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THE NUCLEAR SPIN AND MAGNETIC-DIPOLE MOMENT OF 39-MIN GOLD-190 †

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ABSTRACT

Some of the nuclear properties of 39-min Au^{190} have been investigated with the atomic-beam magnetic-resonance method. We have obtained the result I = 1 for the nuclear spin and $|\Delta\nu| = 3105 \pm 425$ Mc/sec for the hyperfine-structure separation. Substitution of this $\Delta\nu$ and the known values of $\Delta\nu$ and μ for Au^{197} into the Fermi-Segrè formula yields a calculated magnetic-dipole moment of $|\mu_I| = 0.065$ nm.

I. INTRODUCTION

The nuclear spins and hyperfine-structure separations (hfs) of the odd-odd gold isotopes with mass numbers from 192 to 198 have been investigated previously by the atomic-beam magnetic-resonance technique.[1-5] These results may be divided into two distinct groups. One group, represented by Au^{196} and Au^{198}, is characterized by its nuclear spin I = 2 and by its relatively large magnetic-dipole moment, $\mu_I \approx 0.6$ nm. These values agree with the single-particle model prediction, based on the coupling of $\pi(2d_{3/2})^{-1}$ $\nu(3p_{1/2})^{-1}$ according to Nordheim's "weak" rule.[6] The other group, represented by Au^{192} and Au^{194}, is characterized by I = 1 and by its very small magnetic-dipole moments, $|\mu_I| < 0.07$ nm. Although a strongly-deformed nuclear model has been used in an attempt to explain this situation,[7] a reasonable theoretical understanding of these small magnetic moments has not yet been attained. Therefore, experimental investigations of the nuclear properties for the lighter and heavier odd-odd gold isotopes may yield additional information. The investigation of Au^{190} became feasible when 70-MeV α particles first became available at the new 88-inch cyclotron of the Lawrence Radiation Laboratory, Berkeley. Accordingly we chose Au^{190} as the isotope for our initial studies.

II. EXPERIMENT

Atoms of Au^{190} were produced by the nuclear reaction $Ir^{191}(\alpha, 5n)Au^{190}$. The target material, small pieces of 6-mil natural iridium foil, was bombarded with 70-MeV α particles for 90 minutes at an average beam intensity of about 7 μA. A beam of gold atoms was obtained by direct evaporation of gold from the iridium target inside a tantalum oven heated by electron bombardment. The radioactive beam was detected by collecting the atoms on sulfurcoated collector buttons. The activity of each button was counted in NaI(Tl) crystal scintillation counters which were set to count the K x ray of gold.

A conventional flop-in atomic-beam apparatus was used for all measurements. All data were analyzed for the best fit to the Breit-Rabi formula by means of a least-squares method. The magnetic field was calibrated with atomic-beam resonances of Rb^{85} and Rb^{87}.

III. RESULTS

A spin search was performed at a low magnetic field (≈ 4 G) for the observable $\Delta F = 0$ transition in the $^2S_{1/2}$ electronic ground state of gold. The activity collected at a frequency corresponding to $I = 1$ showed a definite enrichment of the 39-min Au^{190} isotope.[8] The decay of the $I = 1$ activity is compared in Fig. 1 with the decay of the beam background. The long-lived components of $I = 1$ activity can be attributed mostly to the activity of 4.8-h Au^{192} and 39-h Au^{194}, as their nuclear spins are also $I = 1$. Several resonances of 39-min activity were then observed at higher magnetic fields in order to measure the hfs separation; one of these resonances is shown in Fig. 2. All experimental data and computer results are tabulated in Table I. The best fit of the hyperfine-structure separation to the observed data for the $^2S_{1/2}$ electronic ground state is given by

$$|\Delta \nu| = 3105 \pm 425 \text{ Mc/sec.}$$

Using the Fermi-Segrè formula and the previously-measured Au^{197} constants,[9] we calculate the nuclear magnetic-dipole moment of Au^{190} to be

$$|\mu_I| = 0.065 \pm 0.009 \text{ nm},$$

which is very close to that of Au^{194}. These results are in agreement with the more accurate ones obtained independently by Liljegren et al at Uppsala.[10]

The stated uncertainty in the magnetic moment is derived only from the uncertainty in $\Delta\nu$ and does not include any allowance for a possible hyperfine-structure anomaly. The anomaly between Au^{190} and Au^{197} will most likely be large, because of the high Z and the difference in the nuclear ground state of the two isotopes. Thus we prefer to quote our final result without an assigned uncertainty, and give

$$|\mu_I| = 0.065 \text{ nm}.$$

The results for Au^{190}, like those of Au^{192} and Au^{194}, cannot be explained satisfactorily by the existing theory. Although the collective model can explain the spin, it fails to predict the magnitude of the nuclear dipole moment. It would be interesting to measure the signs of the dipole moments for Au^{190}, Au^{192}, and Au^{194} to ascertain whether these moments lie along a parabola with Au^{192} at the minimum, or whether they lie along a straight line, with the sign of the moment of Au^{190} opposite to that of Au^{194}.

Several spin searches were also conducted in an attempt to determine the spin of Au^{189}. The fact that no evidences of the spin or presence of this isotope were found corroborated the observations of Liljigren et al., who attempted to produce it using a (p, xn) reaction. Thus it appears that the 42-min half-life attributed to Au^{189} may be in error.

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Table I. Summary of data and results for Au^{190}.

Run	Calibration isotope		H	ν obs	Residual freq.
	Name	Frequency (Mc/sec)	(G)	(Mc/sec)	(kc/sec)
784	Rb^{87}[a]	7.202(35)	10.26(5)	9.652(40)	2
786	Rb^{87}	28.362(45)	40.04(6)	38.300(200)	-38
789	Rb^{85}[a]	19.285(35)	40.05(7)	38.370(150)	23

Best least-squares fit for

Au^{190}: $I = 1$, $\Delta\nu = 3105(425)$ Mc/sec, $\mu_I(\text{uncorr}) = \pm 0.065(9)$ nm, $\chi^2 = 5$

[a]The calibration constants were obtained from S. Penselin, T. Moran, V. W. Cohen, and G. Winkler, Phys. Rev. 127, 524 (1962).

FOOTNOTES AND REFERENCES

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FIGURE CAPTIONS

Fig. 1. The decay of activity collected on a sample exposed at a frequency corresponding to I = 1, as compared with the decay of a beam-background sample. The straight line has a slope corresponding to the Au^{190} half life of 39 min.

Fig. 2. A resonance of 39-min Au^{190} activity observed at 10.3 G.

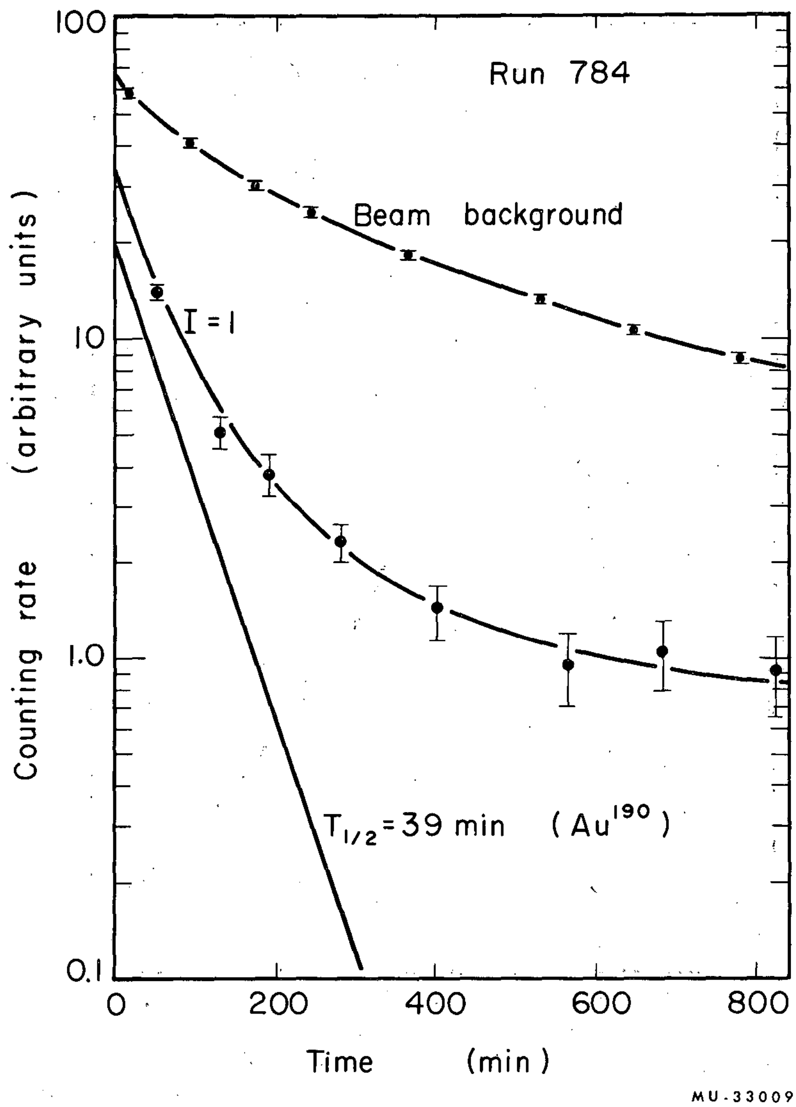
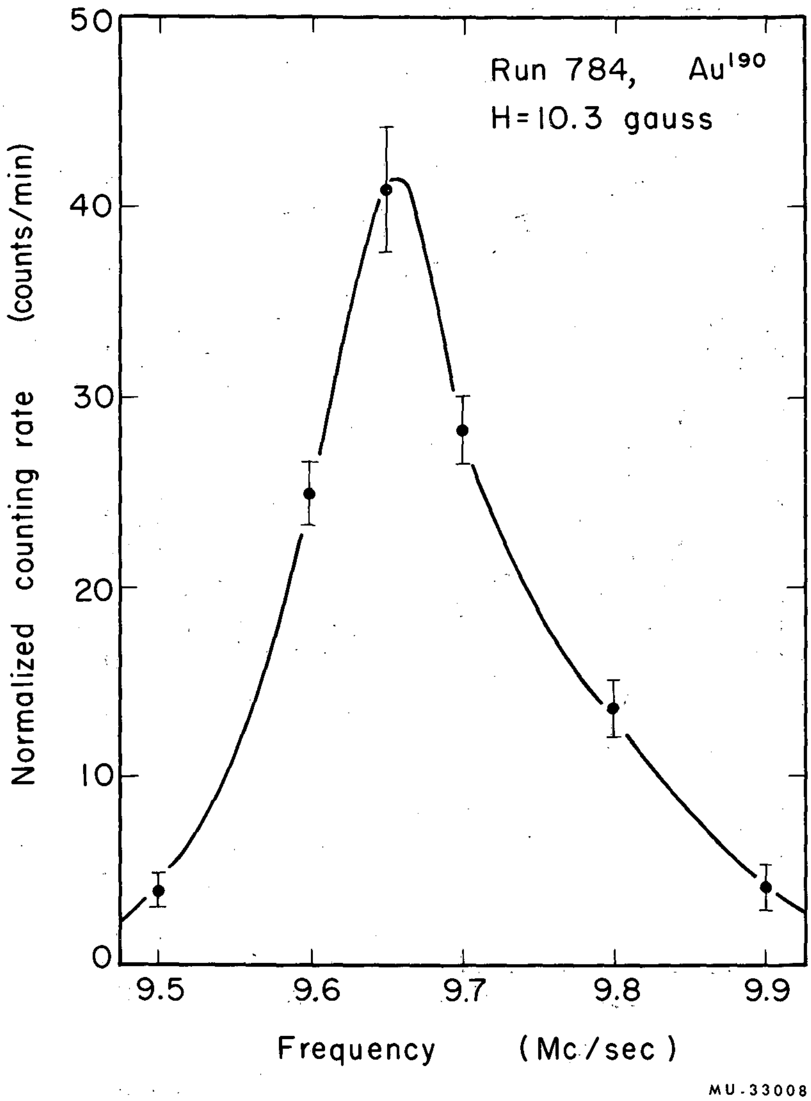

Run 784
Beam background
I = 1
$T_{1/2}$ = 39 min (Au^{190})
Counting rate (arbitrary units)
100
10
1.0
0.1
0
200
400
600
800
Time (min)
MU-33009

Fig. 1



Run 784, Au190
H=10.3 gauss
Normalized counting rate (counts/min)
50
40
30
20
10
0
9.5
9.6
9.7
9.8
9.9
Frequency (Mc/sec)
MU-33008

Fig. 8