The Magnetic Moments of Ag^{107} and Ag^{109} and the Hyperfine Structure Anomaly

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The nuclear magnetic moments of Ag^{107} and Ag^{109} are measured by nuclear induction and found to be $\mu(Ag^{107}) = -(0.113042 \pm 0.000013)$ nm and $\mu(Ag^{109}) = (0.129955 \pm 0.000013)$ nm. The ratio of the moments is measured to be $\mu(Ag^{107})/\mu(Ag^{109}) = 0.86985 \pm 0.00001$; this ratio combined with the ratio of the hfs separations as measured by Wessel and Lew yields for the hfs anomaly $\Delta = -(0.412 \pm 0.006)$ percent, which is compared to calculated values.

USING a nuclear induction spectrometer, we have observed the nuclear magnetic resonances of Ag^{107} and Ag^{109} in a 6-molar aqueous solution of $AgNO_3$ containing 2-molar $MnNO_3$ as a paramagnetic catalyst. For both Ag isotopes, the polarity of the signals indicates that the magnetic moments are negative. Using this sample we have compared in the same magnetic field the resonance frequency of Ag^{109} to that of Ag^{107} and also to that of D in D_2O containing 1-molar $MnCl_2$, with the results

$$\frac{\nu(Ag^{107})}{\nu(Ag^{109})} = 0.86985 \pm 0.00001 \quad (1)$$

and

$$\frac{\nu(Ag^{109})}{\nu(D)} = 0.30316 \pm 0.00003. \quad (2)$$

From (1) and (2) we find for the magnetic moments, without diamagnetic correction,

$$\mu(Ag^{107}) = -(0.113042 \pm 0.000013) \text{ nm} \quad (3)$$

$$\mu(Ag^{109}) = -(0.129955 \pm 0.000013) \text{ nm}, \quad (4)$$

where we have used in this calculation the known spin value of $\frac{1}{2}$ for both Ag isotopes and the values $\mu(D)/\mu(H) = 0.307015$ and $\mu(H) = 2.7925$ nm. The ratio of the magnetic moments is given precisely by (1). The value of the moments as determined from optical hfs by Brix, Kopfermann, Martin, and Walcher,[1] namely -0.111 and -0.129, are in excellent agreement with our values.

We have also observed the Ag^{107} and Ag^{109} resonances in precipitated metallic powder (Merck Reagent) at frequencies (0.522 ± 0.003) percent higher than the corresponding resonance frequencies in the aqueous $AgNO_3$ sample. This "metallic shift," first observed by Knight,[2] is due to the paramagnetism of the conduction electrons. Our value of the shift for Ag is in approximate agreement with expectations.

Using atomic beams, the hfs separations in the ground state of silver for Ag^{107} and Ag^{109} have been precisely determined by Wessel and Lew:[3] $\Delta\nu(Ag^{107}) = 1712.56 \pm 0.04$ Mc/sec and $\Delta\nu(Ag^{109}) = 1976.94 \pm 0.04$ Mc/sec. These data, together with our result (1), provide a measurement of the so-called hfs anomaly Δ, where

$$\Delta = \frac{\Delta\nu(Ag^{107})/\Delta\nu(Ag^{109}) - \mu(Ag^{107})/\mu(Ag^{109})}{\mu(Ag^{107})/\mu(Ag^{109})}$$

$$= -(0.412 \pm 0.006) \text{ percent}. \quad (5)$$

A similar anomaly has also been observed for the isotopes of Rb and K and has been explained by Bitter[4] and others[5] as resulting from a difference in the distribution of nuclear magnetism within the nuclear volume for the two isotopes. In their theory of the anomaly, Bohr and Weisskopf[6] relate Δ to the nuclear g factors: g_s and g_L. Using their Eq. (22), one calculates for Ag^{107} and Ag^{109} a value of $\Delta = -0.21$ percent for $g_s = 5.58$ (that of the free proton) and $g_L = 1$, as required by the single-particle model. On the other hand, for the same g_s but with $g_L = Z/A \cong 0.43$, as required by the collective model, one obtains $\Delta = -0.08$ percent. By comparing these results with the experimental value (5), it is seen that the single-particle model is favored in this case, as is also evidenced by the fact that the magnetic moment values lie very near the Schmidt limit. Using Bohr's refined theory[7] based on an asymmetric core, we have calculated Δ using his Eq. (15) and taking his $(R/R_0)^2_{Av} = 0.6$ and his $\zeta = 2$ (the case for the extreme single-particle model), with the result $\Delta = -0.47$ percent, which compares favorably with the measured value (5). Since the empirical values of the magnetic moments also lie between the two limits corresponding to Bohr's coupling cases B_1 and B_2, we have calculated the anomaly for coupling intermediate between these two cases, with the result $\Delta = -0.23$ percent, for $(R/R_0)^2_{Av} = 0.6$ and $g_R = \frac{1}{2}$.

[1] Brix, Kopfermann, Martin, and Walcher, Z. Physik **130**, 88 (1951).
[2] W. D. Knight, Phys. Rev. **76**, 1259 (1949).
[3] G. Wessel and H. Lew, Phys. Rev. **91**, 476 (1953). We are indebted to Dr. Wessel for an informative discussion of the results.
[4] F. Bitter, Phys. Rev. **76**, 150 (1949).
[5] Ochs, Logan, and Kusch, Phys. Rev. **78**, 184 (1950); Eisinger, Bederson, and Feld, Phys. Rev. **86**, 73 (1952).
[6] A. Bohr and V. F. Weisskopf, Phys. Rev. **77**, 94 (1950).
[7] A. Bohr, Phys. Rev. **81**, 331 (1951).

The hfs anomaly for the Ag isotopes has also been calculated by Eisinger[8] and by Staub,[9] with results comparable to those above.

Slightly prior to our measurements on Ag^{107} and Ag^{109}, reported here, Staub[10] and his colleagues in Zürich obtained similar results.

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[8] J. T. Eisinger (private communication).
[9] H. H. Staub (private communication).
[10] Brun, Oeser, Staub, and Telschow, Phys. Rev. **93**, 172 (1954).

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A New Neutron-Deficient Isotope of Krypton*

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A new neutron-deficient isotope of krypton, Kr^{76}, with a half-life of 9.7±0.5 hours has been produced by the spallation of yttrium. Its genetic relationship with its 17.2-hour Br^{76} daughter was established by isolation experiments. Kr^{76} decays by weak positron emission (probably >0.6 Mev). A search for electron capture by this nuclide gave negative results.

WHILE investigating the spallation reactions which occurred when yttrium was bombarded with 150-, 175-, and 240-Mev protons in the Rochester cyclotron, a new krypton isotope, Kr^{76}, with a (9.7 ±0.5)-hour half-life was observed.

About 200 mg of spectroscopically pure yttrium oxide[1] placed in a rectangular envelope of 5-mil aluminum foil about 2 mm×2 mm×3 cm and clamped to the cyclotron probe, was exposed to the internal beam for one hour. At the end of the bombardment the yttrium oxide was removed from the envelope and placed in a distilling flask containing carriers of niobium, zirconium, strontium, rubidium, bromine, selenium, arsenic, and germanium, together with sufficient nitric acid to dissolve the yttrium oxide. The distilling flask was attached to an all-glass gas collecting system which consisted of a helium inlet tube, a trap containing carbon tetrachloride at 0°, two potassium hydroxide coated glass wool filled traps at dry-ice temperature, and finally a charcoal filled U-tube trap at liquid nitrogen temperature. With helium flowing slowly through the system the distilling flask was heated until all the yttrium oxide had dissolved. The bromide carrier was oxidized to bromine and trapped in the carbon tetrachloride trap. The two traps at dry-ice temperature prevented water vapor and acid gases from reaching the charcoal trap. The krypton was adsorbed on the charcoal U tube at liquid-nitrogen temperature and sealed from the line. The U tube was cemented to a Lucite disk for counting.

The decay of the krypton activities, as counted through the glass walls of the U tubes (0.5–1.0 mm thick), was followed with a scintillation counter having a NaI(Tl) phosphor and a beta-proportional counter. The gross decay curve (Fig. 1) on either counter showed the 1.1-hour Kr^{77},[2] followed by the growth of 17.2-hour

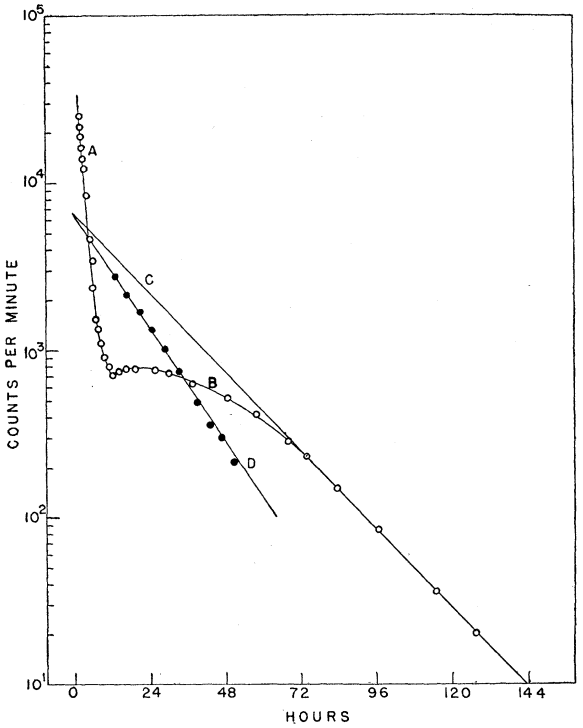

FIG. 1. Open circles—observed activity. Solid circles—subtraction of observed curve from extrapolated asymptote. Curve *A*, decay of 1.1-hour Kr^{77}. Curve *B*, growth and decay of Br^{76}. Curve *C*, extrapolated asymptote to curve *B*. Curve *D*, difference curve obtained by subtracting curve *B* from curve *C*. Curve *D* shows a half-life of (9.7±0.5) hours for Kr^{76}.

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[1] Part of the yttrium oxide was supplied through the courtesy of the Ames Laboratory, Iowa State College, Ames, Iowa.

[2] Hollander, Perlman, and Seaborg, "Table of isotopes," Revs. Modern Phys. **25**, 469 (1953).