VII. NUCLEAR MAGNETIC RESONANCE AND HYPERFINE STRUCTURE

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A. HYPERFINE STRUCTURE OF Tl^{203} AND Tl^{205} IN THE $7\,^2S_{1/2}$ STATE

Our investigations of the hyperfine structure of the radioactive thallium isotopes (1) have shown a discrepancy between quoted values (2) of the natural thallium hyperfine structure in the $7\,^2S_{1/2}$ state and those resulting from our observations. Natural thallium is used for calibration in our radioactive thallium work. The previously published values (3, 4) resulted from measurements of the 5350 A line arising from the $7\,^2S_{1/2}$-$6\,^2P_{3/2}$ transition (Fig. VII-1). The hyperfine structure of the $^2P_{3/2}$ level was not resolved in these measurements; it was estimated at approximately +8 mk. Actually, more recent measurements by atomic-beam magnetic-resonance techniques (5) showed the separations to be 17.49 mk and 17.69 mk for Tl^{203} and Tl^{205}, respectively. Therefore it is better to use the $7\,^2S_{1/2}$-$6\,^2P_{1/2}$ (ground-state) transition (3776 A) in order to obtain $\Delta\nu\left(^2S_{1/2}\right)$, since $\Delta\nu\left(^2P_{1/2}\right)$ is well resolved spectroscopically (approximately 700 mk). Jackson (4) also measured this line but, because of problems of overlapping orders, he preferred not to use the results on this line to obtain $\Delta\nu\left(^2S_{1/2}\right)$.

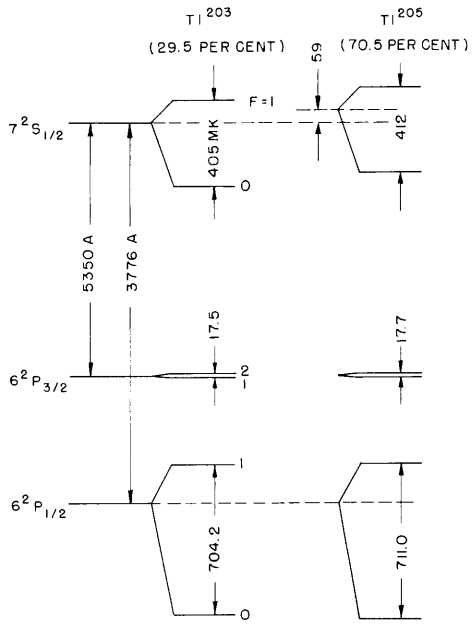

Fig. VII-1. Thallium energy-level diagram.

We have measured the hyperfine structure of the 3776 A line, using both the 40-ft grating in the Spectroscopy Laboratory, as well as the two-grating arrangement described in a previous report (6). The photographic plates (Fig. VII-2) were analyzed with a comparator microscope. Five plates were used in the measurements, some of which were repeated for checking systematic errors in estimating line centers — both

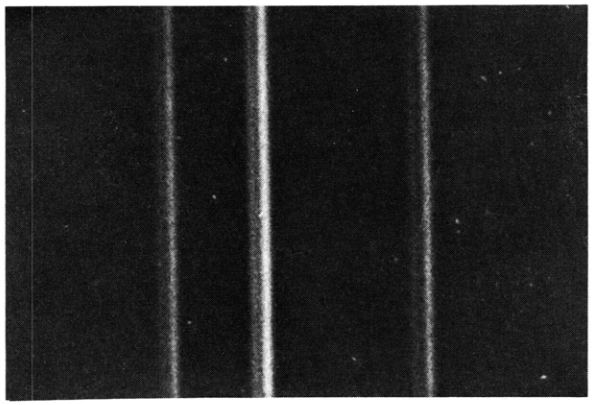

Fig. VII-2. Hyperfine structure of the 3776 A line.

those of a personal nature, and those attributable to the comparator screw. The results, based on 140 measurements of individual separations, indicate that approximately three times the calculated rms deviation (equivalent to approximately 1/10 of the linewidth) has to be taken as the error in order to give internal consistency for the measurements; that is, to obtain agreement in $\Delta\nu\left(^2P_{1/2}\right)$ for Tl^{203} when $\Delta\nu\left(^2P_{1/2}\right)$ of Tl^{205} is used for calibration. The combined Doppler and instrumental width of the lines was approximately 40 mk (the instrumental width alone is approximately 20 mk).

The results that we obtained for the $7\ ^2S_{1/2}$ hyperfine structure are:

Tl^{203}: 405 ± 5 mk

Tl^{205}: 412 ± 4 mk

The isotope shift Tl^{203}-Tl^{205} in this line was found to be 59±3 mk. The resulting Tl^{203} $\Delta\nu\left(^2P_{1/2}\right)$ is 709±6 mk, while the atomic-beam value (7) is 704.20 mk. The previous values (2) for $\Delta\nu\left(^2S_{1/2}\right)$ were +395 mk and +403 mk for Tl^{203} and Tl^{205}, respectively.

We are grateful to the Spectroscopy Laboratory, M.I.T., for the use of their facilities.

R. J. Hull, H. H. Stroke

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B. HYPERFINE STRUCTURE OF Cd^{111} AND Cd^{113} IN THE $5s5p\ ^3P_1$ STATE

The hyperfine-structure separations of the f = 3/2 and f = 1/2 levels of the $5s5p\ ^3P_1$ state of Cd^{111} and Cd^{113} have been measured by the double-resonance method (1). The hfs separation of Cd^{111} is 6185.74±0.05 mc, and that of Cd^{113} is 6470.77±0.05 mc.

The ratio of the hfs splittings in this state is, therefore, 1.046079±16. The ratio of the nuclear moments of these two isotopes (2) is 1.046083±3, and the ratio of the hfs separations (3) in the $5s5p\ ^3P_2$ state is 1.0460676±6. The small differences in these ratios are attributable to the finite size of the nucleus and the consequent differences in the distribution of nuclear magnetism and electronic current, and hence of their interaction between two isotopes of the same element (4).

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C. CALCULATIONS OF SIGNAL-TO-NOISE RATIOS IN DOUBLE-RESONANCE EXPERIMENTS

Techniques of AM transmission system analysis have been applied to the calculation of signal-to-noise ratios in double-resonance experiments.

In an AM transmitter we have a source of carrier power and a modulator that impresses information on the carrier by varying its amplitude. In a double-resonance experiment, "carrier" power is supplied by a spectroscopic lamp. The lamplight is modulated by changes of state produced in the atoms in the resonance cell.

In an AM receiver the modulation is stripped from the carrier and converted to meaningful form. Inevitably, the receiver introduces a certain amount of thermal

noise. The "receiver" in a double-resonance experiment consists of a photomultiplier tube together with an electronic amplifier, filters, and a chart recorder. The greatest part of the thermal noise arises at the photomultiplier cathode. Other noise of substantial magnitude may arise in the electric apparatus, but this is avoidable.

The signal-to-noise ratio for double-resonance experiments was obtained by using this analogy, and the method has been summarized in an unpublished memorandum.

Numerical values of the signal-to-noise ratio have been computed for the particular experiment described by Melissinos (1). With even mercury isotopes in the resonance cell in equilibrium with the liquid at 0° C, S/N is calculated as 64 db for a 1-cps filter bandwidth. Observed values of S/N are from 35 to 40 db. The discrepancy is believed to result from avoidable noise in the apparatus. If 10^{13} atoms of Hg^{197*} are put in a resonance cell in the same experiment, S/N is calculated as 35 db for a particular resonance between two of the Zeeman components of the $^3P_1$ level. The Hg^{197*} experiment is therefore considered feasible.

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