Title
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MAGNETIC MOMENT OF THE 12⁻ ISOMER OF ¹⁹⁶Au

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The magnetic hyperfine interaction of the 12⁻ state of ¹⁹⁶Au in Fe and Ni has been determined by low-temperature nuclear orientation. A value of μ(12⁻) = ±5.35±0.20 n.m. was derived using the hyperfine fields of ¹⁹⁷,¹⁹⁸Au(Fe)" and correcting for hyperfine anomalies.

A measurement of the magnetic moment of the 12⁻ isomer of ¹⁹⁶Au (T₁/₂ = 9.7 h) is desirable for testing its interpretation as a [π h₁₁/₂⁻, v 1₃/₂⁻] 12⁻ shell model configuration [1]. We have used thermal equilibrium nuclear orientation [2] of ¹⁹⁶mAu 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 ¹⁹⁶mAu activity was produced by the ¹⁹⁶Pt(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, $\gamma$-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 $\gamma$ transitions of $^{196}$Au and for the $^{60}$Co $\gamma$ lines, the latter being used for thermometry.

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

$$W(\theta) = 1 + \sum_{k=2,4} B_{k} U_{k} F_{k} P_{k}(\cos \theta)$$

to the $^{196m}$Au(Fe) data, with the magnetic hyperfine interaction $\mu H$ 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 (μΗ), taking the amplitude factor from the fit of the $^{196\text{m}}\text{Au(Fe)}$ data. The importance of reaching high saturation of the nuclear polarization is thus clearly demonstrated.

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

From the weighted average for μΗ determined for $^{196\text{m}}\text{Au(Fe)}$ 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 $^{196,197,198}\text{Au}$. 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 μ($12^{-}$). From the measured hyperfine fields of $^{197}\text{Au}$ and $^{198}\text{Au}$ in Fe given in column 2, together with references, the values for μ($12^{-}$), presented in column 3, are obtained. The theoretical hyperfine anomalies $^{196\text{m}}\text{Au(Fe)}$ΔμN, calculated as described, are given in column 4. The corrected values for μ($12^{-}$), listed in column 5, agree rather well with each other, leading to a weighted average of μ = ±5.35±0.20 n.m. for the magnetic moment of the $12^{-}$ state.

A [$\pi h_{11/2}^{-1}, v_{13/2}^{+}]$ $12^{-}$ shell model assignment is suggested for $^{196\text{m}}\text{Au}$ by the low-lying $11/2^{-}$ and $13/2^{+}$ states in $^{195,197}\text{Au}$ and $^{195,197}\text{Pt}$, $^{195,197}\text{Hg}$, respectively. The known magnetic moment of the $13/2^{+}$ state of
$^{195}\text{Hg}$ [9] provides a value for the neutron contribution, and for the $11/2^-$ proton we take a value of $\mu(11/2^-)_{\text{th}} = 6.7$ n.m., calculated with the spin polarization procedure of Arima and Horie [10]. The coupling of these moments leads to $\mu(12^-)_{\text{th}} = 5.67$ 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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References


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

| Host lattice | $\theta$  | $|\mu H|$  | $|\mu H|_{\text{average}}$ |
|--------------|---------|-----------|--------------------------|
| Fe           | $0^\circ$ (a) | 31.8±1.6 |                      |
| Fe           | $90^\circ$ (a) | 27.3±3.1 | 30.6±1.2                |
| Fe           | $0^\circ$ (b) | 30.0±2.4 |                      |
| Ni           | $0^\circ$    | 6.0±0.4  | 6.4±0.4                 |
| Ni           | $90^\circ$   | 7.4±0.7  |                      |
Table 2. Derivation of the magnetic moment of the $12^-$ state of $^{196}$Au.

| Au isotope | $H_{\text{int}}$ | $|\mu(12^-)|$ | $196m_{\Delta BW}$ | $|\mu(12^-)|_{\text{corr}}$ |
|------------|-----------------|----------------|-----------------|-----------------|
| $^{197}$   | -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 $\gamma$ rays of $^{196m}_{\text{Au}}(\text{Fe})$ (circles) and $^{196m}_{\text{Au}}(\text{Ni})$ (squares).
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