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MAGNETIC MOMENT OF THE 12^- ISOMER OF ^{196}Au †

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The magnetic hyperfine interaction of the 12^- state of ^{196}Au in Fe and Ni has been determined by low-temperature nuclear orientation. A value of $\mu(12^-) = \pm 5.35 \pm 0.20$ n.m. was derived using the hyperfine fields of $^{197,198}Au$(Fe) and correcting for hyperfine anomalies.

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A measurement of the magnetic moment of the 12^- isomer of ^{196}Au ($T_{1/2}$ = 9.7 h) is desirable for testing its interpretation as a [$\pi\ h_{11/2^-}$, $\nu\ i_{13/2^+}$] 12^- shell model configuration [1]. We have used thermal equilibrium nuclear orientation [2] of ^{196m}Au in Fe and Ni to study the magnetic hyperfine interaction of this high spin state. Both the large induced hyperfine field of Au(Fe) [3] and the expected large magnetic moment of the 12^- state make it a favorable candidate for this technique. Since high saturation of the nuclear polarization is reached, the magnetic hyperfine interaction can be determined from the temperature dependence of the γ-ray anisotropy alone, independent of uncertainties in factors influencing the absolute magnitude of the anisotropy.

The ^{196m}Au activity was produced by the $^{196}Pt(d,2n)$-reaction, with 18 MeV deuterons on a 46% enriched metallic Pt target. The carrier free Au

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††On leave from the Hahn-Meitner Institut, Berlin.

activity, separated from Pt by the standard ethyl acetate procedure [4], was electroplated on foils of Fe or Ni, already containing ^{60}Co activity for thermometry. The samples were wrapped in additional Fe or Ni foils, melted in a H_2 atmosphere, rolled, annealed, and finally attached with Bi/Cd-solder to the copper fin of an adiabatic demagnetization apparatus. Using CMN as cooling salt, temperatures down to 8 mK were obtained. The samples were magnetized in a magnetic field of 4 kOe produced by a superconducting Helmholtz pair.

During the warming-up of the samples over a typical period of 10 hours, γ-ray spectra were taken with high-resolution Ge(Li)-detectors parallel and perpendicular to the direction of the external polarizing field. After background correction, anisotropies were obtained for the 148-keV and 188-keV γ transitions of ^{196}Au and for the ^{60}Co γ lines, the latter being used for thermometry.

Figure 1 shows the temperature dependence of the function 1 - W(0) for the 148-keV γ rays, both for ^{196m}Au(Fe) (circles) and ^{196m}Au(Ni) (squares). The solid curve is the result of a least-squares fit of

$$W(\theta) = 1 + \sum_{k=2,4} B_k U_k F_k Q_k P_k(\cos\theta)$$

to the ^{196m}Au(Fe) data, with the magnetic hyperfine interaction μH and an amplitude factor as free parameters. The saturation value of W(0) obtained from the fit agrees within error limits with the theoretical one calculated from the ^{196m}Au decay scheme [2]. The ^{196m}Au(Ni) data, due to the small degree of nuclear polarization reached in this host, were fitted with only one free parameter (μH), taking the amplitude factor from the fit of the $^{196m}Au(\underline{Fe})$ data. The importance of reaching high saturation of the nuclear polarization is thus clearly demonstrated.

The results obtained for the magnetic hyperfine splitting μH from two $^{196m}Au(\underline{Fe})$ samples and one $^{196m}Au(\underline{Ni})$ sample are summarized in table 1. Their ratio agrees within error with the ratio of the hyperfine fields of ^{197}Au in Fe and Ni [3].

From the weighted average for μH determined for $^{196m}Au(\underline{Fe})$ a value for the magnetic moment of the 12^- state can be derived, taking into account the rather large hyperfine anomalies of the Au isotopes [5-7]. Using Bohr-Weisskopf theory [8], extended to odd-odd nuclei, the calculated anomalies agree within 20% with the measured ones for $^{196,197,198}Au$. This comparison was made by calculating the proton and neutron fractions of the spin and orbital parts of the nuclear moments, using the coupling rule, and adjusting the spin g-factors of proton and neutron to reproduce the measured moments. Table 2 summarizes the procedure used to derive a value for $\mu(12^-)$. From the measured hyperfine fields of ^{197}Au and ^{198}Au in Fe given in column 2, together with references, the values for $\mu(12^-)$, presented in column 3, are obtained. The theoretical hyperfine anomalies $^{196m}\Delta^{A}_{BW}$, calculated as described, are given in column 4. The corrected values for $\mu(12^-)$, listed in column 5, agree rather well with each other, leading to a weighted average of $\mu = \pm 5.35 \pm 0.20$ n.m. for the magnetic moment of the 12^- state.

A $[\pi\, h_{11/2^-}, \nu\, i_{13/2^+}]\ 12^-$ shell model assignment is suggested for ^{196m}Au by the low-lying $11/2^-$ and $13/2^+$ states in $^{195,197}Au$ and $^{195,197}Pt$, $^{195,197}Hg$, respectively. The known magnetic moment of the $13/2^+$ state of

^{195}Hg [9] provides a value for the neutron contribution, and for the $11/2^-$ proton we take a value of $\mu(11/2^-)_{th} = 6.7$ n.m., calculated with the spin polarization procedure of Arima and Horie [10]. The coupling of these moments leads to $\mu(12^-)_{th} = 5.67$ n.m., in good agreement with our experimental value, assuming the positive sign. The experimental value for the magnetic moment of the 12^- state therefore provides strong evidence for the correctness of the assumed shell model configuration.

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Table 1. Summary of experimental results for two different samples of $^{196m}Au(\underline{Fe})$ (a and b) and one sample of $^{196m}Au(\underline{Ni})$, obtained from the temperature dependence of the anisotropy of the 148 keV γ rays.

Host lattice	θ	$\lvert\mu H\rvert$ [10^{-18} erg]	$\lvert\mu H\rvert_{average}$ [10^{-18} erg]
Fe	0° (a)	31.8±1.6	
Fe	90° (a)	27.3±3.1	30.6±1.2
Fe	0° (b)	30.0±2.4	
Ni	0°	6.0±0.4	6.4±0.4
Ni	90°	7.4±0.7	

Table 2. Derivation of the magnetic moment of the 12^- state of ^{196}Au.

Au isotope	H_{int} [kOe]	$\|\mu(12^-)\|$ [n.m.]	$^{196m}\Delta^A_{BW}$ [%]	$\|\mu(12^-)\|_{corr}$ [n.m.]
197	-1280 [3]	4.73	-12.2	5.39
198	-1169 [6]	5.19	-2.3	5.30

Figure Caption

Fig. 1. Temperature dependence of 1 - W(0) for the 148 keV γ rays of ^{196m}Au(Fe) (circles) and ^{196m}Au(Ni) (squares).

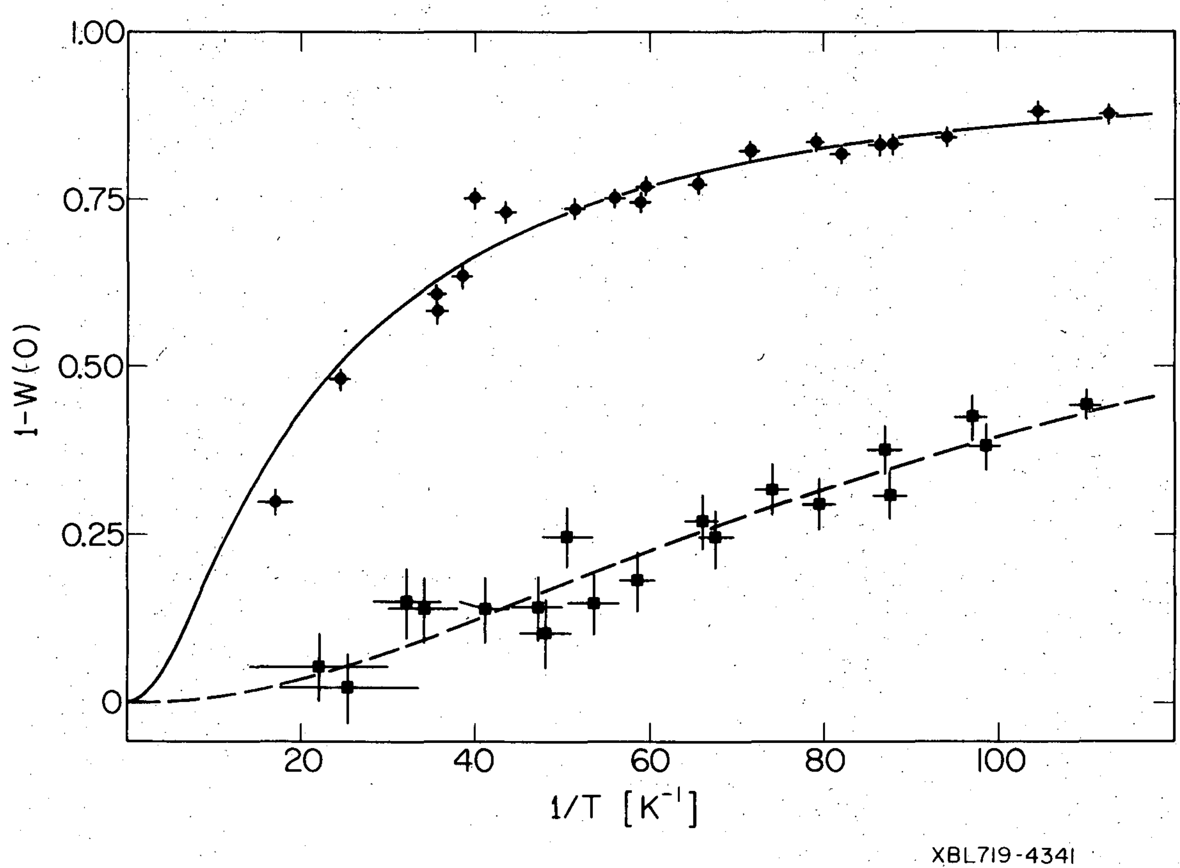

Fig. 1

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