V. NUCLEAR MAGNETIC RESONANCE AND HYPERFINE STRUCTURE

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A. THE HYPERFINE STRUCTURE OF RADIO-THALLIUM 199 AND 200

The hyperfine structure and isotope shift of Tl^{200} and Tl^{199} have been measured spectroscopically. The procedure described in Quarterly Progress Report No. 51 (pages 51-52) and Quarterly Progress Report No. 52 (page 32) has been followed except for changes that will be discussed here.

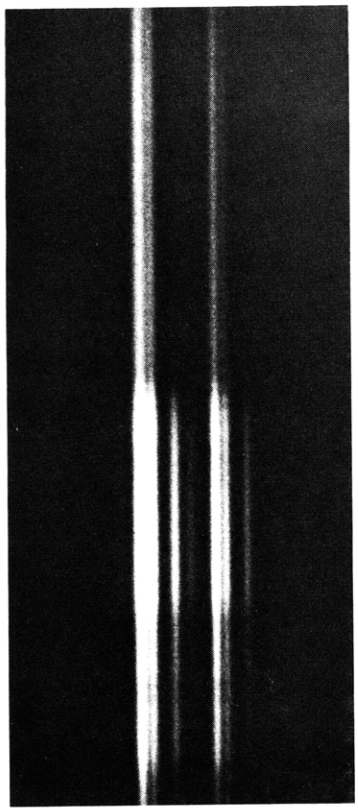

Fig. V-1. The 5350 A line of thallium. The components from left to right belong to isotopes 205, 203, 199, 200, 205, 203, and 199, respectively. The upper part of the picture is the Tl^{203} and Tl^{205} calibration spectrum.

An extra mirror (1) was used in the 40-ft monochromator of the Spectroscopy Laboratory, M. I. T., to allow the simultaneous recording of the two resonance lines of thallium at 3776 A and 5350 A. Two improvements were made in the preparation of the light source. First, more atoms were produced for the source by going to the internal beam of the cyclotron. This procedure increased the number of atoms in the lamp by a

factor of nearly 5. Second, approximately 1 μgm of indium in the form of indium chloride was placed in the lamp. It had been found experimentally that a small amount of such impurity in the lamp increased the useful life of the lamp appreciably. The calibration of the plates was improved by using an Osram thallium lamp. The spectrum emitted by this lamp is extremely stable and reliable for photographic work. Finally, to prevent overexposure of the radio-thallium spectrum, a rotating step sector was placed before the slit of the spectrograph.

The measurements previously made on Tl^{199} have been confirmed within an accuracy of approximately 2 per cent. New data were obtained from a spectrogram of both isotopes in the green line (see Fig. V-1). This plate, just as the plate of the ultraviolet line, showed a single line for Tl^{200}; thus it is confirmed that its hyperfine structure is indeed less than the observed linewidth (~40 mk). This is consistent with the extremely small hfs separations that have been observed by means of atomic-beam magnetic-resonance techniques in other odd-odd isotopes of thallium. The measured isotope shifts between Tl^{199} and Tl^{205} are 164 mk and 177 mk for the ultraviolet and green lines, respectively. The corresponding values for Tl^{200}-Tl^{205} are 148 mk and 169 mk. The accuracy of these results is approximately ±5 mk.

R. J. Hull, H. H. Stroke

References

1. K. K. Y. Li and H. H. Stroke, Quarterly Progress Report No. 55, Research Laboratory of Electronics, M. I. T., Oct. 15, 1959, p. 60.

B. HYPERFINE STRUCTURE IN THE $^3P_1$ LEVEL OF Hg^{197*}

The hyperfine structure of Hg^{197*} has been measured in the $^3P_1$ level with greater accuracy than that obtained in previous spectroscopic work (1). The level-crossing and double-resonance experiments were used to obtain the hfs separations, and the isotope shift was determined by a magnetic-scanning experiment.

The level crossing described in Quarterly Progress Report No. 58 (page 101) has been identified as the intersection between the F = 15/2, m = 15/2 and F = 13/2, m = 11/2 levels. This crossing occurs at a field whose proton-resonance frequency is 33,364.2 ± 8.0 kc. A double resonance has been observed between the F = 15/2, m = 15/2 and F = 15/2, m = 13/2 levels with a radio frequency of 3053.91 ± .02 mc and a magnetic field proton-resonance frequency of 24,268.4 ± 4.8 kc. With the use of magnetic scanning, the separation between the Hg^{197*}, F = 11/2 and Hg^{198} levels at zero field has been measured as 19,360 ± 130 mc.

In order to use these data for the calculation of the Hg^{197*} hyperfine structure, it is necessary to know the electronic g value of the $^3P_1$ level. Level-crossing experiments

Table V-1. Hyperfine structure in the $^3P_1$ level of Hg^{197*}

Quantity	Value (mc)
W_L	18246 ± 14
W_H	14236 ± 20
W_I	2240 ± 130
A	-2328.8 ± 1.7
B	-901 ± 13

Explanation of Symbols

W_L: The separation between the F = 15/2 and F = 13/2 levels at zero field.
W_H: The separation between the F = 13/2 and F = 11/2 levels at zero field.
W_I: The isotope shift of Hg^{197*} relative to Hg^{198}.
A: The magnetic dipole interaction constant.
B: The electric quadrupole interaction constant.

in Hg^{199} and Hg^{197} and a double-resonance experiment in Hg^{198} lead to the value, 1.4861 ± .00036.

Table V-1 gives the numerical results pertinent to the hyperfine structure of Hg^{197*}. The limits of error are three times the standard deviation of the individual measurements from the mean of the quantity. A much more detailed report of this work, together with an interpretation of the data in terms of nuclear moments, is contained in a thesis (2) that has been submitted to the Department of Physics and in a paper, based on the thesis, which will be submitted for publication to the Journal of the Optical Society of America.

H. R. Hirsch

References

1. A. C. Melissinos and S. P. Davis, Dipole and quadrupole moments of the isomeric Hg^{197*} nucleus; Isomeric isotope shift, Phys. Rev. 115, 130 (1959).

2. H. R. Hirsch, Hyperfine Structure in the $^3P_1$ Level of the Twenty-Four Hour Isomer of Mercury 197, Ph. D. Thesis, Department of Physics, M. I. T., 1960.

C. HYPERFINE STRUCTURE IN THE $^3P_1$ STATE OF Hg^{197}

The previously described experiment (1) on the hyperfine structure of Hg^{199} has been extended to the 65-hr half-life isotope Hg^{197}. The value of the zero-field hfs splitting is 23,086.37 ± 0.02 mc. The error is the probable error obtained from a

least-square fit of the data. Systematic errors have been estimated and are believed to be smaller than the probable error quoted here.

C. V. Stager

References

1. C. V. Stager, Hyperfine structure of the $^3P_1$ state of Hg^{199}, Quarterly Progress Report No. 57, Research Laboratory of Electronics, M. I. T., April 15, 1960, p. 63.

D. DIRECT MEASUREMENT OF THE HYPERFINE SPLITTING OF THE $^3P_1$ LEVEL OF Hg^{197*}

The hyperfine interval F = 13/2→F = 11/2 of the $^3P_1$ level of Hg^{197*} (nuclear isomer; half-life, 23 hours, nuclear spin I = 13/2) was measured by the direct double-resonance method developed by Kohler (1, 2, 3). The sample of Hg^{197*} was prepared by bombardment of gold with deuterons and extracted by following the technique of Bitter et al. (4).

The double-resonance experiment was made possible by the fortuitous coincidence of the $^3P_1$ level of Hg^{196} with the $^3P_1$ F = 13/2 level of Hg^{197*}. We therefore used a lamp and an absorption filter cell, both of which contained Hg^{196} enriched to a value of 8.5 per cent.

The data obtained both at zero field and with weak magnetic-field sweep indicate that (a) the interval F = 13/2→F = 11/2 is 14,234.86 ± 0.09 mc; (b) the value I = 13/2 of the nuclear spin is confirmed.

P. C. Brot

References

1. R. H. Kohler, Hyperfine structure of the $^3P_1$ state of mercury by double-resonance methods, Quarterly Progress Report, Research Laboratory of Electronics, M. I. T., July 15, 1956, pp. 20-21.

2. R. H. Kohler, Heavy absorption of a spectral line, Quarterly Progress Report No. 52, Research Laboratory of Electronics, M. I. T., Jan. 15, 1959, pp. 32-37.

3. R. H. Kohler, Detection of double resonance by frequency change: Application to Hg^{201} (submitted for publication to Phys. Rev.).

4. F. Bitter, S. P. Davis, B. Richter, and J. E. R. Young, Optical studies of radioactive mercury, Phys. Rev. 96, 1531 (1954).