JULY, 1928 *PHYSICAL REVIEW* *VOLUME 32*

THE FIRST SPARK SPECTRUM OF PALLADIUM (Pd II)

BY A. G. SHENSTONE

ABSTRACT

An analysis of Pd II is given which differs completely from the previous one made by McLennan and Smith. The terms found include $4d\,^2D(4d^9)$; $5s\,^{4\&2}F$, $^{4\&2}P$, ^2D, $^2G(4d^85s)$; all the related triads from the structure $4d^85p$; $6s\,^{4\&2}F$, $^4P_3$, $^2G_5(4d^86s)$; and fragments of terms due to $4d^85d$. Zeeman effects of the majority of the lines have been measured and approximate g-values found for the low and middle sets of terms. The g-values depart largely from Landé's values, as do also the term intervals. Evidence is given that the term predicted by theory, $5s\,^2S(4d^85s)$, is present but it has not been fixed with respect to the other terms. The lowest term $4d\,^2D$ gives lines in the vacuum region and was found by Mr. H. E. White, of Cornell University, from plates taken there. The ionization potential is calculated from the $s\,^4F$ terms as 19.8 volts from $4d^9$ to $4d^8$. As in other spectra of this type there is some indication in the limits of the component series that the Hund theory of limits is incorrect.

AN ANALYSIS of the first spark spectrum of palladium has been given by McLennan and Smith.[1] The great dissimilarity between that analysis and the one found for the spark spectrum of nickel[2] led the author to examine the previous analysis of Pd II in detail. The following paper presents a new analysis which differs in every detail from that given by McLennan and Smith.

The spectrum has been measured by a number of observers, but the old measurements of Exner and Haschek have been utilized in the present analysis, because they are in general very reliable and in addition are more complete. The author has also had the advantage of the measurements and intensity estimates made by Dr. Meggers of the Bureau of Standards, to whom he is very grateful. In the region below λ2250, new measures have been made using an Hilger E.1 quartz spectrograph, the standards being the copper spark lines calculated by the author.[3] In addition the whole spectrum has been photographed in order to make observations of the relative intensities in the spark and in long arc exposures. The lines may be divided into a number of very distinct classes: (1) lines which are sharp and of comparable intensity in the arc and spark exposures; (2) lines which are diffuse in the spark and appear with lower intensity in the arc; and (3) lines which are sharp in the spark and which appear faintly or not at all in the arc. Class 1 contains the lines due to transitions to the low set of terms; Class 2, lines due to transitions to the middle terms; and Class 3, lines due to higher ionizations. The appearance of some lines of Class 3 in the arc is probably due to the very unsteady nature of the arc which allows high potential differences to exist momentarily. The wave-lengths of the lines of Class 2 are of

---

[1] J. C. McLennan and H. G. Smith, Proc. Roy. Soc. **A112**, 110 (1926).

[2] A. G. Shenstone, Phys. Rev. **30**, 255 (1927).

[3] A. G. Shenstone, Phys. Rev. **29**, 380 (1927).

the order of 0.08 angstroms longer in the spark than in the arc. This is the usual experience with diffuse spark lines.

The term structure of Pd II can be simply predicted from the Hund theory. The low terms should be ^2D from the structure $4d^9$: ^4F, ^2F, ^4P, ^2P, ^2D, ^2G, ^2S from the structure $4d^85s$. The middle set of terms should be the triads associated with each of these terms, excluding $^2D(d^9)$ which, of course, has no triad of its own but may combine with all the other triads. In particular, the strongest lines should be due to the transitions from the triad $^{4\&2}D$, F, $G(d^8p)$ to $^{4\&2}F(d^8s)$. The leading lines of the three multiplets can be assigned immediately as λ2488.92, λ2296.53, λ2231.59, the only three spark lines found by Meggers and Laporte[4] as reversals in the under-water spark. The three corresponding diffuse lines λ2539.44, λ2776.85, λ2878.01, due to the combinations with the next series member $^4F_5(4d^86s)$, yield immediately the approximate I.P. = 16.7 volts, from $4d^85s$ to $4d^8$. The remaining terms were found by the usual method of frequency differences.

TABLE I. *Term Table for Pd II.*

No.	Term	Desig.	*g* Obs.	*g* Landé	No.	Term	Desig.	*g* Obs.	*g* Landé	Intervals	
1	−25081.	$4d\,^2D_3$			36	51673.5	$bp\,^4P_2$	*1.33*	1.73	$4d\,^2D$	3539.
2	−21542.	$4d\,^2D_2$			37	51686.4	$bp\,^4P_3$	1.36	1.60	$5s\,^4F$	2013.3; 1832.7; 1018.6
					38	51726.4	$bp\,^4P_1$	*2.25*	2.67	^2F	2144.1
3	0.0	$5s\,^4F_5$	1.33	1.33	39	53684.3	$cp\,^2F_3$	1.10	.86	^4P	1083.5; 1137.4.
4	2013.3	$5s\,^4F_4$	1.24	1.24	40	54531.4	$cp\,^2P_1$	*1.16*	.67	^2D	−1627.2
5	3846.0	$5s\,^4F_3$	1.03	1.03	41	54627.0	$cp\,^2F_4$	1.26	1.14	^2P	292.0
6	4864.6	$5s\,^4F_2$	*.40*	.40	42	55875.1	$cp\,^2P_2$	1.16	1.33	^2G	108.2
7	7196.9	$5s\,^2F_4$	1.20	1.14	43	56476.2	$cp\,^2D_2$	*1.26*	.80	$ap\,^4D$	2715.2; 2157.6; 1059.1
8	9341.0	$5s\,^2F_3$	1.10	.86	44	56724.0	$bp\,^4D_1$	*.07*	.00	^4F	1366.3; 1867.7; −764.4
9	11200.5	$5s\,^4P_3$	1.36	1.60	45	56976.0	$cp\,^2D_3$	1.25	1.20	^4G	−1312.5; 2311.2; 1459.3
10	12284.0	$5s\,^4P_2$	*1.47*	1.73	46	57252.7	$bp\,^4D_2$	*1.22*	1.20	^2D	2365.4
11	13421.4	$5s\,^4P_1$	*2.73*	2.67	47	57369.0	$bp\,^4D_3$	1.30	1.37	^2F	2426.1
12	14490.1	$5s\,^2D_2$	1.20	.80	48	57975.3	$bp\,^4D_4$	1.29	1.43	^2G	2033.7
13	16117.3	$5s\,^2D_3$	1.30	1.20	49	58708.7	$kp\,^2H_5$	.91	.91		
14	18566.8	$5s\,^2P_2$	*1.25*	1.33	50	58721.5	$ep\,^2D_3$	1.20	1.20	$bp\,^4P$	−12.9; 52.9
15	18858.8	$5s\,^2P_1$	*.69*	.67	51	59291.3	$ep\,^2D_2$	.80	.80	^4D	−606.3; −116.3; −528.7
16	19424.7	$5s\,^2G_5$	1.11	1.11	52	59989.7	$ep\,^2S_1$	*1.88*	2.00		
17	19532.9	$5s\,^2G_4$	.89	.89	53	60070.0	$ep\,^2P_2$	*1.50*	1.33	$cp\,^2P$	−1343.7
					54	60511.9	$kp\,^2H_6$	1.09	1.09	^2D	−499.8
18	40166.0	$ap\,^4D_4$	1.43	1.43	55	60962.1	$kp\,^2F_4$	1.14	1.14	^2F	−942.7
19	42218.0	$ap\,^4G_5$	1.17	1.17	56	61198.6	$bp\,^4S_2$	2.00	2.00	$ep\,^2P$	2887.1
20	42881.2	$ap\,^4D_3$	1.37	1.37	57	62039.4	$kp\,^2F_3$	.86	.86	^2D	569.8
21	43530.5	$ap\,^4G_6$	1.27	1.27	58	62957.1	$ep\,^2P_1$	*.70*	.67	$kp\,^2F$	1077.3
22	44529.2	$ap\,^4G_4$	.97	.97	59	64601.5	$kp\,^2G_4$	.89	.89	^2G	−299.9
23	44797.4	$ap\,^4F_5$	1.33	1.33	60	64901.4	$kp\,^2G_5$	1.11	1.11	^2H	−1803.2
24	45038.8	$ap\,^4D_2$	*1.20*	1.20							
25	45988.5	$ap\,^4G_3$	.66	.57	61	79532.8	$6s\,^4F_5$			$6s\,^4F$	691.8; 2839.7; 1182.2
26	46097.9	$ap\,^4D_1$	.00	.00	62	80224.6	$6s\,^4F_4$			^2F	1782.7
27	46163.7	$ap\,^4F_4$	1.18	1.24	63	83062.9	$6s\,^2F_4$				
28	47204.0	$ap\,^2G_5$	1.11	1.11	64	83064.3	$6s\,^4F_3$				
29	47267.0	$ap\,^4F_2$	.68	.40	65	84246.5	$6s\,^4F_2$			Ionization Potential	
30	47651.6	$ap\,^2D_3$	*1.05*	1.20	66	84845.6	$6s\,^2F_3$			$4d^9$ to $4d^8 = 19.8$ Volts	
31	48031.4	$ap\,^4F_3$	*1.04*	1.03	67	85122.2	$5d\,^4D_4$			$4d^85s$ to $4d^8 = 16.7$ Volts	
32	48246.5	$ap\,^2F_4$	1.14	1.14	68	85804.0	$5d\,^4F_5$				
33	49237.7	$ap\,^2G_4$	.89	.89	69	86007.5	$5d\,^4F_4$				
34	50017.0	$ap\,^2D_2$	*.86*	.80	70	87791.7	$5d\,^4G_5$				
35	50672.6	$ap\,^2F_3$	1.16	.86	71	89856.5	$6s\,^4P_3$				
					72	97621.8	$6s\,^2G_5$				

Terms	*g*-sums Obs.	*g*-sums Landé	Terms	*g*-sums Obs.	*g*-sums Landé	Terms	*g*-sums Obs.	*g*-sums Landé
$5s$			ap			bp, cp		
$j=4$	3.33	3.27	$j=4$	5.61	5.67	ep, kp		
$j=3$	4.79	4.69	$j=3$	5.28	5.03	$j=4$	4.58	4.60
$j=2$	4.32	4.26	$j=2$	2.74	2.40	$j=3$	7.07	7.09
$j=1$	3.42	3.34	$j=1$	.00	.00	$j=2$	9.27	9.19
						$j=1$	6.01	6.06

---

[4] W. F. Meggers and Otto Laporte, Phys. Rev. **28**, 642 (1926).

The main criterion used in determining the nature of the terms was intensities, the large scale on which these were estimated by Dr. Meggers being particularly useful. In addition, however, Zeeman effects of the majority of the sharp lines were measured. They are discussed below.

In Table I are given the term values, taking the low term $5s^4F_5$ as zero. The lower term $4d^2D_3$ has not been taken as zero because of the fact that its value is based on the less accurately determined wave-lengths around λ1300. The intensities in the principal multiplets are shown in Table II. It will be seen that the intensity rules are reasonably satisfied, with the exceptions (1.) the entire absence of the line $5s^4F_4$–ap^4D_4, theoretically of intensity at least 20, and (2.) the rather large intensity of $5s^4F_3$–ap^4F_4. The term which has been taken as ap^2F_4 might have been interchanged with ap^4F_4 but for the fact that the combinations with $6s^4F$ settle the multiplicities unambiguously.

TABLE II. *Intensities in principle multiplets.*

	$5s^4F_5$	$^4F_4$	$^4F_3$	$^4F_2$	$^2F_4$	$^2F_3$
ap^4D_4	300	—	—		30	25
$^4D_3$		150	20	—	8	50
$^4D_2$			100	10		—
$^4D_1$				75		
$^4F_5$	100R	30			150	
$^4F_4$	10	40	50		150	30
$^4F_3$		20	30	10	80	40
$^4F_2$			10	40		70
$^4G_6$	200R					
$^4G_5$	75	250			200	
$^4G_4$	—	50	100		10	30
$^4G_3$		10	60	100	30	20
$^2D_3$		—	25	30	100	1
$^2D_2$			10	30		60
$^2F_4$	10	50	20		100	100
$^2F_3$		15	3	50	20	75
$^2G_5$	15	50			200	
$^2G_4$	—	7	30		20	150

It will be noticed in Table I that the interval rule is not even approximately true in this spectrum. But it is very surprising that the term ap^4F_2 is lower than ap^4F_3. As far as intensities are concerned there is no choice between ap^4F_2 and ap^2D_2, but the intervals would be more anomalous if they were interchanged and in addition their Zeeman g's would be less in agreement with the Landé values.

ZEEMAN EFFECTS

The Zeeman patterns of the great majority of the sharp lines have been measured on plates taken with an Hilger E. 1 spectrograph. The magnetic field was about 34000 gauss and the times of exposure always less than an hour. Naturally, with such a spectrograph only wide patterns appear resolved, the remainder appearing as triplets, or as doublets in each polarization. The resolved patterns are given in Table III together with a few essential unresolved triplets, but it has been considered unnecessary to reproduce the very large number of unresolved effects measured. The resolved patterns have made it possible to calculate some of the g-values with reasonable accuracy and such values are in italics in the term table. The remainder of the g-values were determined from the unresolved patterns by choosing such values as would fit all the combinations of a given term most closely. The resulting g's are, of course, inaccurate; but, in cases where a large number of combinations occur they should not be in error by more than 5 percent. The pattern of every line measured is consistent with the G's calculated.

TABLE III. *Resolved Zeeman patterns of Pd II.*

	λ	$X-Y$	Z. E. Pattern	Approximate		Remarks
				g_x	g_y	
1.	2488.41	$5s^4F_2-ap^4D_2$	O (−*1.20*) *0* .86? 1.63 C (−1.20) 0 *.80* 1.60	.40	1.20	Resolved completely
2.	2424.49	$5s^4F_2-ap^4D_1$	O (0) .56 C (.20) .20, .60	.40	0.0	
3.	2336.43	$5s^4F_2-ap^2D_3$	O (−.96)———*2.00* C (−.96)———*2.00*	.40	1.04	Resolved completely
4.	2315.87	$5s^4F_2-ap^4F_3$	O (−.93)———*1.99* C (−.93)———*1.99*	.44	1.06	Resolved completely
5.	2282.11	$5s^4F_3-ap^2D_3$	O (0) 1.06 C (0) 1.06	1.06	1.06	
6.	2262.52	$5s^4F_3-ap^4F_3$	O (0) 1.03 C (0) 1.03	1.03	1.03	
7.	2534.37	$5s^4P_2-bp^4P_1$	O (.39) *1.07* 1.86 C (.39) *1.08* 1.86	1.47	2.25	
8.	2731.80	$5s^4P_1-ap^2D_2$	O (.93) *0* C (.93) *.07* 1.79	2.72	.86	
9.	2613.42	$5s^4P_1-bp^4P_2$	O (.65) *.68* C (.68) *.68* 2.04	2.63	1.33	Very faint pattern
10.	2431.78	$5s^4P_1-cp^2P_1$	O (.80) 1.96 C (.80) 1.96	2.76	1.16	Very faint pattern
11.	2354.76	$5s^4P_1-cp^2P_2$	O (.78) *.39* 1.97 C (.78) *.38* 1.94	2.76	1.16	
12.	2321.91	$5s^4P_1-cp^2D_2$	O (.75) *.50* 2.01 C (.75) .51 2.01	2.76	1.26	
13.	2308.60	$5s^4P_1-bp^4D_1$	O (1.34) 1.41 C (1.34) 1.41	2.75	.07	
14.	2280.79	$5s^4P_1-bp^4D_2$	O (.74) *.47* 1.96 C (.74) *.48* 1.96	2.70	1.22	
15.	2637.08	$5s^2P_2-cp^2D_2$	O (0) 1.25 C (0) 1.25	1.25	1.25	
16.	2602.76	$5s^2P_2-cp^2D_3$	O (0) 1.24 C (0) 1.24	1.24	1.24	
17.	2413.37	$5s^2P_2-ep^2S_1$	O (.30) *.95*— C (.30) *.95* 1.55	1.25	1.85	
18.	2430.53	$5s^2P_1-ep^2S_1$	O (.62) 1.28 C (.62) 1.28	.66	1.90	
19.	2425.78	$5s^2P_1-ep^2P_2$	O (.39) 1.14 *1.89* C (.39) 1.11 *1.89*	.72	1.50	
20.	2266.96	$5s^2P_1-ep^2P_1$	O (0) .70 C (0) .70	.70	.70	Very faint
21.	2433.11	$5s^2G_5-kp^2H_6$	O (0) 1.07 C (0) 1.05 (Blend)	1.11	1.09	
22.	2218.15	$5s^2G_4-kp^2G_4$	O (0) .93 C (0) .89	.89	.89	
23.	2330.05	$5s^2S_1-{}^2P_1$?	O (.70) 1.36 C (.67) 1.33	2.00	.67	Unplaced line

An examination of the g's given in the term table shows at once how far from regular this spectrum is. Amongst the low terms, $5s^2F_3$ and $5s^2D_2$ have exceptionally high values, whereas $5s^4P_3$ and $5s^4P_2$ have very low ones. The outstanding features in the ap triad are the very high g-values for ap^4F_2 and ap^2F_3. With the term table there is also given a comparison of the sums of the observed g's with the g-sums obtained from Landé's values. The agreement is excellent except in two cases in the ap triad.

The triads associated with the low $5s^4P$, ^2P, ^2D, ^2G are all overlapping in the region of terms between 51000 and 65000. By considering the intensities and the Zeeman effects for this group of terms, it is possible to assign designations to all of them with considerable certainty. They then fall naturally into groups which, from the fact that they combine most strongly with one or another of the low terms, evidently belong together. Table IV shows this grouping.

TABLE IV. *Origin of Terms of Pd II.*

Pd III		Added Electron	Terms	
Config.	Term		Theoretical	Empirical
$4d^8$	All	$4d$	^2D	$4d^2D$
	^3F	$5s$	$^{4\&2}F$	$5s^{4\&2}F$
		$5p$	$^{4\&2}D, F, G$	$ap^{4\&2}D, F, G$
		$6s$	$^{4\&2}F$	$6s^{4\&2}F$
		$5d$	$^{4\&2}P, D, F, G, H.$	$5d^4D, F, G,$ (Parts of)
	^3P	$5s$	$^{4\&2}P$	$5s^{4\&2}P$
		$5p$	$^{4\&2}S, P, D.$	$bp^4S, P, D.$
				$ep^2S, P, D.$
		$6s$	$^{4\&2}P$	$6s^4P_3$
	^1S	$5s$	^2S	Possibly present
		$5p$	^2P	
	^1D	$5s$	^2D	$5s^2D$
		$5p$	$^2P, D, F$	$cp^2P, D, F.$
	^1G	$5s$	^2G	$5s^2G.$
		$5p$	$^2F, G, H.$	$kp^2F, G, H.$
		$6s$	^2G	$6s^2G_5$

The extreme irregularity of the intervals and g's should be noted. bp^4P is very narrow and bp^4D is completely inverted; the kp group contains both positive and negative intervals.

THE LOW ^{2}D TERM

The lowest term of Pd II should theoretically be the ^2D arising from the structure $4d^9$. Since this term is now known in Ni II[2] a prediction of its position in Pd II can be made from the relative change in the equivalent $^1S(d^{10})$ between the spectra Cu II[3] and Ag II.[5] The prediction places the ^2D term about 25500 below $5s^4F_5$, which would bring its strong combinations with the ap triad about λ1400. The term is actually found to have the values $-25081(j=3)$ and $-21542(j=2)$ and gives 51 lines in combination

---

[5] A. G. Shenstone, Phys. Rev. **31**, 317 (1928).

with the terms of the structure $4d^8 5p$. This $4d^2D$ term was found by Mr. H. E. White, of Cornell University, from his own measurements and the values of the $5p$-terms found by the author. The term combines indiscriminately with quartet and doublet terms as is the case also in Rh I.[6] The strongest lines are produced in combination with ap^2D, the ap^2F lines being unexpectedly weak.

In a recent letter to "Nature"[7] the author has pointed out that there are three complete series members of the ${}^3D{}^1D(d^9s)$ series of Pd I. The third member of this series includes McLennan and Smith's term a^3G_4 as ${}^3D_3$, the remainder being their 3^3D & ${}^1D$ with the ${}^1D_2$ and ${}^3D_2$ interchanged. The series of ${}^3D_3$ and ${}^3D_1$ terms have as limits the 4^2D_3 & 4^2D_2 terms of Pd II. As in all other series of this type, the separation ${}^3D_3 - {}^3D_1$ is practically constant and equal to ${}^2D_3 - {}^2D_2$. The term differences in the present case are as follows:

1st member $({}^3D_2 - {}^3D_1) = 3529.9$
2nd member $({}^3D_2 - {}^3D_1) = 3532.1$
3rd member $({}^3D_2 - {}^3D_1) = 3538.7$
Limit Pd II $({}^2D_3 - {}^2D_2) = 3539.$

MISSING TERMS

Table I includes all the terms predicted by the Hund theory for the assumed structures, with the following exceptions: (1) a ${}^2S_1$ from $4d^8 5s$, and (2) the ${}^2P(4d^8 5p)$ which forms the whole triad connected with that ${}^2S$. There are just five lines of Class 1 which remain unaccounted for by the terms of Table I. Of these lines λ2430.05 (2) has the Zeeman pattern characteristic of ${}^2S_1 - {}^2P_1$ and λ2322.59 (5) a pattern which could be that of ${}^2S_1 - {}^2P_2$. All attempts to connect these lines with the rest of the spectrum have failed because of the paucity of combinations. It should be noted that neither the terms in question, nor the ${}^1S(d^8)$ on which they are built, have been identified in any spectrum, as far as the author is aware.

DIFFUSE LINES

The spectrum contains a very large number of diffuse lines which must be produced by combinations of the middle terms with high terms from the structures $4d^8 6s$ and $4d^8 5d$. All the most intense are accounted for by the former structure which gives the terms $6s\,{}^{4\&2}F$. Some search has been made for other high terms and a few are given in the term table as identified. Undoubtedly, a great many more could be found, but the inaccuracy of the measurements of the diffuse lines is so great that it is frequently difficult to be sure of the reality of a term.

In Table V are given all the identified lines of the spectrum. The five unidentified lines, mentioned above, have also been included.

---

[6] L. A. Sommer, Zeits. f. Physik **45,** 147 (1927).

[7] A. G. Shenstone, Nature **121,** 619 (1928).

TABLE V. *Classified lines of the palladium spark spectrum.*

λ	Auth.	Int.	ν	Combination
4156.95	E	1	24049.3	$5s^2D_3-ap^4D_4$
3999.46	E	1	24996.3	$5s^2G_4-ap^4G_4$
3982.25	E	1	25104.4	$5s^2G_5-ap^4G_4$
3818.70	E	1	26179.5	$5s^2P_1-ap^4D_2$
3778.83	E	1	26455.7	$5s^2G_4-ap^4G_3$
3738.84	E	6	26738.7	$5s^2G_5-ap^4F_4$
3735.36	E	1	26763.6	$5s^2D_3-ap^4D_3$
3670.12	E	1	27239.3	$5s^2P_1-ap^4D_1$
3598.72	E	1	27779.8	$5s^2G_5-ap^2G_5$
3555.33	E	1	28118.8	$5s^2G_4-ap^2D_3$
3507.95	E	7A	28498.6	$5s^2G_4-ap^4F_3$
3468.57	E	8A	28822.1	$5s^2G_5-ap^2F_4$
3451.37	E	20A	28965.7	$5s^4P_3-ap^4D_4$
3382.90	E	1	29552.0	$ap^2F_3-6s^4F_4$
3353.36	E	4A	29812.3	$5s^2G_5-ap^2G_4$
3346.77	E	2A	29871.0	$5s^2D_3-ap^4G_3$
3327.23	E	10A	30046.4	$5s^2D_3-ap^4F_4$
3272.56	E	10A	30548.3	$5s^2D_2-ap^4D_2$
3267.36	E	30A	30597.0	$5s^4P_2-ap^4D_3$
3243.13	E	25A	30825.5	$5s^2F_3-ap^4D_4$
3210.43	E	10A	31139.5	$5s^2G_4-ap^2F_3$
3209.42	E	2A	31149.3	$5s^2D_3-ap^4F_2$
3178.77	E	5A	31449.6	$5s^2P_2-ap^2D_2$
3173.88	E	2A	31498.1	$5s^2D_2-ap^4G_3$
3170.26	E	20A	31534.1	$5s^2D_3-ap^2D_3$
3162.86	E	4A	31607.8	$5s^2D_2-ap^4D_1$
61.95	E	25A	31616.9	$5s^4P_1-ap^4D_2$
55.59	E	15A	31680.7	$5s^4P_3-ap^4D_3$
35.78	S	10ua	31880.8	$bp^4D_4-6s^4P_3$
32.49	E	10A	31914.3	$5s^2D_3-ap^4F_3$
11.53	E	2A	32129.2	$5s^2D_3-ap^2F_4$
09.16	E	7A	32153.6	$5s^2G_4-bp^4P_3$
3105.33	E	8ua	32193.4	$ap^4F_3-6s^4F_4$
3086.53	S	3u	32389.5	$ap^2F_3-6s^2F_4$
69.2	E	3ua	32572.3	$ap^2D_3-6s^4F_4$ $bp^4P_2-6s^4F_2$
59.43	E	25A	32676.3	$5s^4P_1-ap^4D_1$
55.3	E	10ua	32720.5	$kp^2G_5-6s^2G_5$
52.14	E	20A	32754.4	$5s^4P_2-ap^4D_2$
50.06	E	10A	32776.7	$5s^2D_2-ap^4F_2$
46.49	E	2A	32815.1	$5s^2P_1-bp^4P_2$
41.66	E	8A	32867.2	$5s^2P_1-bp^4P_1$
32.20	E	30A	32969.8	$5s^2F_4-ap^4D_4$
19.63	E	7A	33107.0	$5s^2P_2-bp^4P_2$
18.47	E	8A	33119.8	$5s^2D_3-ap^2G_4$ $5s^2P_2-bp^4P_3$
15.06	S	5ua	33157.2	$bp^4P_3-6s^2F_3$?
3013.90	S	5ua	33170.0	$bp^4P_2-6s^2F_3$?
2999.55	E	40A	33328.7	$5s^4P_3-ap^4G_4$
80.63	E	50A	33540.2	$5s^2F_3-ap^4D_3$ $5s^2D_2-ap^4F_3$
2956.48	E	8A	33814.2	$5s^4P_2-ap^4D_1$
55.53	S	2ua	33825.0	$ap^2G_4-6s^2F_4$
54.37	E	15A	33838.3	$5s^4P_3-ap^4D_2$
53.78	E	2A	33845.1	$5s^4P_1-ap^4F_2$
49.09	E	3A	33898.9	$5s^2D_3-ap^2D_2$
35.01	E	20ua	34061.5	$ap^4F_4-6s^4F_4$
27.25	E	8A	34151.8	$5s^2G_4-cp^2F_3$
25.41	E	10ua	34173.3	$ap^2F_3-6s^2F_3$
2920.6	E	5ua	34229.5	$ap^2D_2-6s^4F_2$
2893.09	E	10A	34555.0	$5s^2D_3-ap^2F_3$
78.01	E	100ua	34736.1	$ap^4F_5-6s^4F_5$
71.37	E	100ua	34816.4	$ap^2F_4-6s^2F_4$
70.4	E	1ua	34828.2	$ap^2D_2-6s^2F_3$
59.29	E	8A	34963.5	$5s^4P_3-ap^4F_4$
57.70	E	20A	34982.9	$5s^4P_2-ap^4F_2$
54.59	E	200A	35021.0	$5s^2F_4-ap^4G_5$
53.64	E	10ua	35032.7	$ap^4F_3-6s^4F_3$
46.74	E	10A	35117.6	$5s^2P_2-cp^2F_3$
41.02	E	30A	35188.3	$5s^2F_3-ap^4G_4$
39.89	E	20A	35202.3	$5s^2G_5-cp^2F_4$
37.64	E	20ua	35230.2	$cp^2F_4-6s^4P_3$
29.2	E	5ua	35335.3	$ap^2F_3-5d^4F_4$
23.1	E	10ua	35411.7	$ap^2D_3-6s^2F_4$
21.91	E	30ua	35426.6	$ap^4F_5-6s^4F_4$
13.98	E	10A	35526.4	$5s^2D_2-ap^2D_2$
11.59	E	3A	35556.6	$5s^2D_3-bp^4P_2$
07.59	E	50ua	35607.3	$ap^2G_4-6s^2F_3$
02.46	E	10A	35672.4	$5s^2P_1-cp^2P_1$
01.54	E	8A	35684.2	$5s^2F_4-ap^4D_3$
2800.64	E	50ua	35695.6	$ap^4G_4-6s^4F_4$
2796.62	E	3A	35746.9	$5s^4P_2-ap^4F_3$
87.92	E	100ua	35858.5	$ap^2G_5-6s^2F_4$
79.69	E	5A	35964.6	$5s^2P_2-cp^2P_1$
76.85	E	150ua	36001.4	$ap^4G_6-6s^4F_5$
71.88	E	5A	36066.0	$5s^4P_3-ap^4F_2$
42.57	E	25A	36451.4	$5s^4P_3-ap^2D_3$
2731.80	E	15A	36595.1	$5s^4P_1-ap^2D_2$
27.82	E	20A	36647.4	$5s^2F_3-ap^4G_3$
26.92	E	5ua	36660.6	$kp^2F_4-6s^2G_5$
14.89	E	30A	36823.0	$5s^2F_3-ap^4F_4$
14.30	E	15A	36831.0	$5s^4P_3-ap^4F_3$
09.15	E	15ua	36901.0	$ap^4F_4-6s^4F_3$
2703.37	E	5ua	36979.8	$ap^4F_2-6s^4F_2$
2698.53	E	25A	37046.2	$5s^4P_3-ap^2F_4$
96.4	E	5ua	37075.5	$ap^4G_3-6s^4F_3$
93.9	E	10ua	37109.9	$kp^2H_6-6s^2G_5$
88.53	E	20A	37184.0	$5s^2D_2-bp^4P_2$
87.65	E	20A	37196.2	$5s^2D_2-bp^4P_3$
84.77	E	8A	37236.1	$5s^2D_2-bp^4P_1$
79.59	E	12A	37308.1	$5s^2P_2-cp^2P_2$
79.10	E	5ua	37314.9	$ap^4G_5-6s^4F_5$
77.86	E	10A	37332.2	$5s^2F_4-ap^4G_4$
77.05	E	5ua	37343.5	$ap^4D_3-6s^4F_4$
69.95	E	1	37442.8	$5s^2G_4-cp^2D_3$
61.15	E	10A	37566.6	$5\ {}^2D_3-cp^2F_3$
60.3	E	1u	37578.6	$ap^4F_2-6s^2F_3$
58.75	E	150A	37600.5	$5s^2F_4-ap^4F_5$
57.58	E	25A	37617.0	$5s^2P_1-cp^2D_2$
49.48	E	20A	37732.0	$5s^4P_2-ap^2D_2$
42.20	E	12A	37836.0	$5s^2G_4-bp^4D_3$
40.18	E	5A	37865.0	$5s^2P_1-bp^4D_1$
37.08	E	15A	37909.5	$5s^2P_2-cp^2D_2$
35.92	E	70A	37926.1	$5s^2F_3-ap^4F_2$
32.45	E	2u	37976.1	$ap^4F_3-5d^4F_4$
30.30	E	20ua	38007.2	$ap^4G_5-6s^4F_4$
29.00	E	5ua	38026.0	$ap^4D_2-6s^4F_3$
28.24	E	50A	38037.0	$5s^4P_3-ap^2G_4$
20.56	E	2ua	38148.4	$ap^4D_1-6s^4F_2$
19.07	E	4ua	38170.1	$bp^4P_3-6s^4P_3$
18.22	E	2ua	38182.5	$bp^4P_2-6s^4P_3$
13.42	E	20A	38252.6	$5s^4P_1-bp^4P_2$
13.15	S	4ua	38256.5	$ap^4G_3-6s^4F_2$
09.85	E	8A	38305.0	$5s^4P_1-bp^4P_1$
09.49	M	1	38310.9	$5s^2F_3-ap^2D_3$
06.36	E	2ua	38356.2	$ap^2D_3-5d^4F_4$
03.82	M	1A	38393.7	$5s^2P_1-bp^4D_2$
2602.76	E	35A	38409.3	$5s^2P_2-cp^2D_3$
2595.98	E	40A	38509.6	$5s^2D_3-cp^2F_4$
94.3	E	10ua	38534.3	$ap^4G_4-6s^4F_3$
93.24	E	60A	38550.3	$5s^2G_5-bp^4D_4$
89.70	S	1u	38602.9	$ap^2G_5-5d^4F_5$
84.13	E	5A	38686.2	$5s^2P_2-bp^4D_2$
83.84	E	40A	38690.5	$5s^2F_3-ap^4F_3$
77.08	E	30A	38792.0	$5s^2F_4-ap^4G_3$
76.39	E	15A	38802.4	$5s^2P_2-bp^4D_3$
75.46	E	10A	38816.4	$5s^4P_3-ap^2D_2$
72.7	E	1ua	38858.0	$ap^4G_3-6s^2F_3$
69.56	E	100A	38905.5	$5s^2F_3-ap^2F_4$
65.51	E	150A	38966.9	$5s^2F_4-ap^4F_4$
61.02	E	20A	39035.2	$5s^4F_3-ap^4D_3$
51.84	E	150A	39175.7	$5s^2G_4-kp^2H_5$
51.01	E	8A	39188.4	$5s^2G_4-ep^2D_3$
50.64	E	40A	39194.1	$5s^2D_2-cp^2F_3$
44.82	E	25A	39283.7	$5s^2G_5-kp^2H_5$
39.44	E	50ua	39367.0	$ap^4D_4-6s^4F_5$
37.94	E	8A	39390.2	$5s^4P_1-bp^4P_2$
37.13	E	10A	39403.8	$5s^4P_2-bp^4P_3$
34.57	E	80A	39442.6	$5s^4P_2-bp^4P_1$
32.66	E	1A	39472.3	$5s^4P_3-ap^2F_3$
21.86	E	4ua	39641.3	$ap^4F_4-5d^4F_5$
21.49	E	2u	39647.2	$bp^4D_4-6s^2G_5$
14.47	E	50A	39757.8	$5s^2D_3-cp^2P_2$
09.11	E	10ua	39842.8	$ap^4F_4-5d^4F_4$
2505.73	E	150A	39896.5	$5s^2F_3-ap^2G_4$
2498.81	E	200A	40007.0	$5s^2F_4-ap^2G_5$
96.72	E	40A	40040.5	$5s^2D_2-cp^2P_1$
89.61	E	75A	40154.8	$5s^2P_2-ep^2D_3$
88.92	E	300A	40166.0	$5s^4F_5-ap^4D_4$
88.41	E	10A	40174.2	$5s^4F_2-ap^4D_2$
86.52	E	250A	40204.7	$5s^4F_4-ap^4G_5$
79.11	E	20ua	40324.9	$ap^4F_5-5d^4D_4$
77.02	E	15A	40358.9	$5s^2D_3-cp^2D_2$
72.55	E	50A	40431.9	$5s^2P_1-ep^2D_2$
71.18	E	100A	40454.3	$5s^2F_4-ap^2D_3$
70.06	E	80A	40472.6	$5s^4P_3-bp^4P_2$
69.29	E	150A	40485.2	$5s^4P_3-bp^4P_3$
57.76	E	60A	40675.1	$5s^2F_3-ap^2D_2$
57.29	E	100A	40682.9	$5s^4F_3-ap^4G_4$
54.75	E	30A	40725.0	$5s^2P_2-ep^2D_2$
48.15	E	80A	40834.7	$5s^2F_4-ap^4F_3$
46.72	E	75A	40858.7	$5s^2D_3-cp^2D_3$
46.17	E	150A	40867.8	$5s^4F_4-ap^4D_3$
37.89	E	10ua	41006.6	$ap^4F_5-5d^4F_5$

TABLE V. (continued)

λ	Auth.	Int.	ν	Combination
2435.32	E	100A	41049.9	$5s^2F_4-ap^2F_4$
33.11	E	100A	41087.2	$5s^2G_5-kp^2H_6$
31.78	E	3A	41109.7	$5s^4P_1-cp^2P_1$
30.94	E	100A	41123.9	$5s^4F_2-ap^4G_3$
30.53	E	10A	41130.8	$5s^2P_1-ep^2S_1$
30.27	E	2A	41135.2	$5s^2D_3-bp^4D_2$
30.05	E	2A	41139.2	$5s^2S_1-{}^2P_1$?
26.87	E	100A	41192.8	$5s^4F_3-ap^4D_2$
25.78	E	10A	41211.3	$5s^2P_1-ep^2P_2$
24.49	E	75A	41233.3	$5s^4F_2-ap^4D_1$
23.42	E	2A	41251.5	$5s^2D_3-bp^4D_3$
22.09	E	2ua	41274.1	$ap^4G_4-5d^4F_5$
18.72	E	75A	41331.6	$5s^2F_3-ap^2F_3$
16.67	E	6ua	41366.7	$ap^4D_3-6s^4F_2$?
15.62	E	15A	41384.7	$5s^2D_2-cp^2P_2$
14.73	E	60A	41399.9	$5s^4P_3-cp^2F_3$
13.37	E	10A	41423.2	$5s^2P_2-ep^2S_1$
10.15	E	5ua	41478.6	$ap^4G_4-5d^4F_4$
08.71	E	20A	41503.4	$5s^2P_2-ep^2P_2$
06.75	E	40A	41537.2	$5s^2G_5-kp^2F_4$
01.47	E	30ua	41628.5	$ap^4F_4-5d^4G_5$
88.29	E	50A	41858.2	$5s^2D_3-bp^4D_4$
81.99	S	1A Fe?	41968.9	unidentified
81.02	E	1A	41986.0	$5s^2D_2-cp^2D_2$
77.90	E	20A	42041.1	$5s^2F_4-ap^2G_4$
72.16	E	60A	42142.8	$5s^4F_3-ap^4G_3$
67.92	E	75A	42218.2	$5s^4F_5-ap^4G_5$
67.00	E	2A	42234.7	$5s^2D_2-bp^4D_1$
66.27	E	2A	42247.7	$5s^4P_1-cp^2P_1$
64.79	E	3ua	42274.1	$ap^4G_6-5d^4F_5$
62.31	E	50A	42318.5	$5s^4F_3-ap^4F_4$
61.47	E	4A	42333.6	unidentified
61.14	E	2A	42339.5	$5s^2P_1-bp^4S_2$
57.61	E	40A	42402.9	$5s^4F_2-ap^4F_2$
54.76	E	8A	42454.2	$5s^4P_1-cp^2P_2$
52.99	E	1A	42487.1	$5s^2D_2-cp^2D_3$
51.85	E	25A	42506.7	$5s^2G_4-kp^2F_3$
51.32	E	50A	42516.3	$5s^4F_4-ap^4G_4$
47.52	E	5A	42585.2	unidentified
47.26	E	8ua	42589.8	$ap^4F_2-6s^4P_3$?
46.46	E	7A	42604.3	$5s^2D_3-ep^2D_3$
44.95	E	3A	42631.8	$5s^2P_2-bp^4S_2$
37.75	E	15A	42763.0	$5s^2D_2-bp^4D_2$
36.59	E	30A	42784.3	$5s^4F_4-ap^4F_5$
36.43	E	30A	42787.2	$5s^4F_2-ap^2D_3$
31.41	E	30A	42879.3	$5s^2D_2-bp^4D_3$
30.0	E	3ua	42905.3	$ap^4G_5-5d^4D_4$
25.2	E	3ua	42993.8	$\begin{cases} ap^4F_5-5d^4G_5 \\ cp^2F_4-6s^2G_5 \end{cases}$
22.59	E	5A	43042.1	unidentified
21.91	E	8A	43054.7	$5s^4P_1-cp^2D_2$
18.07	E	2ua	43126.1	$ap^4D_3-5d^4F_4$
15.87	E	10A	43167.0	$5s^4F_2-ap^4F_3$
08.60	E	10A	43302.9	$5s^4P_1-bp^4D_1$
02.35	E	10A	43420.5	$5s^4F_3-ap^4F_2$
2302.02	E	40A	43426.7	$5s^4P_3-cp^2F_4$
2299.58	E	5A	43472.7	$5s^2P_2-kp^2F_3$
99.43	E	20A	43475.6	$5s^2F_4-ap^2F_3$
96.53	E	200RA	43530.5	$5s^4F_5-ap^4G_6$
93.71	E	5ua	43584.0	$ap^4G_5-5d^4F_5$
93.35	E	8A	43590.9	$5s^4P_2-cp^2P_2$
82.98	E	3u	43788.9	$ap^4G_5-5d^4F_4$
82.11	E	25A	43805.5	$5s^4F_3-ap^2D_3$
80.79	E	15A	43830.9	$5s^4P_1-bp^4D_2$
74.47	E	8A	43952.7	$5s^2D_3-ep^2P_2$
73.34	E	10A	43974.5	$5s^4F_4-ap^4G_3$
66.96	E	8A	44098.3	$5s^2P_1-ep^2P_1$
64.33	E	40A	44149.5	$5s^4F_4-ap^4F_4$
62.52	E	30A	44184.8	$5s^4F_3-ap^4F_3$
62.15	E	15A	44192.0	$5s^4P_2-cp^2D_2$
60.13	E	5A	44231.5	$5s^2D_2-ep^2D_3$
54.45	S	3A	44343.0	$5s^2F_3-cp^2F_3$
52.04	S	20A	44390.4	$5s^2P_2-ep^2P_1$
51.51	S	20A	44400.8	$5s^4F_3-ap^2F_4$
49.52	S	3A	44440.0	$5s^4P_2-bp^4D_1$
47.00	S	1A	44489.9	$5s^2F_4-bp^4P_3$
37.72	S	5A	44674.5	$5s^4P_3-cp^2P_2$
36.84	S	3A	44692.1	$5s^4P_2-cp^2D_3$
31.59	S	100RA	44797.2	$5s^4F_5-ap^4F_5$
29.22	S	25A	44844.8	$5s^2D_3-kp^2F_4$
23.75	S	25ua	44955.1	$ap^4D_4-5d^4D_4$
23.06	S	3A	44968.9	$5s^4P_2-bp^4D_2$
18.15	S	30A	45068.6	$5s^2G_4-kp^2G_4$?
17.53	S	15A	45081.2	$5s^2D_3-bp^4S_2$
17.32	S	10A	45085.4	$5s^4P_2-bp^4D_3$
14.03	S	30A	45152.3	$5s^4F_2-ap^2D_2$
12.15	S	50A	45190.8	$5s^4F_4-ap^2G_5$
2207.97	S	0	45276.2	$5s^4P_3-cp^2D_2$
07.47	S	25A	45286.1	$5s^2F_3-cp^2F_4$
03.48	S	10A	45368.5	$5s^2G_4-kp^2G_5$
2202.36	S	30A	45391.7	$5s^4F_3-ap^2G_4$
2198.24	S	30A	45476.7	$5s^2G_5-kp^2G_5$
97.14	S	2A	45499.5	$5s^2D_2-ep^2S_1$
94.56	S	3u	45573.7	$ap^4G_5-5d^4G_5$
93.27	S	3A	45579.7	$5s^2D_2-ep^2P_2$
90.53	S	10ua	45636.7	$ap^4D_4-5d^4F_5$
82.35	S	50A	45807.8	$5s^4F_2-ap^2F_3$
80.80	S	0u	45840.3	$ap^4D_4-5d^4F_4$
79.41	S	5A	45869.6	$5s^4P_1-ep^2D_2$
76.91	S	25a	45922.2	$5s^2D_3-kp^2F_3$?
72.38	S	20A	46018.0	$5s^4F_4-ap^4F_3$
70.76	S	1	46052.3	$5s^4P_3-bp^4D_2$
65.50	S	10A	46163.0	$5s^4F_5-ap^4F_4$
65.30	S	5A	46168.4	$5s^4P_3-bp^4D_3$
65.20	S	10A	46170.7	$5s^4F_3-ap^2D_2$
62.27	S	50A	46233.1	$5s^4F_4-ap^2F_4$
52.76	S	30A	46437.3	$5s^4P_2-ep^2D_3$
48.27	S	15A	46534.4	$5s^2F_3-cp^2P_2$
46.69	S	3A	46568.3	$5s^4P_1-ep^2S_1$
41.36	S	5A	46648.6	$5s^4P_1-ep^2P_2$
40.26	S	20A	46708.4	$5s^2D_2-bp^4S_2$
37.26	S	20A	46774.6	$5s^4P_3-bp^4D_4$
35.64	S	8A	46809.6	$5s^4F_2-bp^4P_2$
35.07	S	10A	46822.1	$5s^4F_2-bp^4P_3$
34.85	S	3A	46826.9	$5s^4F_3-ap^2F_3$
33.25	S	0	46862.0	$5s^4F_2-bp^4P_1$
26.64	S	10A	47007.5	$5s^4P_2-ep^2D_2$
20.85	S	1A ?	47135.9	$5s^2F_3-cp^2D_2$
17.80	S	5A	47203.9	$5s^4F_5-ap^2G_5$
16.88	S	7A	47224.4	$5s^4F_4-ap^2G_4$
07.69	S	3A	47430.2	$5s^2F_4-cp^2F_4$
03.67	S	10A	47520.8	$5s^4P_3-ep^2D_3$
2102.43	S	10A	47548.8	$5s^2D_2-kp^2F_3$
2098.64	S	5A	47634.7	$5s^2F_3-cp^2D_3$
95.54	S	5A	47705.2	$5s^4P_2-ep^2S_1$
92.39	S	15A	47776.9	$5s^4P_1-bp^4S_2$
92.01	S	15A	47785.7	$5s^4P_2-ep^2P_2$
90.17	S	8A	47827.7	$5s^4F_3-bp^4P_2$
89.61	S	10A	47840.6	$5s^4F_3-bp^4P_3$
86.50	S	12A	47911.9	$5s^2F_3-bp^4D_2$
81.43	S	10A	48028.6	$5s^2F_3-bp^4D_3$
72.05	S	10A	48245.9	$5s^4F_5-ap^2F_4$
62.60	S	3A	48467.0	$5s^2D_2-ep^2P_1$
55.51	S	1A	48634.0	$5s^2F_3-bp^4D_4$
54.46	S	15A	48659.0	$5s^4F_4-ap^2F_3$
45.62	S	10A	48869.2	$5s^4P_3-ep^2P_2$
43.79	S	8A	48913.0	$5s^4P_2-bp^4S_2$
08.21	S	8A	49779.4	$5s^2F_4-cp^2D_3$
λ (vac.)				
2000.07	S	8A	49998.3	$5s^4P_3-bp^4S_2$
1971.27	S	0 ?	50728.8	$5s^2F_3-ep^2P_2$
1552.19	W	3	64425	$4d^2D_2-ap^4D_3$
1532.81	W	6 ?	65240	$4d^2D_3-ap^4D_4$
1480.78	W	1 ?	67532	$4d^2D_2-ap^4G_3$
78.42	W	1	67640	$4d^2D_2-ap^4D_1$
71.34	W	5	67965	$4d^2D_3-ap^4D_3$
53.25	W	10	68811	$4d^2D_2-ap^4F_2$
45.20	W	5	69195	$4d^2D_2-ap^2D_3$
37.29	W	30	69575	$4d^2D_2-ap^4F_3$
36.53	W	3	69612	$4d^2D_3-ap^4G_4$
26.10	W	3 ?	70121	$4d^2D_3-ap^4D_2$
07.06	W	5	71070	$4d^2D_3-ap^4G_3$
1403.59	W	25	71246	$4d^2D_3-ap^4F_4$
1397.46	W	15	71558	$4d^2D_2-ap^2D_2$
84.79	W	3	72213	$4d^2D_2-ap^2F_3$
82.23	W	3	72347	$4d^2D_3-ap^4F_2$
74.92	W	50	72732	$4d^2D_3-ap^2D_3$
67.76	W	25	73112	$4d^2D_3-ap^4F_3$
65.80	W	25	73217	$4d^2D_2-bp^4P_2$
65.58	W	15	73229	$4d^2D_2-bp^4P_3$
64.81	W	1	73270	$4d^2D_2-bp^4P_1$
63.76	W	20	73327	$4d^2D_3-ap^2F_4$
45.57	W	25	74318	$4d^2D_3-ap^2G_4$
31.61	W	5	75097	$4d^2D_3-ap^2D_2$
29.34	W	5	75225	$4d^2D_2-cp^2F_3$
20.05	W	35	75754	$4d^2D_3-ap^2F_3$
14.61	W	5	76068	$4d^2D_2-cp^2P_1$?
02.85	W	7	76755	$4d^2D_3-bp^4P_2$
1302.66	W	8	76766	$4d^2D_3-bp^4P_3$
1281.79	W	1	78017	$4d^2D_2-cp^2D_2$
73.60	W	10	78518	$4d^2D_2-cp^2D_3$
69.62	W	10	78764	$4d^2D_3-cp^2F_3$
67.27	W	10	78910	$4d^2D_2-bp^4D_3$
54.59	W	20	79707	$4d^2D_3-cp^2F_4$

TABLE V. (continued)

λ	Auth.	Int.	ν	Combination	λ	Auth.	Int.	ν	Combination
1245.92	W	5	80262	$4d^2D_2-ep^2D_3$	1208.68	W	5d	82735	$4d^2D_2-bp^4S_2$
37.12	W	15	80833	$4d^2D_2-ep^2D_2$	04.00	W	30	83057	$4d^2D_3-bp^4D_4$
35.23	W	15	80957	$4d^2D_3-cp^2P_2$	1196.43	W	10	83582	$4d^2D_2-kp^2F_3$
26.54	W	5	81530	$4d^2D_2-ep^2S_1$	85.27	W	1	84369	$4d^2D_3-ep^2D_2$
26.19	W	1	81553	$4d^2D_3-cp^2D_2$	83.45	W	20	84499	$4d^2D_2-ep^2P_1$
25.33	W	10	81611	$4d^2D_2-ep^2P_2$	74.37	W	20	85152	$4d^2D_3-ep^2P_2$
18.66	W	15	82057	$4d^2D_3-cp^2D_3$	62.20	W	15	86044	$4d^2D_3-kp^2F_4$
14.58	W	10	82333	$4d^2D_3-bp^4D_2$	59.05	W	10	89278	$4d^2D_3-bp^4S_2$
12.88	W	3	82448	$4d^2D_3-bp^4D_3$	1115.16	W	1	89673	$4d^2D_3-kp^2G_4$?

E. Exner and Haschek.
S. Author.
W. Communication from H. E. White.
M. Communication from W. F. Meggers.
R. Reversed.
u. Diffuse
A. Relatively strong in the arc.
a. Relatively weak in the arc, but present.

LIMITS AND IONIZATION POTENTIAL

The identification of the $6s^{4\&2}F$ terms allows an approximate calculation of the series limits to be made. Theoretically, the limits should coincide in pairs $^4F_5$, $^2F_4$; $^4F_4$, $^2F_3$; $^4F_3$, $^4F_2$. There is, however, no indication of such a grouping in the calculated limits which are as follows:

Limit	$^4F_5$	135524	Limit	$^4F_2$	140185
	$^4F_4$	135765		$^2F_4$	137713
	$^4F_3$	139006		$^2F_3$	139329

It seems more probable that the $^4F_5$ and $^4F_4$, instead of $^2F_4$, limits coincide. This is another indication that the Hund theory of limits yields erroneous results for spectra of which the nature is determined by nearly completed electron groups. More definite evidence has been recently given by the author in the letter to Nature before mentioned.

The limit for the $^4F_5$ series can, however, be used to calculate an approximate ionization potential of 16.7 volts from $4d^85s$ to $4d^8$ or 19.8 volts from $4d^9$ to $4d^8$.

COMPARISON WITH SIMILAR SPECTRA

There are three analyzed spectra which should contain terms of the same origin as those of Ph II, namely, Rh I,[6] Co I,[8] and Ni II.[2] All four spectra do, in fact, include equivalent terms, although the two arc spectra are complicated by the additional presence of the structures built on seven d-electrons. The $^2D(d^9)$ of Co I has not been found but its position can be estimated at about 30,000 on the scale used in the analysis just referred to. Although the term intervals in Pd II are generally very large, the over-all separations between the lowest and highest levels of the groups of terms are smaller than in Ni II. For example, the $5s$-group of levels occupies about 5000 wave-numbers less in Pd II than in Ni II. It is particularly noteworthy that $5s^4P$ and bp^4P occupy such relatively low positions.

The author thanks Dr. Meggers, of the Bureau of Standards, and Mr. H. E. White, of Cornell University, for allowing him the full use of their material. Mr. H. A. Blair, of this University, has materially aided the author throughout the investigation.

PALMER PHYSICAL LABORATORY,
PRINCETON UNIVERSITY.
April 5, 1928.

---

[8] M. A. Catalan and K. Bechert, Zeits. f. Physik **32**, 336 (1925).