Letters to the Editor

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Isotope Shift in λ4415 Cd II

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THE isotope shifts in λ4415 Cd II ($4d^{10}5p\ {}^2P_{3/2} - 4d^95s^2\ {}^2D_{5/2}$) have been reported by several workers[1–4] using either natural cadmium or separated isotopes, although all of the latter were not employed. In view of the complex structure of this line, it seemed desirable to study suitable mixtures of all the isotopes. By using a Schüler hollow-cathode discharge tube cooled with liquid nitrogen as a source, and a Fabry-Perot etalon in conjunction with a large prism spectrograph as the dispersive element, the following isotopes and their mixtures were studied: Cd^{110} and Cd^{114}, Cd^{110} and Cd^{116}, Cd^{112} and Cd^{116}, Cd^{113}, Cd^{113} and Cd^{116}, Cd^{111}, Cd^{111} and Cd^{116}, Cd^{108} and Cd^{114}, Cd^{106} and Cd^{114}, and Cd^{106} and Cd^{110}.

Table I lists the separations in millikaysers of the lines due to the various isotopes as compared to those of previous workers. A positive value indicates a shift toward the violet. The Cd^{110} line is taken as the origin.

From the consistency of the data the separations in the present work are accurate to ±1.5 mK.

Both Cd^{111} and Cd^{113} showed only two components in their hyperfine structure. The strong component lay toward the red in each case. The ratio of intensities was measured by photographic photometry to be 1.35±0.05. Thus the hyperfine structure of both Cd^{111} and Cd^{113} is due to two close-lying components in the ${}^2D_{5/2}$ state. This is analogous to the results of Ritschl[5] on the spectrum of Cu I and of Schüler and Westmeyer[6] on the spectrum of Zn II. Using the theoretical ratio of intensities of 1.40, the center of gravity of the Cd^{111} pattern is located at +7.3 mK with respect to the Cd^{110} line, and the center of gravity of the Cd^{113} pattern is located at +62.9 mK with respect to the Cd^{110} line, giving a relative shift between Cd^{111} and Cd^{113} of 55.6 mK. The anomalous shift of Cd^{113} reported by Woodward[2] was in error because of inadequate cleansing of the hollow cathode between use with different samples. The ratio of magnetic moments of Cd^{113} to Cd^{111} was found to be 1.046±0.027, in good agreement with the value 1.0461±0.0001 found by Proctor and Yu.[7]

TABLE I. Separations with respect to Cd^{110} line, in millikaysers (1 kayser = 1 cm^{-1}).

Cadmium isotope	Separation (mK) Present work	Schüler and Westmeyer[a]	Murakawa[b]	Hindmarsh, Kuhn, and Ramsden[c]
106	−112.2	···	−106	···
108	−51.2	···	−56	···
111 strong component	−15.2	···	−20	···
110	0.0	0	0	0.0
111 weak component(s)	38.8	···	33	···
	···	···	59	···
113 strong component	39.4	···	35	···
112	53.1	54	55	53.3
113 weak component(s)	95.9	···	91	···
	···	···	118	···
114	99.9	105	109	101.2
116	135.6	···	147	135.6

[a] See reference 1.
[b] See reference 3.
[c] See reference 4.

[1] H. Schüler and H. Westmeyer, Z. Physik **82**, 685 (1933).
[2] E. C. Woodward, Phys. Rev. **93**, 948 (1954).
[3] K. Murakawa, Phys. Rev. **93**, 1232 (1954).
[4] Hindmarsh, Kuhn, and Ramsden, Proc. Phys. Soc. (London) **A67**, 478 (1954).
[5] R. Ritschl, Z. Physik **79**, 1 (1932).
[6] H. Schüler and H. Westmeyer, Z. Physik **81**, 565 (1933).
[7] W. G. Proctor and F. C. Yu, Phys. Rev. **76**, 1728 (1949).

Quantum Theory of Cyclotron Resonance in Semiconductors

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WE have investigated in detail the quantum theory of "cyclotron" resonance of holes in semiconductors such as Si and Ge. In the case of electrons the quantum theory of cyclotron resonance is identical with the classical theory.[1] This is connected with the fact that the classical or W.K.B. approximation gives *exactly* the correct quantum levels for a simple harmonic oscillator. For holes the situation is very different because of complications arising from the degeneracy at the top of the valence band.[2] In this case we have shown that the quantum theory leads to different energy levels and selection rules for low quantum numbers, though of course for high quantum numbers the classical results are again valid.[1] Under the conditions of experiments such as those of Lax *et al.*[3] conducted at liquid helium temperature, the mean quantum number is ~5. By lowering the temperature further (to say 1 or 1.5°K) it should be possible to enhance the quantum effects and observe additional resonances. In fact there may be some evidence of these resonances in the structure observed by Dresselhaus, Kip, and Kittel.[4]

The quantum result may be formulated as follows. Consider first the case of no spin-orbit coupling. Then it is known[2] that in the absence of an external magnetic field the energy surfaces are found by solving the secular