line widths (including a total frequency modulation band width of 1 MHz) were found to be 1.6(2), 1.8(2), and 2.4(5) MHz for the measurements with $B_0=0.80$, 1.60, and 2.40 kG, respectively, which is relatively small for such a large hyperfine splitting frequency, especially as the samples were not annealed after the irradiation. The resonance effect of NMR-ON spectra mea-

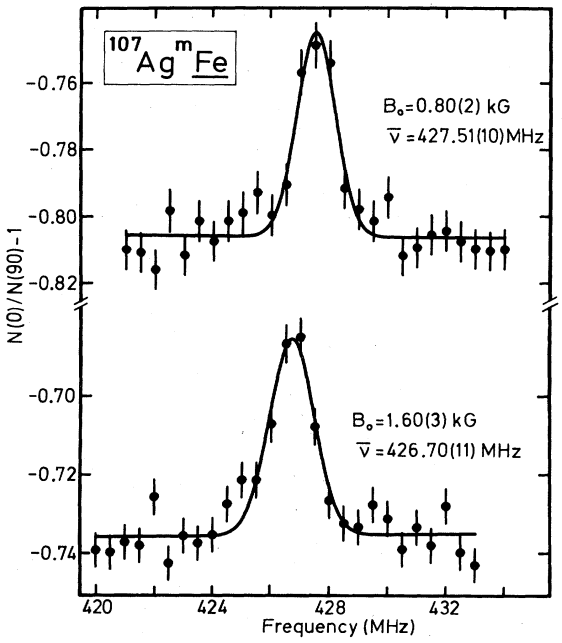

FIG. 8. ^{107}Ag^m*Fe* NMR-ON resonances measured with a total modulation band width of 1.0 MHz for two different external fields.

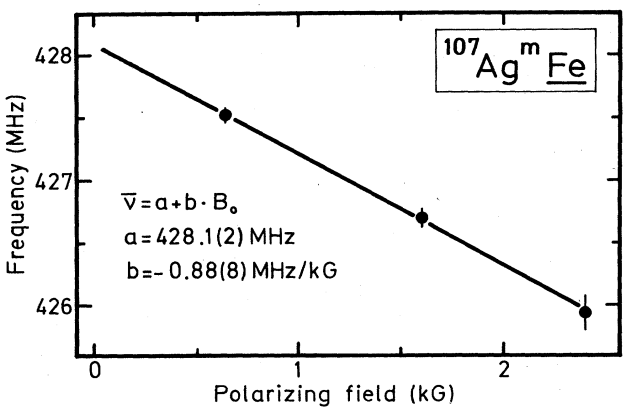

FIG. 9. Shift of the NMR-ON resonances of $^{107}Ag^m Fe$ with the external magnetic field B_0.

sured with a total modulation band width of 2 MHz indicated that only $\sim 30\%$ of the γ anisotropy could be destroyed. This can be interpreted that $\sim 70\%$ of the nuclei contributing to the γ anisotropy are not subject to the (exact) substitutional hyperfine field. (Impurity nuclei on "zero-field sites" are not taken into account here, as they do not contribute to the γ anisotropy.) This means that the quantitative interpretation of an "integral quantity," such as the γ anisotropy, could yield erroneous results for the hyperfine splitting. The NMR-ON method is, however, sensitive only to nuclei on sites with a sharp hyperfine interaction. The resonance centers vs B_0 are illustrated in Fig. 9. The least-squares fit yields

$$\bar{\nu}(B_0 = 0) = 428.1(2) \text{ MHz} ,$$

$$d\bar{\nu}/dB_0 = -0.88(8) \text{ MHz/kG} .$$

As the unequal population of the $^{107}Ag^m$ substates immediately after the β decay, which is due to the hyperfine splitting of the parent state $^{107}CdFe$, contributes ~ 5–8% to the γ anisotropy, there was a realistic hope that the $^{107}CdFe$ NMR-ON resonance could also be detected via the γ anisotropy of the 93 keV transition. It was searched in an additional experiment in the frequency region 60–79 MHz. No resonance could be detected with statistical significance, most probably because of the fact that small temperature variations strongly influence the γ anisotropy because of the much larger hyperfine splitting of $^{107}Ag^m Fe$.

V. DISCUSSION

In Table I, the presently known magnetic hyperfine splitting frequencies of Ag isotopes in Fe and Ni are listed. Our ratio for the hyperfine splittings of $^{107}Ag^m$ in Fe and Ni is in good agreement with the corresponding ratio for $^{106}Ag^m$ (Ref. 12) and with the ratio for $^{110}Ag^m$ of Rüter *et al.*,[5] but in disagreement with the ratio of Fox *et al.*[13] This is a further proof that, as already pointed out in Ref. 12, the NMR-ON resonance on $^{110}Ag^m Ni$ of Fox *et al.*[13] must be erroneous. The average ratio for the hyperfine fields of Ag in Fe and Ni is

TABLE I. Hyperfine splittings of Ag isotopes in Fe and Ni.

Isotope	I^π	ν_{Fe}/MHz	ν_{Ni}/MHz	ν_{Fe}/ν_{Ni}	Ref.
$^{106}Ag^m$	6^+	210.57(3)	50.76(4)	4.148(5)	12
$^{107}Ag^m$	$\frac{7}{2}^+$	428.1(2)	103.19(12)	4.149(5)	This work
$^{109}Ag^m$	$\frac{7}{2}^+$		103.26(6)		This work
$^{110}Ag^m$	6^+	204.8(2)	56.0(2)	3.66(2)	13
		204.78(2)	49.40(4)	4.145(5)	5

$$B_{hf}(AgFe)/B_{hf}(AgNi) = 4.1468(22) .$$

Taking the magnetic moment of $^{110}Ag^m$ as $\mu = 3.607(4)\ \mu_N$,[1] the g factor and magnetic moment of $^{107}Ag^m$ and $^{109}Ag^m$ are, from the ratios of resonance frequencies, found to be

$$g(^{107}Ag^m) = (+)1.2567(15) ,$$

$$\mu(^{107}Ag^m) = (+)4.398(5)\ \mu_N ,$$

$$g(^{109}Ag^m) = 1.2571(17) ,$$

$$\mu(^{109}Ag^m) = (+)4.400(6)\ \mu_N .$$

Within this accuracy, hyperfine anomalies between $^{107,109}Ag^m$ and $^{110}Ag^m$ can be neglected, as the main contribution to the magnetic moment of $^{110}Ag^m$ results from the $(\pi g_{9/2})^{-3}_{7/2^+}$ state which is the configuration of $^{107,109}Ag^m$. Our magnetic moment for $^{109}Ag^m$ is in good agreement with the less precise value, $\mu = 4.27(13)\ \mu_N$, known from atomic beam magnetic resonance measurements.[2] A small discrepancy exists, however, with the magnetic moment $\mu = 4.31(4)\ \mu_N$ given in the table of Fuller,[14,15] which had been adopted as the recommended value in Nuclear Data Sheets.[7]

From the shift of the NMR-ON resonances with the external magnetic field, Knight shift parameters are obtained: $K(^{107}Ag^m Ni) = 0.03(6)$; $K(^{107}Ag^m Fe) = -0.08(8)$; $K(^{109}Ag^m Ni) = 0.00(3)$. These are consistent with more precise data on $^{106}Ag^m$ (Ref. 12) and $^{110}Ag^m$ (Ref. 5).

The structure of the $\frac{7}{2}^+$ isomers $^{107,109}Ag^m$ has been discussed in detail in Ref. 2. The g factors suggest a $(\pi g_{9/2})^{-3}_{7/2^+}$ intruder configuration, which is obviously lower in energy than the $\pi g_{9/2^+}$ single particle state. [The g factors for the $(\pi g_{9/2})^{-3}_{7/2^+}$ and a $\pi g_{9/2^+}$ single particle state are expected to be equal.] A similar behavior is known for neighboring Rh: With increasing neutron number, the energy difference between the $(\pi g_{9/2})^{-3}_{7/2^+}$ and the $\pi g_{9/2^+}$ single particle state decreases continuously, and becomes negative for ^{105}Rh, for which the $(\pi g_{9/2})^{-3}_{7/2^+}$ state is the ground state. For ^{103}Ag the $(\pi g_{9/2})^{-3}_{7/2^+}$ is also the ground state. The magnetic moment is from atomic beam magnetic resonance known to be $4.47(5)\ \mu_N$,[16] which demonstrates that the core-polarization effect of the neutrons on the proton magnetic moments is small, as had also been observed for the 6^+ isomers in the neighboring odd-odd Ag isotopes.[12]

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