attempts of the electron avalanches to initiate the retrograde streamers which are the forerunners of negative point breakdown with larger points.[13] They result from avalanches which would cause breakdown by positive streamers in a larger uniform gap. The streamers cannot advance all the way to the point cathode owing to the positive space charge which accumulates before the whole discharge is choked off. For still larger points the retrograde streamers reach the point and may cause breakdown.

The authors wish to express their appreciation to Makio Murayama, of the University of California Institute of Experimental Biology, for his valuable assistance in obtaining the photomicrographs.

[13] L. B. Loeb and J. M. Meek, *Mechanism of the Electrical Spark* (Stanford Press, 1941), pp. 82, 87, 99, 170.

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Zeeman Effect Data and Preliminary Classification of the Spark Spectrum of Praseodymium—Pr II

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The Zeeman effect of praseodymium has been studied at fields up to 95,000 oersteds over the range 2400 to 7100A. g and J values have been determined for 74 Pr II levels from resolved Zeeman patterns of 141 lines. With these data, together with new wave-length data from the M.I.T.-W.P.A. Wavelength Project which have been applied to the spectroscopic interval sorter and interval recorder, a quadratic term array has been set up which accounts for 312 lines. This array is consistent with King's temperature classification of the lines and with all previous hyperfine structure observations. It is self-consistent in g values to an average deviation of 0.005 unit, and in wave numbers to an average deviation of 0.08 cm^{-1}. Previously published hyperfine structure measurements were found insufficiently precise to aid the classification, but were of value in its verification. The lowest term of Pr II is found to be $f^3(^4I^\circ)\cdot s-{}^5I^\circ_4$. Most of the strong lines showing hyperfine structure arise from the f^3s configuration.

THE spectra of praseodymium have long defied classification, both because of the complexity of this rare-earth atom, and because many of its lines show hyperfine structure difficult to measure. White[1] has published extensive and valuable data on the hyperfine structure of Pr II, but these prove to be not quite precise enough to establish a classification.

The *M.I.T. Wavelength Tables*[2] list 2708 strong lines of praseodymium, and the unpublished W.P.A. card catalog at M.I.T. contains 3454 lines of all intensities assigned to the element. Actually the spectrum is so rich that the number of observable lines is limited only by the difficulty of distinguishing true lines from bands. The available description of the spectrum between 8000 and 2400A is fairly good, though limited in wave-length precision by the difficulties of measurement introduced by partially resolved hyperfine structure patterns (h.f.s.). Unless wave-length values accurate to ±0.003A can be obtained, it is impossible in so complex a spectrum to determine which is the correct quadratic array of the many obtained from the combination

TABLE I. *Fields for various spectrograms.*

SET NO.	FIELD	SET NO.	FIELD
Z 41 *H*	95,000 oersteds	*Z* 47	89,900 oersteds
Z 41 *L*	72,340	*Z* 48	87,400
Z 42	90,860	*Z* 63	89,290
Z 44	91,500	*Z* 73	87,540
Z 45	91,500	*Z* 75−*p*	85,510
Z 46	86,400	*Z* 75−*n*	87,970

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[1] H. E. White, Phys. Rev. **34**, 1397 (1929).
[2] (John Wiley and Sons, New York, 1939.)

principle with the interval sorter[3] and recorder.[4] In the absence of data of suitable precision regarding wave-length and h.f.s., Zeeman effect measurements appeared to give the most powerful method of attacking the classification of the Pr spectra.

No Zeeman effect measurements on Pr lines appear to have been made hitherto, probably because of the high magnetic and spectrographic resolution needed for lines showing h.f.s. The availability of fields approaching 100,000 oersteds,[5] combined with spectrographs of high dispersion capable of giving Zeeman exposures in a few minutes, has now made possible the resolution of many patterns. The data thus obtained gave the desired start on the classification, which was then verified and extended by wave-length, h.f.s., and temperature class data.

The three concave gratings and other apparatus used have been described in previous papers dealing with the spectra of other elements.[6, 7] An arc carrying 4 amp. was run between electrodes of silver containing 20 percent of powdered praseodymium chloride. The arc so obtained was the brightest and steadiest we have yet produced in a strong magnetic field with any element, but most of the lines emitted were found to belong to Pr II and Pr III. Eleven sets of spectrograms were obtained, at fields listed in Table I. Each set contained *p*, *n*, and no-field exposures on each of from 12 to 24 plates 20 inches long, distributed throughout the spectrum.

All spectrograms were measured in both directions with an automatic comparator,[8] and were reduced by W.P.A. clerical workers, who have been of great assistance in reading, recording, and averaging the measurements used in calculating the data which follow. The field intensities given in Table I were calculated from measurements on the *raies ultimes* of silver, copper, and calcium, and are believed to be correct to within ±0.3 percent.

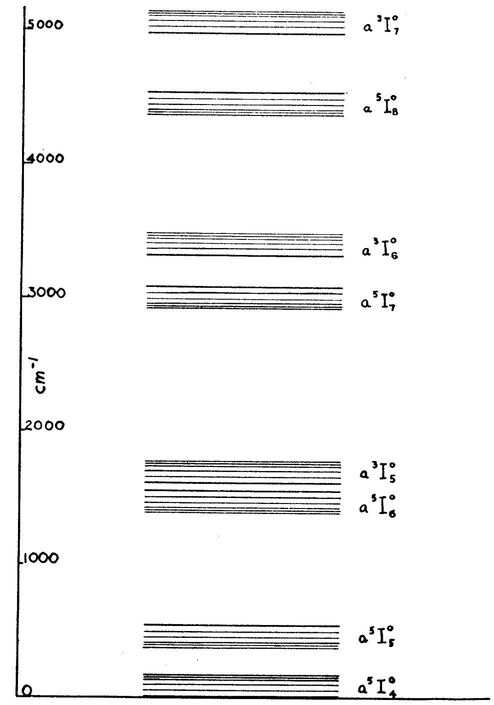

FIG. 1. Lowest terms of Pr II, showing alternate inverted and normal hyperfine-structure multiple terms in pairs.

RESULTS

Table II contains the lines of Pr II which we have classified thus far with reasonable assurance. The wave-lengths in angstroms given in the first column have been taken from the *M.I.T. Wavelength Catalogs*, as have the arc intensities in the second column. The third column gives the temperature class, while the fourth gives the h.f.s. of the line according to White,[1] or in cases marked *a*, from King.[9] *v* and *r* in this column indicate shaded toward short and long wave-lengths, respectively. The next column contains the observed wave number, while the column headed $o-c$ gives the difference, in 0.01 cm^{-1} units, between the observed wave nunber and that calculated from the difference between the finally assigned wave numbers of the parent levels. The column headed "Comb." gives the lower and upper terms which appear to produce the line. This is followed by two columns giving the *g* values for these lower and upper levels as deduced from the observed patterns of the line where these could be interpreted.

[3] G. R. Harrison, Rev. Sci. Inst. **4**, 581 (1933).
[4] G. R. Harrison, J. Opt. Soc. Am. **28**, 290 (1938).
[5] G. R. Harrison and F. Bitter, Phys. Rev. **57**, 15 (1940).
[6] G. R. Harrison and J. Rand McNally, Jr., Phys. Rev. **58**, 703 (1940).
[7] J. P. Molnar and W. J. Hitchcock, J. Opt. Soc. Am. **11**, 523 (1940).
[8] G. R. Harrison, J. Opt. Soc. Am. **25**, 169 (1935); Rev. Sci. Inst. **9**, 15 (1938); G. R. Harrison and J. P. Molnar, J. Opt. Soc. Am. **30**, 343 (1940).
[9] A. S. King, Astrophys. J. **68**, 194 (1928).

TABLE II. Pr II *Lines*.

λ	I	CLASS	H.F.S.	σ OBS.	o−c	COMB.	g_1	g_2
7099.54	2	—	—	14081.54	+8	$b^5I^\circ_5-3_5$	—	—
7021.54	6	—	—	14237.97	−13	$a^3H^\circ_5-8_5$	—	—
6850.55	4	—	—	14593.35	−12	$b^5I^\circ_4-2_5$	—	—
6564.632	10	V	—	15228.95	+6	$b^5I^\circ_4-z^5K_5$	0.622	0.818
6475.287	3	—	—	15439.07	+2	$b^5I^\circ_4-5_5$	—	—
6454.865	3	—	—	15487.75	−11	$b^5I^\circ_5-11_6$	—	—
6397.996	12	V	—	15625.58	+13	$b^5I^\circ_5-z^5K_6$	0.926	(0.959)
6305.262	9	V	—	15885.39	+1	$b^5I^\circ_7-z^5I_7$	—	—
6278.675	9	V	—	15922.52	+2	$b^5I^\circ_6-z^5K_7$	(1.073)	1.056
6262.539	9	V	—	15963.56	+10	$b^5I^\circ_6-17_6$	(1.073)	1.120
6244.344	10	V	—	16010.08	+6	$b^5I^\circ_6-z^5I_6$	—	—
6200.79	5	—	—	16131.40	−3	$b^5I^\circ_7-z^5K_8$	1.145	(1.143)
6182.343	12	V	—	16170.64	−9	$b^5I^\circ_8-30_8$	1.233	1.073
6165.945	50	V	—	16213.64	−3	$b^5I^\circ_4-z^5I_4$	0.620	(0.684)
6161.194	50	V	—	16226.15	+5	$b^5I^\circ_5-z^5I_5$	0.92	0.89
6159.093	3	—	—	16231.67	+18	$a^3H^\circ_5-17_6$	1.04	1.04
6141.508	6	V	5?a	16278.15	+10	$a^3H^\circ_5-z^5I_6$	—	—
6025.723	25	V	—	16590.93	−2	$b^5I^\circ_8-z^5I_8$	—	—
5967.837	15	V	—	16751.86	+1	$b^5I^\circ_6-22_6$	1.075	0.991
5892.231	10	V	—	16966.81	+1	$b^5I^\circ_8-z^3I_7$	1.235	(1.187)
5879.253	10	V	—	17004.26	0	$b^5I^\circ_7-z^3K_7$	1.149	(1.106)
5823.723	60	V	2	17166.40	−30	$b^5I^\circ_5-z^5I_6$	—	—
5813.593	3	—	—	17196.31	−11	$b^5I^\circ_7-z^5I_8$	1.153	(1.154)
5810.622	10	—	—	17205.10	−2	$b^5I^\circ_8-z^5K_9$	1.227	(1.217)
5807.55	2	—	—	17214.21	−2	$b^5I^\circ_6-z^5I_7$	—	—
5791.382	8	V	—	17262.26	+1	$a^3H^\circ_5-25_5$	1.043	1.063
5775.920	4h	—	—	17308.47	+5	$b^5I^\circ_4-12_4$	—	—
5719.090	10	V	—	17480.46	−4	$a^5L^\circ_8-9_7$	1.08	(1.107)
5717.785	2h	—	—	17484.45	−1	$a^5K^\circ_7-9_7$	—	—
5715.37	4	—	—	17491.84	0	$a^5K^\circ_6-4_6$	—	—
5711.65	8	—	—	17503.23	0	$b^5I^\circ_7-z^5H_6$	1.147	(1.103)
5695.93	8	—	—	17551.54	−1	$b^5I^\circ_6-26_5$	1.078	(1.067)
5689.185	1	—	—	17572.35	+8	$b^5I^\circ_7-z^3I_7$	—	—
5687.19	4h	—	—	17578.51	−20	$a^5K^\circ_5-1_5$	—	—
5685.61	3	—	—	17583.40	+5	$a^3H^\circ_6-z^3H_6$	—	—
5681.896	7	V	—	17594.89	−8	$a^3H^\circ_5-z^5H_5$	1.035	(1.101)
5677.04	3	—	—	17609.94	−1	$a^5L^\circ_7-4_6$	—	—
5662.19	2	—	—	17656.12	+7	$b^5I^\circ_5-19_5$	—	—
5647.64	2	—	—	17701.61	−1	$a^5K^\circ_7-z^5K_6$	—	—
5637.36	2	—	—	17733.64	−14	$b^5I^\circ_6-27_6$	—	—
5634.93	2	—	—	17741.54	−7	$b^5I^\circ_6-28_5$	—	—
5621.854	15	V	—	17782.80	−10	$a^5L^\circ_6-1_5$	—	—
5610.219	6	V	—	17819.68	+10	$a^3H^\circ_5-26_5$	1.043	1.073
5582.39	3	—	—	17908.51	+2	$b^5I^\circ_5-22_6$	—	—
5582.11	2	—	—	17909.41	−9	$a^5K^\circ_8-z^5K_7$	—	—
5580.39	2	—	—	17914.93	+3	$a^5K^\circ_6-6_6$	—	—
5571.841	10	V	—	17942.42	+1	$a^5K^\circ_5-2_5$	0.684	0.998
5560.21	1	—	—	17979.95	+4	$a^5K^\circ_7-z^3K_6$	—	—
5551.08	2	—	—	18009.52	−12	$a^3H^\circ_5-28_5$	—	—
5543.87	2	—	—	18032.95	−6	$a^5L^\circ_7-6_6$	—	—
5519.39	2	—	—	18112.93	+2	$b^5I^\circ_8-z^3K_8$	—	—
5509.146	50	V	—	18146.61	+1	$a^5L^\circ_6-2_5$	0.723	0.998
5502.20	2	—	—	18169.51	+13	$a^5K^\circ_9-z^5K_8$	—	—
5431.135	3	—	—	18407.25	+8	$b^5I^\circ_8-z^5H_7$	—	—
5411.555	25	IV	—	18473.85	+4	$a^5K^\circ_5-3_5$	0.660	1.141
5381.262	60	V	—	18577.85	+2	$a^5K^\circ_5-z^5K_5$	0.685	0.822
5368.830	5d	—	—	18620.87	+13	$a^5K^\circ_5-4_6$	—	—
5352.403	80	V	3?a	18678.02	+2	$a^5L^\circ_6-3_5$	0.712	1.155
5331.483	6	V	—	18751.31	0	$a^5K^\circ_6-11_6$	0.914	1.157
5322.778	30	V	—	18781.97	−5	$a^5L^\circ_6-z^5K_5$	0.718	0.820
5321.82	4	—	—	18785.35	−11	$a^5K^\circ_8-23_7$	—	—
5321.086	8	V	—	18787.94	−5	$a^5K^\circ_5-5_5$	—	—
5312.327	5	V	6ra	18818.92	−2	$a^3I^\circ_7-9_7$	—	—
5311.119	10	V	—	18823.20	−10	$a^5K^\circ_9-30_8$	1.217	1.073
5308.96	3	—	—	18830.86	+9	$a^5L^\circ_8-15_7$	—	—
5300.145	2	—	—	18862.18	+10	$b^5I^\circ_6-z^5H_6$	—	—
5300.145	2	—	—	18862.18	+14	$a^5L^\circ_7-10_8$	—	—
5298.106	25	V	—	18869.44	+2	$a^5L^\circ_7-11_6$	0.928	1.160
5292.630	50	IV	—	18888.95	+1	$a^5K^\circ_6-z^5K_6$	0.914	(0.959)
5292.10	60	V	6ra	18890.85	−24	$a^3I^\circ_7-10_8$	(1.143)	1.138
5289.937	6	—	—	18898.57	+10	$a^3I^\circ_7-11_6$	1.142	(1.156)
5263.878	25	IV	—	18992.13	−5	$a^5L^\circ_6-5_5$	0.724	0.996
5259.743	125	V	—	19007.07	+2	$a^5L^\circ_7-z^5K_6$	0.925	(0.959)
5258.20	2	—	—	19012.64	0	$b^5I^\circ_7-z^5H_7$	—	—
5251.738	10	V	5?a	19036.03	−7	$a^3I^\circ_7-z^5K_6$	1.138	(0.959)
5220.113	80	IV	—	19151.35	0	$a^5L^\circ_8-z^5K_7$	1.03	(1.062)
5219.053	50	IV	—	19155.24	−7	$a^5K^\circ_7-z^5K_7$	1.040	1.064
5216.761	8	—	—	19163.66	−7	$a^5K^\circ_5-7_5$	—	—
5208.460	0	—	—	19194.20	−11	$b^5I^\circ_4-25_5$	—	—
5207.905	15	V	—	19196.27	0	$a^5K^\circ_7-17_6$	—	—
5206.562	30	V	—	19201.20	−3	$a^5K^\circ_8-z^5I_7$	—	—
5195.307	20	V	—	19242.79	−4	$a^5K^\circ_7-z^5I_6$	—	—
5195.110	10	V	—	19243.52	0	$a^5K^\circ_9-z^5I_8$	—	—
5183.848	5	V	—	19285.33	−1	$a^5L^\circ_7-z^3K_6$	—	—
5175.833	10	—	—	19315.20	+1	$a^3I^\circ_6-4_6$	—	—
5173.898	100	IV	—	19322.41	+3	$a^5L^\circ_9-z^5K_8$	1.116	(1.143)
5161.743	40	V	2?a	19367.92	0	$a^5L^\circ_6-7_5$	0.720	(0.896)
5135.125	50	V	—	19468.31	+3	$a^5K^\circ_8-z^5K_8$	1.160	1.141
5129.520	100	IV	—	19489.58	−1	$a^5K^\circ_6-z^5I_5$	0.91	0.91
5121.7	2	—	—	19519.34	+24	$a^5K^\circ_5-8_5$	—	—
5118.021	4	—	—	19533.37	+6	$a^5I^\circ_8-10_8$	—	—
5110.768	80	V	—	19561.10	0	$a^5L^\circ_{10}-z^5K_9$	1.19	(1.217)
5110.382	80	V	—	19562.58	−3	$a^5K^\circ_5-z^5I_4$	0.686	0.686
5064.84	2h	—	—	19738.47	+22	$a^3I^\circ_6-6_6$	—	—
5061.50	1	—	—	19751.50	−14	$b^5I^\circ_4-26_5$	—	—
5060.40	2	—	—	19755.79	+5	$a^3I^\circ_7-z^3I_6$	—	—
5034.415	30	V	—	19857.76	+7	$a^5K^\circ_9-z^5K_9$	1.219	1.219
5015.543	4	—	—	19932.48	−15	$a^3I^\circ_5-1_5$	—	—
5013.20	2	—	—	19941.79	+9	$b^5I^\circ_4-28_5$	—	—
5004.584	5	—	—	19976.14	−1	$a^5L^\circ_9-30_8$	—	—
5002.454	8	V	—	19984.63	−3	$a^5K^\circ_7-22_6$	—	—
4991.774	3	—	—	20027.39	+12	$a^5I^\circ_6-1_5$	—	—
4991.774	3	—	—	20027.39	+8	$a^5L^\circ_8-23_7$	—	—
4977.578	2h	—	—	20084.50	+10	$a^5L^\circ_6-11_6$	—	—
4971.18	4	—	—	20110.35	+18	$a^5K^\circ_7-24_6$	—	—
4968.35	1	—	—	20122.22	+17	$a^5K^\circ_8-30_8$	—	—
4956.645	40	V	6?a	20169.33	+12	$a^3I^\circ_7-15_7$	(1.143)	1.057
4943.735	3	—	—	20221.99	−4	$a^5L^\circ_6-z^5K_6$	—	—
4931.28	1	—	—	20273.07	+4	$a^5K^\circ_6-16_5$	—	—
4925.630	10	V	5?a	20296.32	−1	$a^3I^\circ_5-2_5$	—	—
4914.418	3	—	—	20342.63	0	$a^5K^\circ_6-z^5K_7$	—	—
4912.629	10	V	—	20350.04	−7	$a^5K^\circ_8-z^3K_7$	1.13	(1.106)
4901.483	5	—	—	20396.31	−6	$a^5L^\circ_9-z^5I_8$	—	—
4886.045	20	V	—	20460.75	+1	$a^5L^\circ_7-z^5K_7$	—	—
4879.121	30	—	6r	20489.79	0	$a^3I^\circ_7-z^5K_7$	—	—
4877.81	40	V	6r	20495.30	+17	$a^3I^\circ_6-9_7$	1.046	1.108
4876.257	20	—	—	20501.46	−24	$a^5L^\circ_7-17_6$	—	—
4865.237	40	V	—	20548.26	+13	$a^5K^\circ_7-z^3H_6$	1.057	(1.073)
4859.038	40	V	6r	20574.48	−18	$a^3I^\circ_6-11_6$	—	—
4839.540	25	—	—	20657.37	+1	$a^5K^\circ_5-12_4$	—	—
4826.649	40	—	6r	20712.54	+25	$a^3I^\circ_6-z^5K_6$	—	—
4826.310	9	—	—	20713.99	−10	$a^5K^\circ_7-z^5K_8$	—	—
4824.655	5	—	—	20721.09	−2	$a^5K^\circ_5-13_6$	—	—
4814.344	30	V	—	20765.48	0	$a^5K^\circ_9-z^3K_8$	1.20	(1.145)
4801.150	40	V	—	20822.54	−14	$a^5L^\circ_6-z^5I_5$	0.73	0.92
4799.94	2	—	—	20827.79	+6	$a^3I^\circ_5-3_5$	—	—
4794.903	7	—	—	20849.67	+2	$a^5K^\circ_5-14_5$	—	—
4783.354	125	V	6v	20900.00	+6	$a^5I^\circ_7-9_7$	1.170	1.105
4779.196	15	—	—	20918.19	+7	$a^5K^\circ_8-z^3I_7$	—	—
4778.303	35	—	6v	20922.10	−27	$a^5I^\circ_6-3_5$	—	—
4766.906	35	V	—	20972.13	+4	$a^5I^\circ_7-10_8$	—	—
4766.322	20	—	6r	20974.69	+3	$a^3I^\circ_5-4_6$	—	—
4765.222	80	V	6v	20979.53	+6	$a^5I^\circ_7-11_6$	1.179	(1.156)
4762.727	60	V	6r	20990.52	−6	$a^3I^\circ_6-z^3K_6$	1.038	(0.992)
4758.910	3	—	—	21007.36	−18	$a^5L^\circ_8-29_7$	—	—
4757.937	100	—	—	21011.66	+16	$a^5K^\circ_7-29_7$	—	—
4754.635	15	—	6v	21026.25	−14	$a^5I^\circ_6-z^5K_5$	—	—
4746.635	15	—	6v	21026.25	−14	$a^5I^\circ_6-z^5K_5$	—	—
4746.93	100	V	6r	21060.38	−1	$a^5K^\circ_6-21_5$	(0.915)	0.886
4744.925	100	V	6v	21069.28	−2	$a^5I^\circ_6-4_6$	(1.064)	1.10
4738.622	8d	—	—	21097.30	+10	$a^3I^\circ_7-20_6$	—	—
4734.177	100	V	6v	21117.09	−1	$a^5I^\circ_7-z^5K_6$	1.176	0.961
4728.630	40	V	6r	21141.88	−3	$a^3I^\circ_5-5_5$	(0.860)	0.98
4721.910	3	—	—	21171.97	−1	$a^5K_6^\circ-22_6$	—	—
4707.939	50	IV	6v	21234.79	+45	$a^5I^\circ_5-1_5$	0.858	0.986
4707.541	80	V	6v	21236.58	+3	$a^5I^\circ_6-5_5$	1.064	(0.994)
4689.341	4	—	—	21319.01	−13	$a^3I^\circ_7-22_6$	—	—
4685.447	5	—	—	21336.73	+3	$a^5L^\circ_7-23_7$	—	—
4679.498	2	—	—	21363.94	+4	$a^5L^\circ_8-30_8$	—	—
4679.112	8	—	6r	21365.61	−14	$a^3I^\circ_7-23_7$	—	—
4678.168	12	—	—	21369.93	0	$a^5K^\circ_5-z^5H_4$	—	—
4672.595	3	—	—	21395.41	+2	$a^5I^\circ_7-z^3K_6$	—	—
4672.081	100	IV	6r	21397.76	+4	$a^3I^\circ_5-6_6$	0.868	1.070
4668.454	6	—	—	21414.39	+4	$a^5K^\circ_6-25_5$	—	—
4668.230	10	—	6r	21415.42	−14	$a^3I^\circ_6-13_6$	—	—
4664.647	100	V	6r	21431.87	−6	$a^3I^\circ_6-z^3I_6$	1.037	(1.009)
4651.517	125	V	6v	21492.35	−1	$a^5I^\circ_6-6_6$	1.05	1.07
4646.059	50	V	6r	21517.61	−4	$a^3I^\circ_5-7_5$	0.863	0.893
4628.751	200	III	6v	21598.06	+2	$a^5I^\circ_5-2_5$	0.873	0.994
4627.05	15	—	—	21606.01	−11	$a^5L^\circ_6-16_5$	—	—
4612.072	60	IV	6?a	21676.19	−9	$a^5I^\circ_4-1_5$	0.601	0.995
4603.478	4	—	—	21716.64	−4	$a^5L^\circ_6-17_6$	—	—
4595.87	6	—	—	21752.59	+12	$a^5L^\circ_7-z^5I_7$	—	—
4589.76	5d	—	—	21781.55	+3	$a^3I^\circ_7-z^5I_7$	—	—
4581.584	10	V	6?a	21820.42	+5	$a^5I^\circ_7-13_6$	—	—
4578.139	40	V	6v	21836.84	+10	$a^5I^\circ_7-z^3I_6$	(1.177)	1.010
4576.320	50	V	6ra	21845.51	+11	$a^3I^\circ_6-15_7$	(1.037)	1.066
4574.636	4	—	—	21853.56	0	$a^5L^\circ_7-z^3H_6$	—	—
4570.565	40	V	6r	21873.02	0	$a^3I^\circ_5-8_5$	0.856	1.064
4568.545	30	—	—	21882.69	+8	$a^3I^\circ_7-z^3H_6$	—	—
4561.461	6	—	—	21916.68	+15	$a^3I^\circ_5-z^5I_4$	—	—
4561.10	3	—	—	21918.41	+8	$a^5L^\circ_9-z^3K_8$	—	—
4554.790	4	—	—	21948.78	−13	$a^5L^\circ_6-18_5$	—	—
4550.882	10	V	6v	21967.63	−3	$a^5I^\circ_6-8_5$	1.07	1.07
4550.06	15	—	—	21971.59	−9	$a^5K^\circ_6-26_5$	—	—
4540.151	5	—	—	22019.54	+2	$a^5L_7^\circ-z^5K_8$	—	—
4535.921	125	III	6r	22040.08	+10	$a^5I^\circ_4-2_5$	0.605	0.998
4534.154	150	IV	6r	22048.67	+10	$a^3I^\circ_7-z^5K_8$	(1.143)	1.146
4524.695	5	—	—	22094.76	−13	$a^5K^\circ_7-z^5H_6$	—	—
4524.365	10	—	—	22096.37	−1	$a^3I^\circ_6-16_5$	—	—
4517.595	40	IV	6v	22129.48	−1	$a^5I^\circ_5-3_5$	0.880	1.165
4510.160	200	III	6r	22165.97	−1	$a^3I^\circ_6-z^5K_7$	1.029	(1.062,
4501.828	20	—	—	22206.99	+5	$a^3I^\circ_6-17_6$	—	—
4496.429	200	III	6r	22233.65	−16	$a^3I^\circ_5-11_6$	0.861	1.153
4496.429	200	III	6v	22233.65	+19	$a^5I^\circ_5-z^5K_5$	0.875	(0.821)
4493.119	25	—	6v	22250.03	−21	$a^5I^\circ_6-9_7$	—	—

TABLE II.—*Continued.*

λ	I	CLASS	H.F.S.	σ OBS.	o−c	COMB.	g_1	g_2
4493.119	25	—	6v	22250.03	−18	$a^5I^\circ_7 - 15_7$	—	—
4492.427	25	V	6r	22253.45	− 5	$a^3I^\circ_6 - z^5I_6$	—	—
4487.821	40	V	6v	22276.29	− 8	$a^5I^\circ_5 - 4_6$	—	—
4479.618	35	—	—	22317.09	+16	$a^5L^\circ_7 - 29_7$	—	—
4477.259	125	IV	6v	22328.85	+ 8	$a^5I^\circ_6 - 11_6$	1.054	1.150
4473.835	30	—	—	22345.93	− 5	$a^3I^\circ_7 - 29_7$	—	—
4468.712	125	III	6r	22371.56	−20	$a^3I^\circ_5 - z^5K_6$	0.864	0.963
4458.336	90	V	6v	22423.62	−12	$a^5I^\circ_8 - z^5I_7$	(1.250)	1.125
4454.382	60	IV	6v	22443.52	−10	$a^5I^\circ_5 - 5_5$	—	—
4449.867	125	III	6v	22466.30	−10	$a^5I^\circ_6 - z^5K_6$	1.075	0.961
4429.238	60	III	6r	22570.93	−45	$a^5I^\circ_4 - 3_5$	0.608	1.165
4429.238	100	III	6v	22570.93	+14	$a^5I^\circ_7 - z^5K_7$	(1.177)	1.061
4421.231	100	IV	6v	22611.80	+ 5	$a^5I^\circ_7 - 17_6$	1.175	1.110
4413.765	90	III	6ra	22650.05	0	$a^3I^\circ_5 - z^3K_6$	0.860	0.992
4412.155	50	IV	6v	22658.31	0	$a^5I^\circ_7 - z^5I_6$	(1.177)	1.046
4408.844	125	III	6r	22675.34	− 6	$a^5I^\circ_4 - z^5K_5$	0.605	0.823
4405.849	100	IV	6v	22690.75	− 4	$a^5I^\circ_8 - z^5K_8$	(1.250)	1.146
4403.605	100	V	6r	22702.31	− 3	$a^3I^\circ_7 - 30_8$	—	—
4395.788	30	V	—	22742.68	−17	$a^3I^\circ_6 - 19_5$	1.052	(1.025)
4372.385	10	—	—	22864.41	+ 6	$a^5K^\circ_5 - z^3H_6$	—	—
4368.327	125	III	6r	22885.65	+ 9	$a^5I^\circ_4 - 5_5$	0.605	0.994
4365.328	6	—	—	22901.37	+ 2	$a^5L^\circ_7 - z^3K_7$	—	—
4359.795	100	IV	6r	22930.43	+ 3	$a^3I^\circ_7 - z^3K_7$	(1.143)	1.102
4352.752	4	—	—	22967.54	+ 9	$a^5L^\circ_6 - z^5I_7$	—	—
4351.849	80	III	6r	22972.30	−11	$a^3I^\circ_5 - z^5I_5$	(0.860)	0.904
4347.490	100	IV	6r	22995.33	0	$a^3I^\circ_6 - 22_6$	1.047	(0.990)
4338.694	100	IV	6r	23041.98	+ 4	$a^3I^\circ_6 - 23_7$	(1.037)	1.075
4333.913	150	IV	6v	23067.37	+32	$a^5I^\circ_6 - z^5I_5$	1.062	0.910
4332.487	30	—	—	23074.97	− 6	$a^3I^\circ_5 - 13_6$	—	—
4331.472	5	—	—	23080.37	+21	$a^5L^\circ_6 - z^5H_5$	—	—
4329.415	50	IV	6?r?a	23091.34	− 6	$a^3I^\circ_5 - z^3I_6$	(0.860)	1.009
4327.698	3	—	—	23100.50	− 8	$a^5K^\circ_5 - 26_5$	—	—
4323.922	35	—	6r	23120.67	−17	$a^3I^\circ_6 - 24_6$	—	—
4323.551	100	IV	6r	23122.65	+ 9	$a^3I^\circ_7 - z^5I_8$	(1.143)	1.167
4314.74	2	—	—	23169.87	+20	$a^5I^\circ_6 - 13_6$	—	—
4313.843	4	—	—	23174.69	− 4	$a^5I^\circ_5 - 8_5$	—	—
4308.457	20	—	—	23203.66	+ 9	$a^3I^\circ_5 - 14_5$	—	—
4305.763	150	III	6va	23218.18	− 6	$a^5I^\circ_5 - z^5I_4$	0.877	0.683
4302.100	60	—	—	23237.95	+25	$a^3I^\circ_6 - 25_5$	(1.037)	1.065
4297.764	50	III	6r	23261.40	+10	$a^5I^\circ_4 - 7_5$	0.601	0.895
4292.351	4	—	—	23290.72	+ 8	$a^5K^\circ_5 - 28_5$	—	—
4290.99	5	—	—	23298.11	−10	$a^5I^\circ_6 - 14_5$	—	—
4288.830	8	—	—	23309.85	−19	$a^5K^\circ_7 - z^3K_8$	—	—
4282.440	75	IV	6v	23344.63	+ 7	$a^5I^\circ_8 - 30_8$	1.245	1.071
4272.271	50	III	6v	23400.18	+ 4	$a^5I^\circ_7 - 22_6$	1.177	0.991
4263.805	50	IV	6v	23446.65	−10	$a^5I^\circ_7 - 23_7$	—	—
4261.796	15	IV	6ra	23457.71	0	$a^3I^\circ_6 - z^5I_7$	—	—
4259.64	5d	—	—	23469.58	+22	$a^5L^\circ_7 - z^3I_7$	—	—
4254.420	35	IV	6r	23498.38	− 3	$a^3I^\circ_7 - z^3I_7$	(1.143)	1.191
4249.484	20	V	6va	23525.67	+ 2	$a^5I^\circ_7 - 24_6$	(1.177)	0.98
4247.662	60	III	6v	23535.75	− 9	$a^5I^\circ_5 - 11_6$	0.878	1.156
4243.528	20	III	6r	23558.69	−11	$a^3I^\circ_6 - z^3H_6$	1.022	(1.073)
4241.019	50	IV	6v	23572.62	0	$a^5I^\circ_8 - z^3K_7$	(1.250)	1.108
4236.210	20	III	6v	23599.38	−13	$a^5I^\circ_6 - 15_7$	(1.064)	1.085
4225.327	50	III	6r	23660.17	− 1	$a^5I^\circ_4 - z^5I_4$	0.604	0.685
4222.98	125	III	6v	23673.31	−16	$a^5I^\circ_5 - z^5K_6$	0.877	0.961
4213.96	12	—	—	23723.99	+14	$a^3I^\circ_5 - z^5H_4$	—	—
4208.305	18	III	6ra	23755.87	+ 2	$a^3I^\circ_5 - 16_5$	(0.860)	0.980
4206.739	50	III	6v	23767.71	− 7	$a^5I^\circ_8 - z^5I_8$	1.256	1.160
4191.615	40	III	6v	23850.45	− 4	$a^5I^\circ_6 - 16_5$	(1.064)	0.985
4189.518	100	III	6v	23862.39	−13	$a^5I^\circ_7 - z^5I_7$	1.175	1.121
4180.68	8	—	—	23812.84	−13	$a^3I^\circ_5 - z^5I_6$	—	—
4179.422	200	III	6v	23920.04	− 5	$a^5I^\circ_6 - z^5K_7$	1.061	(1.062)
4172.273	75	III	6v	23961.02	− 3	$a^5I^\circ_6 - 17_6$	(1.064)	1.14
4171.824	75	III	6v	23963.60	− 1	$a^5I^\circ_7 - z^3H_6$	(1.177)	1.074
4169.459	15	V	6r	23977.19	− 7	$a^3I^\circ_6 - 27_6$	—	—
4168.08	20	—	—	23985.12	+ 3	$a^3I^\circ_6 - 28_5$	—	—
4164.192	200	III	6v	24007.52	− 9	$a^5I^\circ_6 - z^5I_6$	—	—
4161.65	8	—	—	24022.18	+ 1	$a^3I^\circ_6 - 29_7$	—	—
4148.457	15	III	5?a	24098.58	+ 2	$a^3I^\circ_5 - 18_5$	0.863	1.011
4143.136	200	III	6v	24129.52	− 5	$a^5I^\circ_7 - z^5K_8$	(1.177)	1.141
4141.257	150	III	6v	24140.47	−16	$a^5I^\circ_8 - z^3I_7$	1.242	1.172
4132.230	15	IV	6va	24193.21	+ 1	$a^5I^\circ_6 - 18_5$	—	—
4118.481	250	III	6v	24273.97	−15	$a^5I^\circ_5 - z^5I_5$	(0.875)	0.920
4111.871	30	IV	5a	24312.99	0	$a^5I^\circ_5 - 12_4$	0.878	0.914
4100.746	200	III	6v	24378.94	− 1	$a^5I^\circ_8 - z^5K_9$	1.256	1.221
4100.22	15	—	—	24382.08	+ 1	$a^5I^\circ_7 - 27_6$	—	—
4096.822	30	III	6?r?a	24402.30	− 2	$a^3I^\circ_5 - 19_5$	0.858	1.024
4091.686	50	—	—	24432.93	+ 7	$a^3I^\circ_5 - 20_6$	—	—
4081.018	50	III	6v	24496.80	−16	$a^5I^\circ_6 - 19_5$	(1.064)	1.035
4075.917	15d	—	—	24527.46	− 4	$a^5I^\circ_6 - 20_6$	—	—
4073.305	9	—	—	24543.18	− 3	$a^3I^\circ_5 - 21_5$	—	—
4062.817	150	III	6r	24606.54	− 5	$a^3I^\circ_6 - z^3K_7$	1.035	1.106
4061.336	4	—	—	24615.51	+ 4	$a^5L^\circ_7 - z^3K_8$	—	—
4056.543	100	III	6r	24644.60	+ 8	$a^3I^\circ_7 - z^3K_8$	(1.143)	1.149
4054.845	50	III	6r	24654.92	+12	$a^3I^\circ_5 - 22_6$	0.862	0.991
4044.818	50	III	6ra	24716.03	− 3	$a^5I^\circ_4 - z^5I_5$	0.605	0.910
4039.357	50	III	6v	24749.45	+ 1	$a^5I^\circ_6 - 22_6$	1.08	0.98
4038.467	15	III	6?ra	24754.91	− 2	$a^5I^\circ_4 - 12_4$	0.613	0.918
4034.30	20	—	6r	24780.47	+16	$a^3I^\circ_5 - 24_6$?	—	—
4033.857	50	III	6v	24783.19	−15	$a^5I^\circ_7 - 30_8$	(1.177)	1.077
4031.755	50	III	6v	24796.11	+ 6	$a^5I^\circ_6 - 23_7$	(1.064)	1.089
4015.389	50	III	6?ra	24897.18	+ 1	$a^3I^\circ_5 - 25_5$	0.858	1.073
4008.714	150	III	6r	24938.64	−14	$a^3I^\circ_7 - z^5H_7$	(1.143)	1.209
4000.190	50	III	6v	24991.77	− 4	$a^5I^\circ_6 - 25_5$	(1.064)	1.080
3997.054	100	III	6v	25011.38	− 2	$a^5I^\circ_7 - z^3K_7$	(1.177)	1.101
3994.834	300	III	6v	25025.28	−28	$a^5I^\circ_5 - z^5H_4$	0.89	0.89
3989.718	200	III	6v	25057 29	−27	$a^5I^\circ_5 - 16_5$	0.873	0.982
3982.063	125	III	6r	25105.53	− 3	$a^3I^\circ_6 - z^5H_6$	(1.037)	1.106
3972.164	125	III	6v	25168.11	− 1	$a^5I^\circ_5 - 17_6$	0.877	1.118
3971.164	100	III	6r	25174.44	−16	$a^3I^\circ_6 - z^3I_7$	(1.037)	1.187
3966.573	100	III	6v	25203.57	+ 1	$a^5I^\circ_7 - z^5I_8$	(1.177)	1.154
3965.263	100	III	6v	25211.90	+ 8	$a^5I^\circ_6 - z^5I_7$	(1.064)	1.128
3964.825	125	III	6v	25214.68	0	$a^5I^\circ_5 - z^5I_6$	(0.875)	1.039
3964.261	60	III	6r	25218.27	0	$a^3I^\circ_5 - z^3H_6$	0.858	1.071
3962.445	60	III	6?a	25229.83	− 6	$a^3I^\circ_5 - z^5H_5$	0.869	1.108
3953.516	150	III	6v	25286.81	+ 7	$a^5I^\circ_8 - z^3K_8$	(1.250)	1.145
3949.438	150	III	6v	25312.92	+ 1	$a^5I^\circ_6 - z^3H_6$	1.08	1.08
3947.633	125	III	6v	25324.49	− 4	$a^5I^\circ_6 - z^5H_5$	(1.064)	1.125
3935.823	125	III	6?va	25400.48	+21	$a^5I^\circ_5 - 18_5$	(0.875)	0.990
3927.454	80	III	6?ra	25454.60	+10	$a^3I^\circ_5 - 26_5$	0.859	1.066
3925.456	125	III	3a	25467.56	+ 6	$a^5I^\circ_4 - z^5H_4$	0.603	0.903
3920.524	30d	III	2a	25499.60	+10	$a^5I^\circ_4 - 16_5$	(0.605)	0.985
3918.856	100	III	4a	25510.45	+ 8	$a^5I^\circ_7 - z^5H_6$	(1.177)	1.094
3912.898	150	III	4a	25549.29	+15	$a^5I^\circ_6 - 26_5$	(1.064)	1.097
3908.033	100	IV	5?a	25581.10	+10	$a^5I^\circ_8 - z^5H_7$	(1.250)	1.220
3899.555	10	—	—	25636.71	− 2	$a^3I^\circ_5 - 27_6$	—	—
3889.330	150	IV	5a	25704.11	+13	$a^5I^\circ_5 - 19_5$	(0.875)	1.025
3885.190	100	IV	4a	25731.51	+14	$a^5I^\circ_6 - 27_6$	1.058	1.068
3884.741	4	—	—	25734.48	− 9	$a^5I^\circ_5 - 20_6$	—	—
3884.039	5	—	—	25739.13	− 7	$a^5I^\circ_6 - 28_5$	—	—
3878.307	—	—	—	25777.17	−11	$a^5I^\circ_6 - 29_7$	—	—
3868.578	15	—	—	25841.99	−22	$a^5I^\circ_4 - 18_5$	—	—
3868.125	4	—	—	25845.02	+10	$a^5I^\circ_5 - 21_5$	—	—
3826.708	—	—	—	26124.74	+ 3	$a^5L^\circ_6 - z^5H_7$	—	—
3823.571	10	—	—	26146.17	+20	$a^5I^\circ_4 - 19_5$	—	—
3803.110	50d	—	—	26286.83	− 3	$a^5I^\circ_4 - 21_5$	—	—
3792.435	4	—	—	26360.82	+12	$a^5I^\circ_6 - z^3K_7$	—	—
3769.695	20d	V	2a	26519.84	−14	$a^5I^\circ_5 - z^3H_6$	—	—
3711.099	8d	V	—	26938.56	+12	$a^5I^\circ_5 - 27_6$	—	—
3710.012	6	—	—	26946.45	+18	$a^5I^\circ_5 - 28_5$	—	—
3699.952	12	—	—	27019.72	− 6	$a^5I^\circ_7 - z^5H_7$	—	—
3650.176	30	—	—	27388.16	− 5	$a^5I^\circ_4 - 28_5$	0.607	0.888

The complexity introduced by h.f.s., coupled with the natural richness of the spectrum, has made the disentangling of overlapping patterns difficult, and less precision can be expected in the g values than is obtained with a spectrum consisting mostly of sharp lines.[10] Where a g value is in parenthesis the pattern of the line was incomplete, overlapped, or unresolved, so this g value was assumed from the average for the level, and the other g value was calculated from this and the experimental data. In other cases unresolved n patterns were used, a procedure which introduces small errors.

On account of the complexity of the patterns and the necessity of using exposures at various field strengths to interpret them, any table of actual measurements would be unduly extensive even if reported in abbreviated notation.[10] For this reason only final g values are given, their use being to substantiate the quantum numbers assigned, and detailed results are held for a later report.

[10] G. R. Harrison, W. E. Albertson, and N. Hosford, J. Opt. Soc. Am. **31**, 439 (1941).

TABLE III. Pr II *terms*.

Term	Wave Number	h.f.s.	No. Comb.	g LS (Theor.)	g (Meas.)	No. Patterns Resolved	Term	Wave Number	h.f.s.	No. Comb.	g LS (Theor.)	g (Meas.)	No. Patterns Resolved
$a^5I^\circ_4$	0.00	$6i$	15	0.600	0.605	12	z^5K_6	24115.41	—	10	0.905	0.959	5
$a^5I^\circ_5$	441.94	$6n$	23	0.900	0.875	12	z^3K_6	24393.70	—	6	0.857	0.992	1
$a^5I^\circ_6$	1649.01	$6n$	32	1.071	1.064	3	z^5I_5	24716.06	—	8	0.900	0.911	2
$a^3I^\circ_5$	1743.65	$6i$	30	0.833	0.860	16	12_4	24754.93	—	4	—	0.911	2
$a^5I^\circ_7$	2998.31	$6n$	24	1.179	1.177	12	13_6	24818.68	—	5	—	—	0
$a^3I^\circ_6$	3403.12	$6i$	26	1.024	1.037	3	z^3I_6	24835.05	—	4	1.024	1.009	2
$a^5L^\circ_6$	3893.38	—	14	0.714	0.721	5	14_5	24947.22	—	4	—	—	0
$a^5K^\circ_5$	4097.57	—	16	0.667	0.683	3	15_7	25248.52	—	5	—	1.07	0
$a^5I^\circ_8$	4437.09	$6n$	10	1.250	1.250	7	z^5H_4	25467.50	—	4	0.900	0.905	1
$a^3I^\circ_7$	5079.31	$6i$	20	1.143	1.143	1	16_5	25499.50	—	7	—	0.984	3
$a^5L^\circ_7$	5108.36	—	16	0.911	0.926	1	z^5K_7	25569.10	—	10	1.054	1.062	1
$a^5K^\circ_6$	5226.47	—	12	0.905	0.915	1	17_6	25610.06	—	9	—	1.116	2
$a^5K^\circ_7$	6413.79	—	14	1.054	1.042	0	z^5I_6	25656.62	—	9	1.071	1.042	2
$a^5L^\circ_8$	6417.75	—	6	1.042	1.06	0	18_5	25842.21	—	4	—	0.999	2
$b^5I^\circ_4$	7446.51	—	9	0.600	0.622	1	19_5	26145.97	—	6	—	1.025	2
$a^5K^\circ_8$	7659.60	—	7	1.153	1.161	0	20_6	26176.51	—	4	—	—	0
$a^5L^\circ_9$	7805.50	—	4	1.133	1.115	0	21_5	26286.86	—	4	—	0.89	0
$b^5I^\circ_5$	8489.94	—	7	0.900	0.93	0	22_6	26398.45	—	9	—	0.990	3
$a^5K^\circ_9$	8958.35	—	5	1.222	1.219	1	23_7	26445.06	—	8	—	1.08	0
$a^5L^\circ_{10}$	9254.94	—	1	1.200	1.19	0	24_6	26523.96	—	4	—	1.02	1
$a^3H^\circ_5$?	9378.57	—	8	1.033	1.044	0	25_5	26640.82	—	6	—	1.075	1
$b^5I^\circ_6$	9646.60	—	11	1.071	1.073	1	z^5I_7	26860.83	—	10	1.179	1.123	3
$b^5I^\circ_7$	11005.45	—	7	1.179	1.153	1	z^3H_6	26961.92	—	9	1.167	1.073	2
$b^5I^\circ_8$	11610.92	—	6	1.250	1.231	2	z^5H_5	26973.54	—	5	1.100	1.101	1
1_5	21676.28	—	6	—	1.001	2	z^5K_8	27127.88	—	9	1.153	1.143	1
2_5	22039.98	—	7	—	0.997	4	26_5	27198.15	—	7	—	1.067	1
3_5	22571.38	—	7	—	1.163	4	27_6	27380.38	—	6	—	1.06	0
z^5K_5	22675.40	—	6	0.667	0.821	4	28_5	27388.21	—	8	—	0.886	1
4_6	22718.31	—	7	—	1.10	0	29_7	27425.29	—	6	—	—	0
5_5	22885.56	—	7	—	0.994	2	30_8	27781.65	—	8	—	1.075	4
6_6	23141.37	—	5	—	1.062	1	z^3K_7	28009.71	—	8	1.018	1.106	3
7_5	23261.30	—	4	—	0.896	3	z^5I_8	28201.87	—	8	1.250	1.154	1
8_5	23616.67	—	5	—	1.068	1	z^5H_6	28508.68	—	6	1.214	1.103	1
z^5I_4	23660.18	—	5	0.600	0.684	2	z^3I_7	28577.72	—	7	1.143	1.187	3
9_7	23898.25	—	6	—	1.107	2	z^5K_9	28816.04	—	4	1.222	1.217	0
10_8	23970.40	—	4	—	1.14	0	z^3K_8	29723.83	—	7	—	1.145	1
11_6	23977.78	—	10	—	1.156	5	z^5H_7	30018.09	—	7	1.286	1.215	0

That so many values of $o-c$ are less than 10 (i.e., less than 0.1 cm^{-1}) is gratifying, as it is difficult to make exact wave-length measurements on lines with partially resolved h.f.s. 132 lines are found to agree with the wave number calculated from the combination principle to within ± 0.05 cm^{-1}, and 78 more to within ± 0.10, leaving only 108 with deviations greater than 0.10 cm^{-1}.

In the first column of Table III are listed the term assignments, followed by the wave number of each and the hyperfine structure deduced from all lines considered as arising from the term, where i indicates wider separations at lower wave numbers, and n at higher. The fourth column gives the number of combinations with the term in the present array. The fifth column contains the theoretical g value of a term of the designation given, calculated from Landé's formula for LS coupling. The next column contains the measured g value of the term, averaged from measurements on the number of resolved patterns given, or on unresolved patterns reduced from several plates. The observed g values are in most cases believed to be correct to within ± 0.005 unit.

LOW CONFIGURATIONS OF Pr II

In accordance with the Bohr-Stoner theory the normal praseodymium atom ($Z=59$) can be expected to have three electrons outside a closed shell. Pr II, with two such electrons, would have a simpler spectrum than Pr I, but in both cases two $6s$ electrons are present which are very loosely bound; and it is necessary in Pr II to take four electrons into account when predicting terms. Among the odd configurations to be expected are fds^2, fd^2s, f^3s and f^3d. Even configurations which should be important are f^2ds, f^2s^2, f^3p, and f^4.

Many of the strongest lines of Pr II, which presumably arise from low levels, show wide h.f.s. patterns. These usually arise when a single s electron occurs in a configuration, making

TABLE IV. *Expected important terms of* Pr II.

$4f^36s$	$^{5,3}(IGFDS)^\circ$, $^{3,1}(LKIH_2G_2F_2D_2P)^\circ$
$4f^35d$	$^{5,3}(LKIHG, IHGFD, HGFDP, GFDPS, D)^\circ$ $^{3,1}(NML_2K_4I_6H_7G_9F_9D_7P_5S_3)^\circ$
$4f^36p$	$^{5,3}(KIH, HGF, GFD, FDP, P)$ $^{3,1}(ML_2K_3I_4H_5G_6F_6D_5P_3S)$

TABLE V. *Principal supermultiplet of* Pr II.*

	$a^5I^\circ_8$	$a^5I^\circ_7$	$a^5I^\circ_6$	$a^5I^\circ_5$	$a^5I^\circ_4$	$a^3I^\circ_7$	$a^3I^\circ_6$	$a^3I^\circ_5$
z^5K_9	200 III 6*v*	X	X	X	X	X	X	X
8	100 IV 6*v*	200 III 6*v*	X	X	X	150 IV 6*r*	X	X
7	—	100 III 6*v*	200 III 6*v*	X	X	30 — 6*r*	200 III 6*r*	X
6	X	100 V 6*v*	125 III 6*v*	125 III 6*v*	X	10 V 5?*a*	40 — 6*r*	125 III 6*r*
5	X	X	15 — 6*v*	200*l* III 6*v*	125 III 6*r*	X	—	—
z^3K_8	150 III 6*v*	—	X	X	X	100 III 6*r*	X	X
7	50 IV 6*v*	100 III 6*v*	4 — —	X	X	100 IV 6*r*	150 III 6*r*	X
6	X	3 — —	—	—	X	—	60 V 6*r*	90 III 6*ra*
z^5I_8	50 III 6*v*	100 III 6*v*	X	X	X	100 IV 6*r*	X	X
7	90 V 6*v*	100 III 6*v*	100 III 6*v*	X	X	5*d* — —	15 IV 6*ra*	X
6	X	50 IV 6*v*	200 III 6*v*	125 III 6*v*	X	—	25 V 6*r*	8 — —
5	X	X	150 IV 6*v*	250 III 6*v*	50 III 6*ra*	X	—	80 III 6*r*
4	X	X	X	150 III 6*va*	50 III 6*r*	X	X	6 — —
z^3I_7	150 III 6*v*	—	—	X	X	35 IV 6*r*	100 III 6*r*	X
6	X	40 V 6*v*	—	—	X	2 — —	100 V 6*r*	50 IV 6?*r*?*a*
5	X	X				X		
z^5H_7	100 IV 5?*a*	12 — —	—	X	X	150 III 6*r*	—	X
6	X	100 III 4*a*	—	—	X	—	125 III 6*r*	—
5	X	X	125 IV 6*v*	—	—	X	—	60 III 6?*a*
4	X	X	X	300 III 6*v*	125 III 3*a*	X	X	12 — —
3	X	X	X	X		X	X	X
z^3H_6	X	75 III 6*v*	150 III 6*v*	20*d* V 2*a*	X	30 — —	20 III 6*r*	60 III 6*r*
5	X	X				X		
4	X	X	X			X	X	

* X—indicates line forbidden by selection principle for ΔJ. ——indicates line not found.

plausible the assumption that the lowest terms of Pr II arise from such a configuration. Three likely configurations are then fd^2s, f^2ds and f^3s. Resulting terms of the latter are given in Table IV. When Hund's theory and Meggers and Laporte's rule are used the lowest terms to be expected from these three configurations are $^5I^\circ_4$, $^5K_5$, and $^5I^\circ_4$, respectively.

Our analysis indicates that the level $f^3(^4I^\circ)\cdot s^5I^\circ_4$ is the lowest. As will be seen from Fig. 1, all eight levels of the low $^5I^\circ$ and $^3I^\circ$ terms arising from the addition of an s electron to the parent $^4I^\circ$ term of Pr III have been found. Combinations of these terms with the even triads ^5KIH and ^3KIH which arise from the f^3p configuration give rise to the strongest lines of the spectrum. The *raies ultimes* of praseodymium are usually given[11] as 4179.422 and 4062.817A. These lines we have classified as $a^5I^\circ_6 - z^5K_7$ and $a^3I^\circ_6 - z^3K_7$. From the usual multiplet intensity rules one would expect the leading line of the supermultiplet to be strongest, with a prediction of $a^5I^\circ_8 - z^5K_9$ as the *raie ultime*. This line, at 4100.746, is of intensity 200, but other lines are stronger. The estimated intensities of the lines of the basic supermultiplet are given in Table V, where an irregularity in intensities is to be noted. A similar irregularity is found in the homologous supermultiplet of Nd II.[12] The intensities need more careful study before the cause of this anomaly can be explained.

[11] *M. I. T. Wavelength Tables.*

HYPERFINE STRUCTURE

The eight levels of the terms $f^3(^4I^\circ)\cdot s^5I^\circ$ and $^3I^\circ$ have marked hyperfine structure which appears to be due mainly to the interaction of the 6s electron with the moment of the nucleus. It is of interest to apply to this case the equations given by Goudsmit and Bacher.[13] The change in atomic energy due to the interactions between electronic and nuclear moments (h.f.s.) is given by

$$\Gamma_F = \tfrac{1}{2}A[F(F+1) - I(I+1) - J(J+1)], \quad (1)$$

where J represents the mechanical moment of the electrons, I that of the nucleus ($=5/2$ for Pr), F the total moment, and A is a number independent of F.

If we assume that the hyperfine structure is due to the s electron and that there is JJ coupling between the latter and the ion, then, as shown by Goudsmit and Bacher,

$$A = a\frac{J(J+1) + s(s+1) - J'(J'+1)}{2J(J+1)}, \quad (2)$$

[12] McNally, Harrison, and Albertson, to be published shortly.

[13] S. Goudsmit and R. F. Bacher, Phys. Rev. **34**, 1501 (1929).

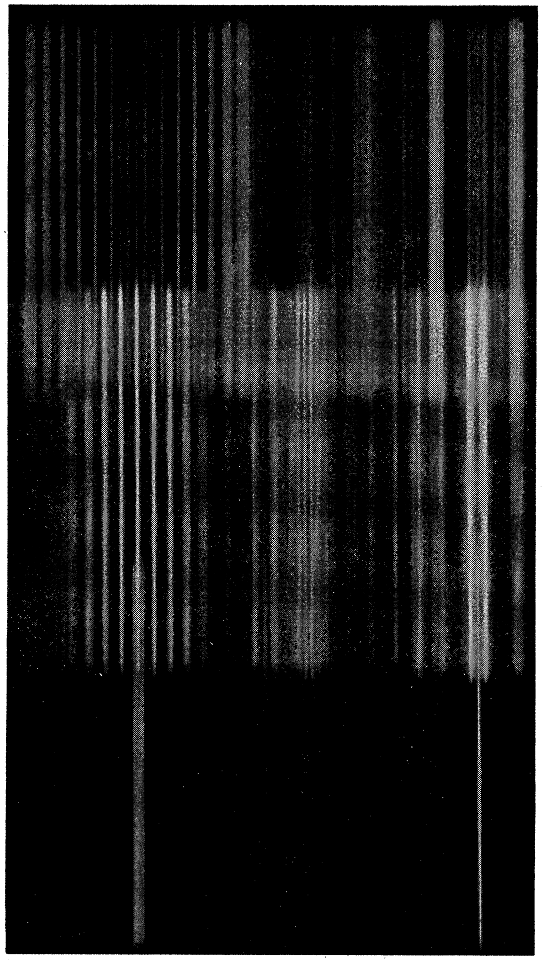

FIG. 2. Zeeman patterns of Pr II line showing hyperfine structure. Below, no-field pattern; middle, n components; above, p components. The strong line at the left is λ4368.327A.

where s is the spin of the electron $(=\frac{1}{2})$, J' the moment of the ion, and a a constant which measures the strength of the interaction between the s electron and the nuclear moment.

There are two cases to be considered. For the levels ${}^5I^\circ{}_{5,6,7,8}$

$$J' = J - \tfrac{1}{2}$$

and (2) gives

$$A = a/2J. \tag{3}$$

For the levels ${}^5I^\circ{}_4$ and ${}^3I^\circ{}_{5,6,7}$

$$J' = J + \tfrac{1}{2}$$

and

$$A = -a/[2(J+1)]. \tag{4}$$

The difference in signs of (3) and (4) is in agreement with the observed difference in the shading of the h.f.s. for lines involving the two groups of levels.

For $J>1$, the total width of the hyperfine structure $\Delta\sigma$ is found from (1) to be given by

$$\Delta\sigma = \Gamma_{J+I} - \Gamma_{J-I} = AI(2J+1). \tag{5}$$

In attempting to make a quantitative comparison of theory and observation, one is confronted with the difficulty that there is a great deal of variation in the measured h.f.s. data[1] for lines going to a common level that is responsible for the observable h.f.s. One can take an average over these lines to get information about the level in question, but it is to be expected that some uncertainty will remain.

Table VI gives the $\Delta\sigma$ values for the eight levels as determined from White's h.f.s. data for those lines the classification of which we have confirmed with Zeeman measurements. A minus sign indicates that the h.f.s. is inverted. From the $\Delta\sigma$ in each case the corresponding value of a was calculated by means of (5) and (3) or (4). The various calculated values differ somewhat,

TABLE VI. *Values of* $\Delta\sigma$ *from White's h.f.s. data.*

LEVEL	$\Delta\sigma$(OBS.)	a(CALC.)	$\Delta\sigma$(CALC.).
${}^5I^\circ{}_4$	−0.80	+0.36	−0.90
${}^3I^\circ{}_5$	−0.74	0.32	−0.92
${}^3I^\circ{}_6$	−0.84	0.36	−0.93
${}^3I^\circ{}_7$	−0.91	0.39	−0.94
${}^5I^\circ{}_5$	+1.13	0.41	+1.10
${}^5I^\circ{}_6$	+1.10	0.41	+1.08
${}^5I^\circ{}_7$	+1.05	0.39	+1.07
${}^5I^\circ{}_8$	+1.11	0.42	+1.06

TABLE VII. *g sums for* $f^3({}^4I^\circ)\cdot s$ *levels of* Pr II.

TERM	g(MEAS.)	$g(LS)$	$g(J_j)$	J_j	SUM g(MEAS.)	SUM g(THEOR.)
$a^5I^\circ{}_4$	0.605	0.600	0.600	$(4\frac{1}{2}, \frac{1}{2})$		
					0.605	0.600
$a^5I^\circ{}_5$	0.875	0.900	0.855	$(4\frac{1}{2}, \frac{1}{2})$		
$a^3I^\circ{}_5$	0.860	0.833	0.878	$(5\frac{1}{2}, \frac{1}{2})$		
					1.735	1.733
$a^5I^\circ{}_6$	1.064	1.071	1.051	$(5\frac{1}{2}, \frac{1}{2})$		
$a^3I^\circ{}_6$	1.037	1.024	1.044	$(6\frac{1}{2}, \frac{1}{2})$		
					2.101	2.095
$a^5I^\circ{}_7$	1.177	1.179	1.171	$(6\frac{1}{2}, \frac{1}{2})$		
$a^3I^\circ{}_7$	1.143	1.143	1.151	$(7\frac{1}{2}, \frac{1}{2})$		
					2.320	2.322
$a^5I^\circ{}_8$	1.250	1.250	1.250	$(7\frac{1}{2}, \frac{1}{2})$		
					1.250	1.250

TABLE VIII. *g sums for even levels of* Pr II.

	9		8		7		6		5		4	
	g_M	g_T	g_M	g_T	g_M	g_T	g_M	g_T	g_M	g_T	g_M	g_T
z^5K_5									0.821	0.667		
z^5I_4											0.684	0.600
z^5K_6							0.959	0.905				
z^3K_6							0.992	0.857				
z^5I_5									0.911	0.900		
z^3I_6							1.009	1.024				
z^5H_4											0.905	0.900
z^5K_7					1.062	1.054						
z^5I_6							1.042	1.071				
z^5I_7					1.123	1.179						
z^3H_6							1.073	1.167				
z^5H_5									1.101	1.100		
z^5K_8			1.143	1.153								
z^3K_7					1.106	1.018						
z^5I_8			1.154	1.250								
z^5H_6							1.103	1.214				
z^3I_7					1.187	1.143						
z^5K_9	1.217	1.222										
z^5H_7					1.215	1.286						
Sums	1.217	1.222	2.297	2.403*	5.693	5.680	6.178	6.238	2.833	2.667*	1.589	1.500*

* Indicates that all terms of that particular j value derivable from parent term ^4I+p have not been found and g sum rule is not applicable. This assumes that ^4I is perfect LS coupling.

partly because of errors in the values of $\Delta\sigma$ and partly, probably, because of incomplete JJ coupling, etc. By taking

$$a=0.40 \text{ cm}^{-1},$$

the value of $\Delta\sigma$ was calculated in each case on the basis of the above equations. It is evident that the agreement is quite satisfactory.

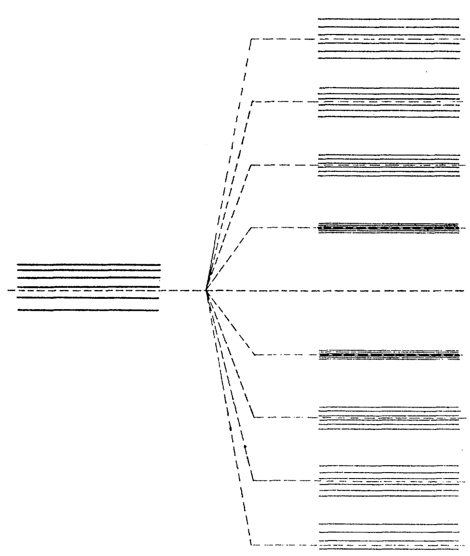

FIG. 3. Effect of a strong magnetic field in breaking a normal hyperfine-multiple level, $a^5I^\circ_4$, containing six levels, up into 54 levels.

In the presence of the magnetic field which is used to produce the Zeeman effects, the character of the h.f.s. changes completely. The magnetic field used in practice is a strong field from the standpoint of the h.f.s. and hence it destroys the coupling between I and J, so that the component of each in the direction of the field is quantized nearly independently (Back-Goudsmit effect).[14]

In this case the change in atomic energy due to the external magnetic field and the magnetic moment of the nucleus is given by

$$\Delta E=(-g_I M_I+gM)\frac{He}{4\pi mc^2}+AM_IM, \quad (6)$$

where M and M_I are the components along the field of J and I, respectively, A is the same constant as in (1), g is the usual g factor for the extra-nuclear electrons, and g_I is the nuclear g factor. Since g_I is usually small compared to g, one can take

$$\Delta E=gM\frac{He}{4\pi mc^2}+AM_IM. \quad (7)$$

The first term in the right-hand member corresponds to the ordinary Zeeman effect, the

[14] E. Back and S. Goudsmit, Zeits. f. Physik **47**, 174 (1928).

second gives the h.f.s. In this case, the width of the h.f.s. is given by

$$\Delta\sigma = (\Delta E)_{M_I=+I} - (\Delta E)_{M_I=-I}. \quad (8)$$

Hence in a Zeeman pattern, the sharpest lines should be found near the center of the p and of each s branch, for which cases $|M|$ is a minimum. An example of this is to be seen in Fig. 2, which shows the no-field line 4368.327A and its Zeeman pattern. A diagram of the h.f.s. for the lower parent level of this line, $a^5I^\circ_4$ without and with a magnetic field, according to Eqs. (1) and (7), is given in Fig. 3, where the h.f.s. spacing has been exaggerated in comparison with the separations of the Zeeman components.

Calculation of g Sums

In Table VII are given the g sums for Pr II levels arising from the configuration $f^3(^4I^\circ)\cdot s$. It will be noted that the agreement between the measured and theoretical sums is usually within a few tenths of a percent, though perturbations much greater than this cause deviations of the individual terms. In Table VIII, which gives the g sums for even levels, the agreement is not quite so satisfactory.

We desire to acknowledge the able assistance of workers on the M.I.T.-W.P.A. Wavelength Project, and of Mr. W. J. Hitchcock. A grant from the Rumford Committee of the American Academy of Arts and Sciences in support of the work is gratefully acknowledged.

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On the $^2\Pi_u \rightarrow {}^2\Pi_g$ Bands of CO_2^+. Part I

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The band spectrum appearing in emission in the region λ2900–4300 and believed to belong to the CO_2^+ or possibly CO_2 molecule has been studied and the excitation conditions found to be in substantial agreement with the former results of Duffendack and collaborators and of Smyth. The bands have been obtained with great intensity and photographs of most of them have been made in the second order of the 30-foot grating (actually obtained resolving power of 350,000). The rotational structure and the excitation conditions show that most of the bands belong to an extensive $^2\Pi \rightarrow {}^2\Pi$ system of bands of the molecule CO_2^+. The molecule is linear in both states; the lower $^2\Pi$ appears to be the ground state $^2\Pi_g$ and the upper $^2\Pi$ is the first excited state $^2\Pi_u$ of this molecule predicted by Mulliken. The complete rotational and vibrational analysis of this band system is still in progress; in this paper the analysis of 5 double bands of the $v''_1 = v''_2 = v''_3 = 0$ progression of the symmetrical vibration (v'_1 varying, $v'_2 = v'_3 = 0$) is presented. The results of the analysis are: $\nu_0^{(0,0)} = 28{,}532.60(^2\Pi_{3/2} \rightarrow {}^2\Pi_{3/2})$ and $\nu_0^{(0,0)} = 28{,}468.48(^2\Pi_{\frac{1}{2}} \rightarrow {}^2\Pi_{\frac{1}{2}})$. The vibrational intervals (i.e., the distances between the origins of successive bands in the progression) are: $\Delta G'_1 = 1126.71$; $\Delta G'_2 = 1122.66$; $\Delta G'_3 = 1120.22$; $\Delta G'_4 = 1120.04$ (all $^2\Pi_{3/2u}$) and $\Delta G'_1 = 1125.97$; $\Delta G'_2 = 1120.79$; $\Delta G'_3 = 1116.09$; $\Delta G'_4 = 1111.76$ (all $^2\Pi_{\frac{1}{2}u}$). Further for $^2\Pi_{3/2g} B''_0 = 0.3796$; for $^2\Pi_{\frac{1}{2}g} B''_0 = 0.3812$; for $^2\Pi_{3/2u} B'_0 = 0.3485$; $B'_1 = 0.3475$; $B'_2 = 0.3465$; $B'_3 = 0.3457$; $B'_4 = 0.3453$; for $^2\Pi_{\frac{1}{2}u} B'_0 = 0.3501$; $B'_1 = 0.3492$; $B'_2 = 0.3483$; $B'_3 = 0.3475$; $B'_4 = 0.3466$. The Λ-doubling is observable only in the $^2\Pi_{\frac{1}{2}} \rightarrow {}^2\Pi_{\frac{1}{2}}$ sub-bands in this progression; in $^2\Pi_u$ it is bigger than in $^2\Pi_g$ ($p''_0 = 0.004$ for $v''_1 = 0$) and increases fast with the vibrational energy.

Introduction

When a gas through which a discharge is passing contains carbon dioxide (or CO), in addition to the bands belonging to CO and CO^+ a great number of bands appear in the spectrum in the region λ2800–4500: the most prominent of these is the double band at λ2883–2896, which appears whenever the smallest traces of CO_2 (or CO) are present. All these bands have been observed by many investigators (some of them as far back as 1802), but there was considerable uncertainty about their emitter,

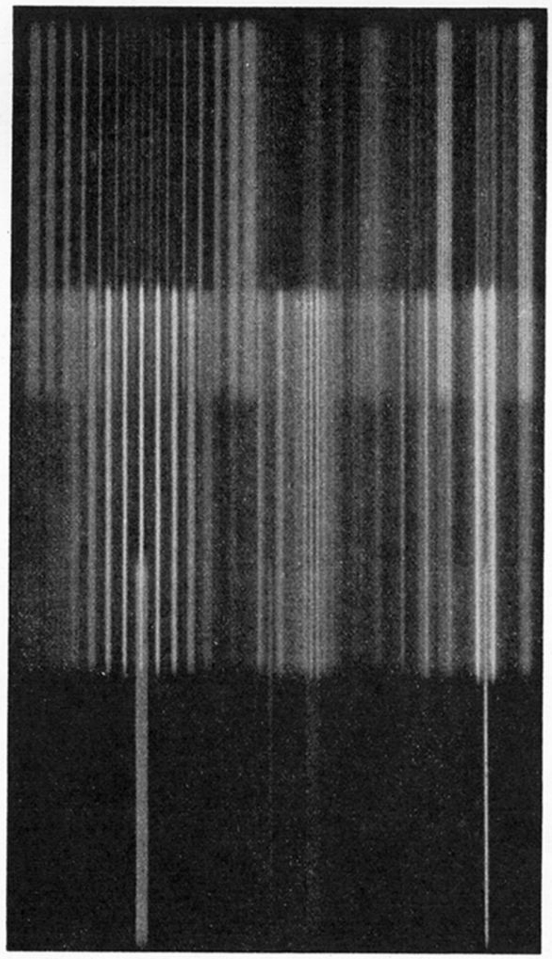

FIG. 2. Zeeman patterns of Pr II line showing hyperfine structure. Below, no-field pattern; middle, *n* components; above, *p* components. The strong line at the left is λ4368.327A.