Ratio of the Magnetic Moments of In^{115} and In^{113}†

Michael Rice and R. V. Pound

Lyman Laboratory of Physics, Harvard University, Cambridge, Massachusetts

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A new measurement of the ratio of the nuclear magnetic resonance frequencies of In^{115} and In^{113} in a solution of $In(ClO_4)_3$ yields $\mu(In^{115})/\mu(In^{113}) = 1.0021437 \pm 0.0000012$. This can be combined with the hfs measurements of Eck et al. to determine the hfs anomalies.

RECENT measurements by Eck and others[1] of the ratios of the hfs splittings of the indium isotopes In^{115} and In^{113} have made a more precise determination of the magnetic moment ratio desirable. The best value so far published for this moment ratio is[2]

$$\mu(In^{115})/\mu(In^{113}) = 1.00213 \pm 0.00004,$$

and represents the direct ratio of the two resonance frequencies in a given magnetic field, using a superregenerative rf spectrometer. This precision is insufficient to determine the existence and magnitude of an hfs anomaly.

We have made a new determination, using the recording oscillating rf spectrometer[3] and a permanent magnet. Precautions were taken to minimize, and correct for, drifts of thermal origin in the static field. The sample, a solution of $In(ClO_4)_3$, approximately $1M$ in $1.3M$ acid, was prepared by dissolving 2 g powdered indium in 30 ml of boiling 70% $HClO_4$, filtering on a sintered glass suction filter, and dissolving the precipitate in several ml water.[4] The points of zero slope in the nuclear magnetic resonance lines were determined by recording their derivatives with the spectrometer steadily scanning in frequency, making frequency marks every 10 cps for the In^{115} line and every 20 cps for In^{113}, as determined by heterodyne methods based on our quartz crystal standard. The ratios of deflection, measured peak-to-peak, to rms noise fluctuations were 55:1 and 20×55:1, or 1100:1, for In^{113} and In^{115}, respectively. The line widths between points of maximum slope were both about 800 cps or 0.86 gauss. The relaxation time T_1, determined by the saturation method is 0.33×10^{-3} sec, nearly equal to the value $T_2 = 0.24 \times 10^{-3}$ sec obtained from the line width, if one assumes Lorentzian line shape. The rate of sweep through each line was about 100 cps/min. There was a small lag introduced by the integrating time constant in the recording system ($RC = 6$ sec in two cascaded stages). Because of the similarity in sweep rates and line widths, the lag is by the same amount for each line. Resonance frequencies were compared only for pairs of lines swept through in the same sense. The modulation field was sinusoidal at 280 cps, with a peak-to-peak amplitude of 0.82 gauss.

The accuracy with which any individual point of zero slope could be read was 2 cps per 6.7 Mc/sec, or about 0.3 ppm (parts per million) for the In^{115} lines, and 20 cps per 6.7 Mc/sec, or about 3 ppm for the In^{113} lines, being limited by noise in the latter case, and by the unevenness of sweep rate in the former. The potentially largest source of error, the thermal drift of the static field of the permanent magnet—amounting to approximately 1 gauss per °C—was minimized by completely surrounding the magnet with Styrofoam. Alternate measurements were made of the two lines, maintaining the same sense of frequency sweep; in each of two runs (which differed in sense of frequency sweep) the In^{115} line was observed six times and the In^{113} line five times. The In^{115} resonance frequencies were interpolated to the times of observation of the In^{113} line. Since the drift was quite steady, the error introduced by the interpolation is of the same order ($\sim$0.3 ppm) as the observational error for these lines.

The average of the ten values yields

$$\mu(In^{115})/\mu(In^{113}) = 1.0021437 \pm 0.0000012,$$

where the error ($\sim$1.2 ppm) is the rms deviation. The values obtained by Eck and others for the hfs splitting ratios in the $^2P_{\frac{1}{2}}$ and $^2P_{\frac{3}{2}}$ states are, respectively,[1]

$$a_{\frac{1}{2}}(In^{115})/a_{\frac{1}{2}}(In^{113}) = 1.00213614 \pm 0.00000028$$

and

$$a_{\frac{3}{2}}(In^{115})/a_{\frac{3}{2}}(In^{113}) = 1.00216753 \pm 0.00000028.$$

Following the definition of Schwartz[5] of the hfs anomaly, $\Delta = (a_1/\mu_1)(\mu_2/a_2) - 1$, where the subscripts 1 and 2 refer to the lighter and heavier isotopes, respectively, the two values for the anomaly are

$$\Delta_{\frac{1}{2}} = (+7.5 \pm 1.3) \times 10^{-6}$$

and

$$\Delta_{\frac{3}{2}} = (-23.8 \pm 1.3) \times 10^{-6}.$$

We are indebted to Professor Kusch and Dr. Eck for suggesting this problem and for communicating their results to us before publication.

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[1] Eck, Lurio, and Kusch, following paper [Phys. Rev. **106**, 954 (1957)]; T. G. Eck and P. Kusch, this issue [Phys. Rev. **106**, 958 (1957)].

[2] H. E. Walchi, Oak Ridge National Laboratory Report ORNL-1775 (unpublished); Yu Ting and D. Williams, Phys. Rev. **89**, 595 (1953).

[3] G. Watkins and R. V. Pound, Phys. Rev. **82**, 343(A) (1951).

[4] Other compounds were tried, but none yielded comparable signal-to-noise ratios. Aquaeous and acidified solutions of commercially obtained $InCl_3$ and $InBr_3$ gave no indium resonance; and the resonance was very weak and broad in a solution of purified $In(OH)_3$ in HCl. We are indebted to Dr. J. W. Meadows for suggesting the chemical method used. An alternative method for preparing $In(ClO_4)_3$ which proved satisfactory was the solution of purified $In(OH)_3$ in $HClO_4$ and water.

[5] Charles Schwartz, Phys. Rev. **99**, 1035 (1955).