RP255

THE STRUCTURE OF THE SPECTRUM OF SINGLY IONIZED ZIRCONIUM

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ABSTRACT

Seventy-five per cent of the lines observed in the spark spectrum of zirconium have been classified as combinations between terms of the quartet and doublet systems of Zr II. The terms which have been found are in all cases those required theoretically for an atom with three outer electrons. All the terms, except one, which can possibly arise from configurations of the electrons when they occupy $4d$, $5s$, and $5p$ orbits have been found. Of the terms possible when one of the electrons removes to a $5d$ or $6s$ orbit only a few have been found, of which some form Rydberg series with the low terms. In all, 10 pairs of series-forming terms have been detected with either ^3F, ^1G, or ^1D of Zr III as limit. The results given by these different series for the distance between $a^4F_{1\frac{1}{2}}$, the lowest term of Zr II, and a^3F_2, the lowest term of Zr III, are very consistent, the mean value being 113,175 cm^{-1}, corresponding to an ionization potential of 13.97 volts for the ion Zr^+. The irregular doublet law shows a close parallelism between the term structures of the neutral Yt atom and the singly ionized Zr atom. The list of Zr II lines appearing in the sun is extended and includes lines which have not been observed in laboratory sources but may be calculated from permissible combinations.

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I. INTRODUCTION

The analysis of the first spark spectrum of zirconium presented in this paper is a part of a general investigation of the spectra of this element in progress for more than a decade at the National Bureau of Standards. This investigation had as its object not only the accurate description of the spectra as far as the available spectrographic equipment at our disposal would permit, but also the discovery of the series relations which would reveal the structure of the spectra. As a first contribution in the completion of this research a previous paper [1] by one of us, presents lists of wave lengths from 2,100 A in the ultra-violet to 9,300 A in the infra-red which are characteristic of the Zr atom in its neutral and three ionized states.

[1] B. S. Sci. Papers, No. 548, 22, p. 47; 1927.

A second contribution, by Kiess and Lang,[2] presents an analysis of the spectra Zr III and Zr IV. In this paper the extreme ultra-violet portion of the spectrum as observed with a vacuum spectrograph is described, and the classification of the lines, as characteristic of the doubly and trebly ionized Zr atoms, is shown to be in strict accord with recent theories of spectral structure.

With the new wave-length data at our disposal, we soon found many pairs of lines separated by constant wave-number differences, which have since proved to be term separations of Zr I and Zr II. With the clue to the nature of complex spectra which was furnished by the work of Catalán [3] on Mn. and of Frl. Gieseler [4] on Cr, we were able to link together many of the constant difference pairs into more or less fragmentary multiplets. However, progress was slow, for there were no temperature classifications of the lines available at that time, and the interpretation of the anomalous Zeeman effect had not yet been found. So we turned aside from Zr for a while and devoted our attention to the spectrum of Ti for which temperature classifications were available, and in which we expected to find a small-scale pattern of the Zr regularities.

Following our work on Ti,[5] which in the meantime had been advanced as a result of Landé's [6] quantum theoretical interpretation of the anomalous Zeeman effect, we returned again to the Zr spectra. The Zeeman effects observed by Moore [7] were now interpretable, and, through the kindness of Dr. A. S. King, of the Mount Wilson Observatroy, we had an advance copy of the results obtained by him and Miss Carter [8] for the temperature classification of the Zr lines. Little difficulty was now experienced in placing most of the stronger lines into mutiplets of the quintet and triplet systems of Zr I [9] and of the quartet and doublet systems of Zr II.[10]

II. EXPERIMENTAL

1. WAVE LENGTHS AND INTENSITIES

When the analysis of Zr II had progressed far enough to account for nearly all the strong lines in the published tables of wave lengths, it was seen that additional observations in the ultra-violet shorter than 2,100 A were desirable. The Hilger E_1 quartz spectrograph of the Bureau of Standards was, therefore, adjusted to record the region down to 1,900 A, and new observations were obtained with it of both the arc and spark spectra. In addition to these prism spectrograms, a few more were obtained with the spectrograph carrying the concave grating ruled with 20,000 lines per inch. The wave lengths derived from these more recent plates have been averaged with those already published in the lists referred to above, and are presented in the second column of Table 2 of this paper. This list of wave lengths supersedes that published in the earlier paper. Faint lines omitted from Table 2, but present in the earlier list have been found to be

[2] B. S. Jour. Research, **5**, p. 305; 1930.
[3] Phil. Trans. Roy. Soc., A **223**, p. 127; 1922.
[4] Ann. der Physik (IV) **69**, p. 147; 1922.
[5] J. Opt. Soc. Am. & Rev. Sci. Inst., **8**, p. 607; 1924
[6] Zeit. für Physik, **15**, p. 189; 1923.
[7] Astrophys, J., **28**, p. 15; 1908.
[8] Astrophys, J., **65**, p. 86; 1927.
[9] Popular Astronomy, **31**, p. 647; 1923; **33**, p. 255; 1925.
[10] J. Opt. Soc. Am. & Rev. Sci. Inst., **12**, p. 427; 1926; **14**, p. 140; 1927.

spurious or are due to impurities. The letters *b* and *B* following the intensity estimate indicate that the line is nebulous, and the letter *l* that it is asymmetrically shaded toward the red. Some of these asymmetrical lines closely resemble unresolved band heads, but there is no evidence of band structure on the plates.

Some of the newer spectrograms were given prolonged exposures so that a finer discrimination could be made of the intensities than is to be found in the published lists. On the grating spectrograms all the strong lines show ghosts of the Rowland type. In a study of the ghosts produced by the Bureau of Standards gratings [11] the ratio of the intensities of parent line to first ghost was set equal to 10:1 for the first order spectrum, and 10:3 for the second order spectrum. Lines which were not strong enough to show ghosts were assigned intensities ranging from 0 to 9. Lines with ghosts of intensity 0 to 1 were assigned an intensity 10. The intensities of all stronger lines were obtained by multiplying the estimated intensities of their ghosts by the above ratios. The intensity scale for the prism spectrograms was obtained from the scale set up for the grating plates in the region from 2,200 A to 3,100 A, which was photographed by both spectrographs. The intensities thus derived are entered in Table 2, where they are compared with similar estimates made by King from arc sources.

2. THE ZEEMAN EFFECTS

New observations of the Zeeman effect have also been made for this investigation. In 1924 the late Prof. B. E. Moore, of the University of Nebraska, made for us several exposures with the magnet and spectrograph of the Brace Laboratory. They were made on long strips of Eastman ordinary and panchromatic films and covered the region from 7,000 A in the red to 3,200 A in the ultra-violet. The source employed by Moore was a spark maintained by a 5,000-volt transformer between electrodes of carbon which had been impregnated with zirconium solutions. The field strengths were of the order of 28,000 gausses/cm^2 and were derived from measurements of the sodium D lines and the calcium H and K lines which appeared as impurities on the films. All the films were measured and reduced at the Bureau of Standards.

Quite recently the Bureau of Standards obtained a water-cooled electromagnet of the Weiss type. Preliminary experiments with it in conjunction with the large grating spectrograph have given some very excellent results for several elements, including zirconium. The source was a condensed spark maintained by a 2,500-volt transformer between metallic Zr electrodes mounted in brass holders. With a current of 150 amperes on the magnet a field strength of 32,300 gausses/cm^2 was attained with a 7 mm gap between the poles. Both the parallel and normal components were obtained in juxtaposition on the spectrograms by means of a Wollaston prism. The zinc and copper impurity lines which appeared on the plates proved very useful in calculating the field strength. The region covered by these recent observations extended from 4,100 A to 5,900 A in the second order of the spectrograph. Some ultra-violet lines of the overlapping third order spectrum were thus obtained.

[11] J. Opt. Soc. Am. & Rev. Sci. Inst. 6, p. 417; 1922.

To secure additional Zeeman effects for lines in the ultra-violet some observations were made with the Hilger E_1 quartz prism spectrograph also. The resolving power of this instrument is only a third that of the large grating spectrograph and, therefore, the results obtained with it do not attain very high accuracy. Nevertheless, Shenstone and Blair [12] have found such Zeeman effects observed by them with a similar instrument quite serviceable in the interpretation

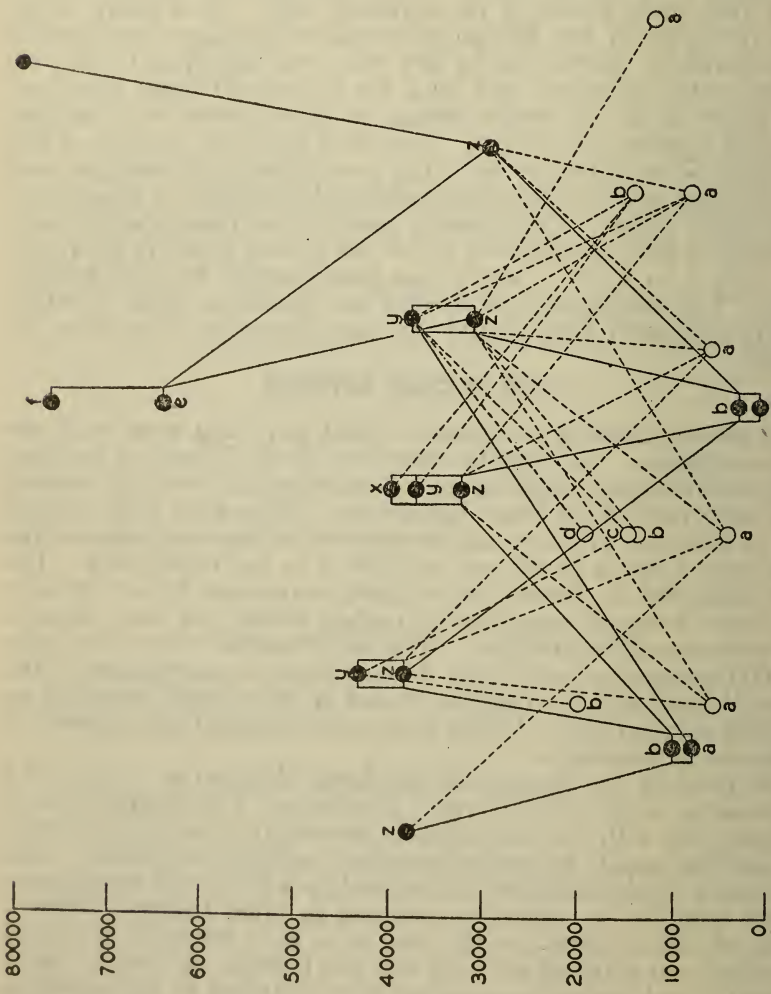

FIGURE 1.—*Term diagram of the quartet system of Zr II*

of Ag II and other spectra. The exposure times are short, ranging from a few seconds for the most intense lines to 5 or 10 minutes for lines listed in Table 2 as of intensity 3. This fact makes it possible to use higher currents on the magnet and narrower gaps between the pole pieces, thereby securing the additional resolution of the magnetic pattern afforded by stronger fields. With a current of 160 amperes

[12] Phil. Mag. (VII), 8, p. 765; 1929.

and a 5 mm gap between the poles a field strength of 35,500 gausses/cm^2 was maintained. The Zeeman effects thus obtained in this investigation lie between wave lengths 3,061 A and 2,449 A, and are appropriately marked in Table 2 with the suffix E_1.

III. STRUCTURE OF THE FIRST SPARK SPECTRUM

1. THE TERM SYSTEMS

It was mentioned above that the first regularities detected in the Zr spectra were pairs of lines separated by constant wave-number differences. Of these, $\Delta\nu = 559.5$ and 448.8 were observed to link together many of the strong lines in the near ultra-violet. Eventually these $\Delta\nu$'s were found to be characteristic of a low ^{4}F term in combination with higher D, F, and G terms of the quartet system. In fact, the four lines at wave lengths 3,572.47, 3,496.18, 3,438.23, and 3,391.96, which were designated by de Gramont [13] as the *raies ultimes* of Zr in the photographic region, constitute the principal diagonal of the multiplet $^4F - {}^4G^\circ$. The theoretical interpretation of the spectrum, given below, confirms de Gramont's characterization of these lines.

With the basic term of the spectrum established, it was soon possible to locate the low ^{4}P terms and the second low ^{4}F term. The identity of these terms was verified by the Zeeman effect. The doublet system was more difficult to unravel, but several well-observed Zeeman patterns in Moore's list enabled us to fix with certainty the low P, D, F, and G terms, and to connect them with the quartet terms already found. Of the doublet terms a^2D is lowest, lying in the term diagram just above the second of the low ^{4}F terms. The terms which have been found to account for the spectrum of Zr^+ are given in Table 1. Figures 1 and 2 show graphically the relations between these terms. The symbols used in defining the terms are those recently proposed as standard by Russell, Shenstone, and Turner.[14]

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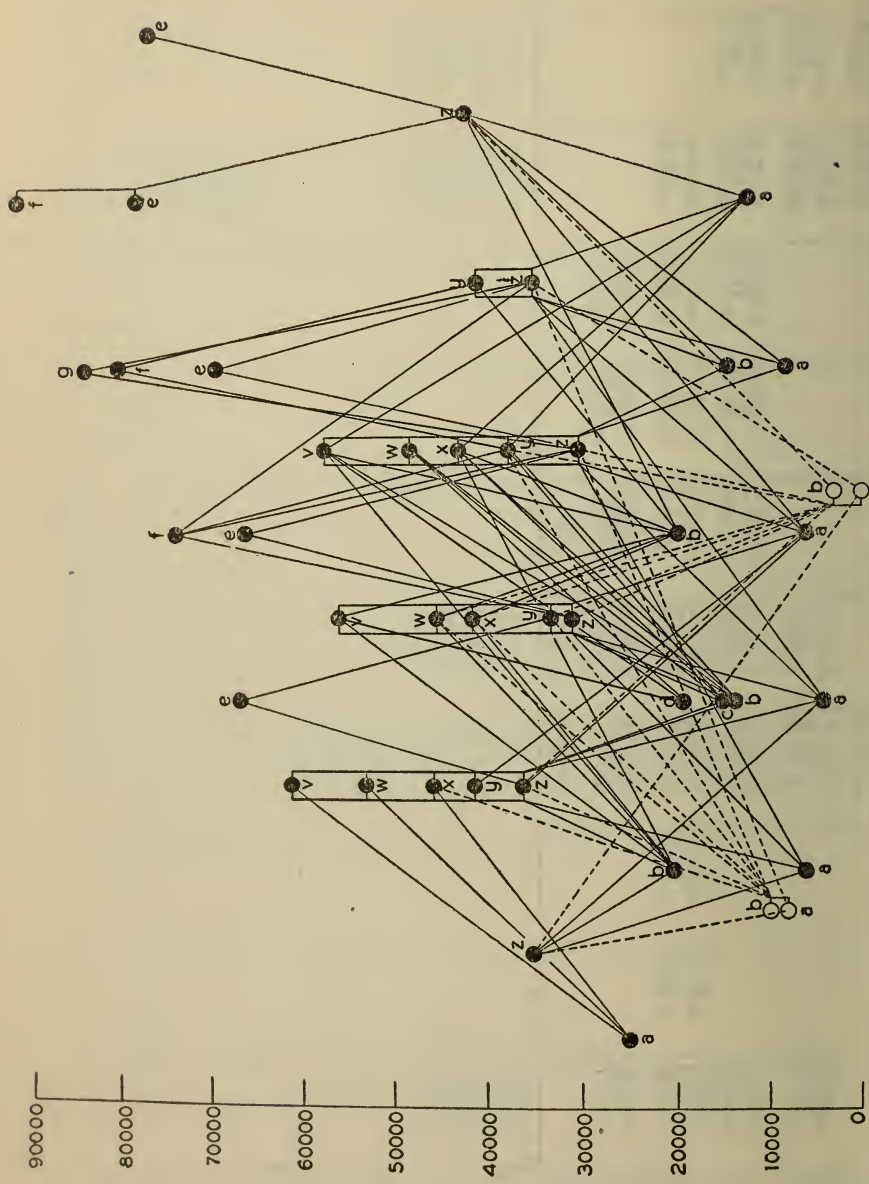
[13] Compt. Rend., 166, p. 365; 1918.

[14] Phys. Rev., 33, p. 900; 1929.

TABLE 1.—*The terms of Zr II*

Term	a	b	c	d	z	y	x	w	v	e	f	g
$^4H_{6\frac{1}{2}}$										79, 280. 30		
										81. 95		
$^4H_{5\frac{1}{2}}$										79, 198. 35		
										350. 63		
$^4H_{4\frac{1}{2}}$										78, 847. 67		
										269. 83		
$^4H_{3\frac{1}{2}}$										78, 577. 85		
$^4G_{5\frac{1}{2}}$					30, 795. 74							
					955. 87							
$^4G_{4\frac{1}{2}}$					29, 839. 87							
					930. 83							
$^4G_{3\frac{1}{2}}$					28, 909. 04							
					955. 21							
$^4G_{2\frac{1}{2}}$					27, 983. 83							
$^4F_{4\frac{1}{2}}$	1, 322. 91	3, 757. 66			31, 866. 49	38, 644. 12				64, 901. 71	76, 593. 58	
	558. 47	*458. 02*			*617. 21*	*1, 214. 36*				*533. 43*	*584. 53*	
$^4F_{3\frac{1}{2}}$	763. 44	3, 299. 64			31, 249. 28	37, 429. 76				64, 368. 28	76, 009. 05	
	448. 77	*404. 59*			*697. 80*	*560. 76*				*499. 83*	*665. 48*	
$^4F_{2\frac{1}{2}}$	314. 67	2, 895. 05			30, 551. 48	36, 869. 00				63, 868. 45	75, 343. 57	
	314. 67	*322. 84*			*773. 88*	*417. 21*				*265. 81*	*732. 29*	
$^4F_{1\frac{1}{2}}$	0. 00	2, 572. 21			29, 777. 60	36, 451. 79				63, 602. 64	74, 611. 28	
$^4D_{3\frac{1}{2}}$					32, 899. 46	38, 041. 49	40, 238. 55					
					284. 75	*870. 27*	*598. 47*					
$^4D_{2\frac{1}{2}}$					32, 614. 71	37, 171. 22	39, 640. 08					
					358. 00	*532. 72*	*447. 73*					
$^4D_{1\frac{1}{2}}$					32, 256. 71	36, 638. 50	39, 192. 35					
					275. 46	*401. 46*	*257. 98*					
$^4D_{0\frac{1}{2}}$					31, 981. 25	36, 237. 04	38, 934. 37					
$^4P_{2\frac{1}{2}}$	8, 058. 16	9, 968. 65			38, 482. 64	43, 202. 45						
	322. 14	*225. 85*			*349. 14*	*308. 91*						
$^4P_{1\frac{1}{2}}$	7, 736. 02	9, 742. 80			38, 133. 50	42, 893. 54						
	223. 35	*189. 70*			*70. 10*	*104. 30*						
$^4P_{0\frac{1}{2}}$	7, 512. 67	9, 553. 10			38, 063. 40	42, 789. 24						
$^4S_{1\frac{1}{2}}$					37, 681. 75							
$^2I_{6\frac{1}{2}}$										76, 838. 70		
										443. 20		
$^2I_{5\frac{1}{2}}$										76, 395. 50		

$^2H_{5\frac{1}{2}}$	12,359.66				42,409.93					78,280.90	91,737.40	
	375.20				*671.72*					*537.90*	*750.90*	
$^2H_{4\frac{1}{2}}$	11,984.46				41,738.21					77,743.00	90,986.50	
$^2G_{4\frac{1}{2}}$	8,152.80	14,190.45			35,185.64	40,878.25				69,283.38	80,311.54	83,547.45
	315.06	*130.69*			*700.22*	*25.51*				*166.68*	*686.94*	*326.00*
$^2G_{3\frac{1}{2}}$	7,837.74	14,059.76			34,485.42	40,852.74				69,116.70	79,624.60	83,221.45
$^2F_{3\frac{1}{2}}$	6,467.61	19,433.24			30,561.75	37,787.59	42,504.11	48,344.91	57,741.16	66,192.68	74,496.80	
	714.69	*−81.60*			*1,056.78*	*441.28*	*−356.61*	*463.03*	*679.16*	*320.27*	*643.85*	
$^2F_{2\frac{1}{2}}$	5,752.92	19,514.84			29,504.97	37,346.31	42,860.72	47,881.88	57,062.00	65,872.41	73,852.95	
$^2D_{2\frac{1}{2}}$	4,505.50	14,162.90	14,733.37	18,396.54	31,160.04	33,419.45	41,676.82	45,186.05	56,569.44	66,868.35		
	257.20	*734.40*	*434.73*	*782.54*	*724.66*	*435.72*	*209.10*	*131.18*	*733.91*	*182.10*		
$^2D_{1\frac{1}{2}}$	4,248.30	13,428.50	14,298.64	17,614.00	30,435.38	32,983.73	41,467.72	45,054.87	55,835.53	66,686.25		
$^2P_{1\frac{1}{2}}$	6,111.70	20,080.30			35,914.81	41,337.36	45,568.21	52,876.80	61,861.90			
	387.32	*466.76*			*−281.76*	*610.10*	*−375.79*	*291.00*	*1,047.40*			
$^2P_{0\frac{1}{2}}$	5,724.38	19,613.54			36,196.57	40,727.26	45,944.00	52,585.80	60,814.50			
$^2S_{0\frac{1}{2}}$	25,201.57				34,810.03							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The lines belonging to Zr II and their classifications are given in Table 2. In the first column is given the key number of the line, the full significance of which is to be seen in Table 3, which, at a glance shows the term combinations of the different multiplets and also the number and types of terms with which any particular term combines. Thus, for example, it is seen that the term a^2D, the lowest of the doublet system, combines with every odd term of the middle groups except z^2H° with which combination is impossible owing to the restrictions imposed by the selection principle for inner quantum numbers. The wave lengths of all the lines entered in Table 2 were derived from measurements of Bureau of Standards spectrograms, except the last 9, which were measured by Lang on the plates obtained by him with the vacuum grating spectrograph of the University of Alberta.[15] Of more than 900 lines in the table, 75 per cent have been classified on the basis of the terms of Table 1. Of the unclassified lines (210 in number) some may be due to impurities and a few may belong to Zr III and Zr IV; but there is good reason to believe that most of them properly belong to Zr II. Many of them possess the property of being nebulous. In spectra which have been fairly well worked out such lines invariably result from combinations of high terms with those of the middle group. Similar term combinations would satisfactorily account for them in Zr II. Indeed, a few terms of the high group have been found which combine with middle terms, and the lines resulting therefrom are nearly all nebulous. It is not easy to establish the high terms, because satellites are usually missing, and only rarely does a high term combine with more than one of the lower terms. No Zeeman effects are available to interpret such lines, and the best one can do is to estimate their origin from theoretical considerations. The theoretical origin of these unassigned lines is discussed more fully in a subsequent paragraph.

TABLE 2.—*Wave lengths in the spark spectrum of Zr*

Key No.	λ I. A.	Intensities		ν	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
		B. S.	King				
1	6,787.15	2		14,729.66	$b^2P_{1\frac{1}{2}}-z^2S^\circ_{0\frac{1}{2}}$	(0.37) 1.09	(0.33) 1.00, 1.67
1*a*	6,678.03	3		14,970.35	$b^2F_{2\frac{1}{2}}-z^2G^\circ_{3\frac{1}{2}}$		
1*a*	6,346.54	1	2	15,752.27	$b^2F_{3\frac{1}{2}}-z^2G^\circ_{4\frac{1}{2}}$		
2	6,313.57	1		15,834.53	$b^2F_{1\frac{1}{2}}-z^2P^\circ_{1\frac{1}{2}}$	(0.00) 1.27	(0.00) 1.33
3	6,114.78	2		16,349.30	$b^2D_{1\frac{1}{2}}-z^4F^\circ_{1\frac{1}{2}}$		
4	6,106.47	2		16,371.55	$b^2G_{4\frac{1}{2}}-z^2F^\circ_{3\frac{1}{2}}$		
3	6,100.04	2		16,388.81	$b^2D_{2\frac{1}{2}}-z^4F^\circ_{2\frac{1}{2}}$		
2	6,028.64	2		16,582.91	$b^2P_{0\frac{1}{2}}-z^2P^\circ_{0\frac{1}{2}}$	(0.00) 0.66	(0.00) 0.67
5	5,477.82	2		18,250.38	$c^2D_{2\frac{1}{2}}-y^2D^\circ_{1\frac{1}{2}}$		
6	5,418.01	1		18,451.85	$b^2D_{2\frac{1}{2}}-z^4D^\circ_{2\frac{1}{2}}$		
5	5,350.36	5	6	18,685.15	$c^2D_{1\frac{1}{2}}-y^2D^\circ_{1\frac{1}{2}}$	(0.00) 0.78	(0.00) 0.80
5	5,350.10	5	6	18,686.06	$c^2D_{2\frac{1}{2}}-y^2D^\circ_{2\frac{1}{2}}$	(0.00) 1.21	(0.00) 1.20
7	5,311.78	2	1	18,820.86	$b^2D_{2\frac{1}{2}}-y^2D^\circ_{1\frac{1}{2}}$		
7	5,191.60	7	15	19,256.54	$b^2D_{2\frac{1}{2}}-y^2D^\circ_{2\frac{1}{2}}$	(0.00) 1.17	(0.00) 1.20
8	5,124.98	2		19,506.85	$a^2H_{5\frac{1}{2}}-z^4F^\circ_{4\frac{1}{2}}$		
7	5,112.28	7	5	19,555.32	$b^2D_{1\frac{1}{2}}-y^2D^\circ_{1\frac{1}{2}}$	(0.00) 0.83	(0.00) 0.80
7	5,000.91	3		19,990.80	$b^2D_{1\frac{1}{2}}-y^2D^\circ_{2\frac{1}{2}}$		
9	4,925.90	1		20,295.21	$b^2G_{4\frac{1}{2}}-z^2G^\circ_{3\frac{1}{2}}$		
10	4,903.67	1		20,366.45	$a^2S_{0\frac{1}{2}}-z^2P^\circ_{1\frac{1}{2}}$		
9	4,894.43	0		20,425.70	$b^2G_{3\frac{1}{2}}-z^2G^\circ_{3\frac{1}{2}}$		
11	4,854.65	0		20,593.07	$b^4P_{2\frac{1}{2}}-z^2F^\circ_{3\frac{1}{2}}$		
12	4,841.98	0		20,646.95	$b^2P_{1\frac{1}{2}}-y^2P^\circ_{0\frac{1}{2}}$		
13	4,816.47	1		20,756.36	$a^2G_{4\frac{1}{2}}-z^4G^\circ_{3\frac{1}{2}}$		
9	4,761.67	1		20,995.18	$b^2G_{4\frac{1}{2}}-z^2G^\circ_{4\frac{1}{2}}$		
12	4,734.94	1		21,113.70	$b^2P_{0\frac{1}{2}}-y^2P^\circ_{0\frac{1}{2}}$		

[15] J. Opt. Soc. Am. & Rev. Sci. Inst., **12**, p. 523; 1926.

TABLE 2.—*Wave lengths in the spark spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities B. S.	Intensities King	ν	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
14	4,719.80	1		21,181.43	$c^2D_{2\frac12}-z^2P^\circ_{1\frac12}$		
12	4,703.03	5	1	21,256.96	$b^2P_{1\frac12}-y^2P^\circ_{1\frac12}$	(0.00) 1.32	(0.00) 1.33
15	4,685.19	4	1	21,337.90	$b^2F_{2\frac12}-y^2G^\circ_{3\frac12}$	(0.00) 1.00	(**0.02**, 0.05, 0.08) ---, 0.90, 0.94, **0.97**
16	4,674.41	1		21,387.11	$b^2P_{1\frac12}-x^2D^\circ_{1\frac12}$		
15	4,661.78	5	1	21,445.05	$b^2F_{3\frac12}-y^2G^\circ_{4\frac12}$	(0.00) 0.95	(**0.02**, 0.05, ---) **1.00**, 1.03, 1.05, ---
16	4,629.07	5	1	21,596.58	$b^2P_{1\frac12}-x^2D^\circ_{2\frac12}$	(0.00) 1.07	(**0.07**, 0.20) **1.00**, 1.13, 1.27, 1.40
14	4,624.86	1		21,616.24	$c^2D_{1\frac12}-z^2P^\circ_{1\frac12}$		
17	4,613.95	5	2	21,667.35	$a^2G_{3\frac12}-z^2F^\circ_{2\frac12}$	(0.00) 0.95	(**0.02**, 0.05, 0.08) ---, 0.90, 0.94, **0.97**
12	4,601.97	2		21,723.76	$b^2P_{0\frac12}-y^2P^\circ_{1\frac12}$		
16	4,574.49	6	1	21,854.25	$b^2P_{0\frac12}-x^2D^\circ_{1\frac12}$	(0.00) 0.85	(0.07) 0.73, **0.87**
14	4,565.43	3		21,897.62	$c^2D_{1\frac12}-z^2P^\circ_{0\frac12}$	(0.00) 0.85	0.07) 0.73, **0.87**
18	4,553.96	12	1	21,952.78	$b^2F_{2\frac12}-x^2D^\circ_{1\frac12}$	(0.00) 0.99	(**0.03**, 0.09) 0.77, 0.83 0.89, **0.94**
19	4,496.96	15	15	22,231.03	$a^2F_{2\frac12}-z^4G^\circ_{2\frac12}$	(0.49) 0.78	(0.14, 0.43, **0.71**) ---, 0.43, **0.71**, 1.00, ---
20	4,495.44	3	1	22,238.54	$b^4P_{1\frac12}-z^4D^\circ_{0\frac12}$		
18	4,494.41	8	2	22,243.64	$b^2F_{3\frac12}-x^2D^\circ_{2\frac12}$	(0.00) 1.08	(**0.03**, 0.09, 0.14) **1.00** 1.06, 1.11, ---
20	4,485.44	2		22,288.12	$b^4P_{2\frac12}-z^4D^\circ_{1\frac12}$	(0.00) 2.12	(**0.20**, 0.60) 1.00, 1.40, 1.80, **2.20**
21	4,482.04	3		22,305.03	$b^2F_{3\frac12}-z^2H^\circ_{4\frac12}$		
17	4,461.22	10	5	22,409.12	$a^2G_{4\frac12}-z^2F^\circ_{3\frac12}$	(0.00) 1.06	(**0.02**, 0.05, ---) **1.00**, 1.03, 1.06, ---
20	4,457.42	8	10	22,428.23	$b^4P_{0\frac12}-z^4D^\circ_{0\frac12}$	(0.00, **1.30**) **1.33**, 2.17	(1.33) 1.33
19	4,454.80	10	8	22,441.42	$a^2F_{3\frac12}-z^4G^\circ_{3\frac12}$	(0.43) 1.08	(--- 0.40, **0.56**) --- 0.91, **1.06**, 1.22, ---
22	4,445.88	1		22,486.44	$b^2D_{1\frac12}-z^2P^\circ_{1\frac12}$		
23	4,442.99	25	12	22,501.07	$a^2H_{4\frac12}-z^2G^\circ_{3\frac12}$	(0.00) 0.97	(**0.01**, 0.03, ---) --- 0.94, 0.96, **0.98**
24	4,442.50	2	1	22,503.55	$a^4P_{2\frac12}-z^2F^\circ_{3\frac12}$		
20	4,440.45	10	5	22,514.17	$b^4P_{1\frac12}-z^4D^\circ_{1\frac12}$	(0.80) 0.91, **1.42**, 1.95	(0.27, **0.80**) 0.93, **1.47** 2.00
25	4,429.34	2		22,570.41	$c^2D_{1\frac12}-y^4F^\circ_{2\frac12}$		
20	4,414.54	5	5	22,646.08	$b^4P_{2\frac12}-z^4D^\circ_{2\frac12}$	(0.57) 1.42	(--0.34, **0.57**) --- 1.26, **1.48**, 1.72, ---
25	4,404.81	2		22,696.10	$c^2D_{2\frac12}-y^4F^\circ_{3\frac12}$	(0.00) 1.30	(**0.02**, 0.06, 0.10) --- 1.22, 1.26, **1.29**
20	4,403.35	6	3	22,703.62	$b^4P_{0\frac12}-z^4D^\circ_{1\frac12}$	(0.68) **0.43**, 1.90	(0.73) **0.47**, 1.93
26	4,401.35	2		22,713.94	$a^2G_{3\frac12}-z^4F^\circ_{2\frac12}$		
17	4,399.44	2		22,723.82	$a^2G_{3\frac12}-z^2F^\circ_{3\frac12}$		
27	4,388.50	2		22,780.45	$b^2P_{1\frac12}-x^2F^\circ_{2\frac12}$		
28	4,383.10	1		22,808.52	$b^2D_{1\frac12}-y^4D^\circ_{0\frac12}$		
29	4,382.95	1		22,809.29	$b^2G_{3\frac12}-y^4F^\circ_{2\frac12}$		
23	4,379.78	9	8	22,825.81	$a^2H_{5\frac12}-z^2G^\circ_{4\frac12}$	(0.00) 1.02	(**0.01**, 0.03, ---) **1.00**, 1.02, ---
20	4,370.96	8	6	22,871.87	$b^4P_{1\frac12}-z^4D^\circ_{2\frac12}$	(0.00) 0.83	(**0.18**, 0.54) **0.83**, 1.19, ---
20	4,359.74	10	8	22,930.72	$b^4P_{2\frac12}-z^4D^\circ_{3\frac12}$	(0.00*w*) 1.07 A[1]	(**0.09**, 0.26, 0.43) **1.00**, 1.17, ---
30	4,342.23	1	1	23,023.19	$b^2D_{1\frac12}-y^4F^\circ_{1\frac12}$		
31	4,339.56	3	1	23,037.36	$a^2F_{3\frac12}-z^2F^\circ_{3\frac12}$		
32	4,337.63	5	1	23,047.61	$c^2D_{1\frac12}-y^2F^\circ_{2\frac12}$	(0.00) 1.20	(**0.03**, 0.09) --- 0.89, **0.94**
32	4,336.36	2		23,054.36	$c^2D_{2\frac12}-y^2F^\circ_{3\frac12}$		
33	4,333.28	15	1	23,070.74	$b^2F_{3\frac12}-x^2F^\circ_{3\frac12}$	(0.00) 1.13	(0.00) 1.14
34	4,325.64	3		23,111.49	$b^2G_{3\frac12}-y^4D^\circ_{2\frac12}$		
35	4,323.62	2		23,122.29	$b^2P_{1\frac12}-y^4P^\circ_{2\frac12}$		
19	4,317.32	12	3	23,156.03	$a^2F_{2\frac12}-z^4G^\circ_{3\frac12}$	(0.00) 1.13	(**0.06**, 0.19, 0.32) --- 1.18, **1.30**
36	4,312.23	3	1	23,183.36	$b^2D_{2\frac12}-y^2F^\circ_{2\frac12}$		
23	4,308.94	4	1	23,201.06	$a^2H_{4\frac12}-z^2G^\circ_{4\frac12}$	(0.77) 1.13	(---0.71, **0.91**) --- 0.81, **1.01**, 1.21, ---
29	4,301.81	5	1	23,239.51	$b^2G_{4\frac12}-y^4F^\circ_{3\frac12}$	(0.00) 0.73 A[1]	(**0.06**, 0.19, ---) **0.67**, 0.80, 0.92, ---
30	4,296.74	8	1	23,266.93	$b^2D_{2\frac12}-y^4F^\circ_{3\frac12}$	(0.00) 1.35	(**0.02**, 0.06, 0.10) --- 1.26, **1.29**
37	4,293.14	7	1	23,286.44	$b^2G_{3\frac12}-y^2F^\circ_{2\frac12}$	(0.00) 0.66 A[1]	(**0.02**, 0.05, 0.08) --- 0.94, **0.97**

TABLE 2.—*Wave lengths in the spark spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities B. S.	Intensities King	ν	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
38	4, 289. 18	2		23, 307. 94	$c^2D_{2\frac{1}{2}}-y^4D^\circ_{3\frac{1}{2}}$		
39	4, 286. 51	5	1	23, 322. 46	$a^2G_{3\frac{1}{2}}-z^2D^\circ_{2\frac{1}{2}}$	(0. 00*w*) 0. 49 A[1]	(**0. 16**, 0. 47, 0. 78) **0. 11**, 0. 42, 0. 73, ---
33	4, 282. 21	6		23, 345. 88	$b^2F_{2\frac{1}{2}}-x^2F^\circ_{3\frac{1}{2}}$	(0. 00) 0. 87	(0. 00) 0. 86
19	4, 277. 37	4	1	23, 372. 30	$a^2F_{3\frac{1}{2}}-z^4G^\circ_{4\frac{1}{2}}$	(0. 00) 1. 28	(**0. 02**, 0. 04, ---) ---, 1. 24, **1. 27**
40	4, 273. 52	4	2	23, 393. 35	$a^2P_{1\frac{1}{2}}-z^2F^\circ_{2\frac{1}{2}}$	(**0. 21**, 0. 67) 0. 00*w*	(**0. 24**, 0. 71) **0. 14**, 0.62 ---
41	4, 266. 72	1	5	23, 430. 63	$b^4P_{0\frac{1}{2}}-y^2D^\circ_{1\frac{1}{2}}$		
30	4, 264. 91	4	1	23, 440. 58	$b^2D_{1\frac{1}{2}}-y^4F^\circ_{2\frac{1}{2}}$	(0. 00*w*) 1. 38	(**0. 11**, 0. 34) ---1. 14, **1. 37**
42	4, 258. 05	12	10	23, 478. 34	$a^2D_{2\frac{1}{2}}-z^4G^\circ_{2\frac{1}{2}}$	(0. 70, **1. 27**) 0. 00, 0. 40 **0. 91**, 1. 39, 2. 00	(0. 31, 0. 94, **1. 57**) 0.26 0.37, **0. 88**, 1.51, 2.14
37	4, 236. 56	5	3	23, 597. 43	$b^2G_{4\frac{1}{2}}-y^2F^\circ_{3\frac{1}{2}}$	(0. 00*w*) 0. 76	(**0. 02**, 0. 05, ---) **1. 00**, 1. 03, 1. 06, ---
36	4, 231. 64	8	2	23, 624. 77	$b^2D_{2\frac{1}{2}}-y^2F^\circ_{3\frac{1}{2}}$	(0. 00) 1. 21	(**0. 03**, 0. 09, 0. 14) **1. 00** 1. 06, 1. 11, ---
43	4, 224. 27	3	2	23, 666. 09	$a^2P_{1\frac{1}{2}}-z^4F^\circ_{1\frac{1}{2}}$		
41	4, 222. 41	3		23, 676. 51	$b^4P_{1\frac{1}{2}}-y^2D^\circ_{2\frac{1}{2}}$	(0. 00) **0. 63**	(**0. 27**, 0. 80) **0. 40**, 0. 93, ---
26	4, 215. 76	1		23, 713. 86	$a^2G_{4\frac{1}{2}}-z^4F^\circ_{4\frac{1}{2}}$		
42	4, 211. 88	12	10	23, 735. 70	$a^2D_{1\frac{1}{2}}-z^4G^\circ_{2\frac{1}{2}}$	(0. 00) 0. 61	(**0. 11**, 0. 34) **0. 23**, 0. 46, 0. 69, 0. 91
28	4, 210. 62	5		23, 742. 81	$b^2D_{1\frac{1}{2}}-y^4D^\circ_{2\frac{1}{2}}$	(0. 00*w*) 1. 41	(**0. 29**, 0.86) 0.51, 1.08, 1. 66, **2. 23**
31	4, 208. 99	30	20	23, 752. 00	$a^2F_{2\frac{1}{2}}-z^2F^\circ_{2\frac{1}{2}}$	(0. 00) 0. 88	(0. 00) 0. 86
44	4, 205. 91	2		23, 769. 40	$b^2F_{3\frac{1}{2}}-y^4P^\circ_{2\frac{1}{2}}$		
34	4, 191. 50	6		23, 851. 11	$b^2G_{4\frac{1}{2}}-y^4D^\circ_{3\frac{1}{2}}$	(0.00*w*) 0.69	(**0. 16**, 0. 48, ---) **0. 00** 0.32, 0.63, ---
28	4, 186. 70	12		23, 878. 45	$b^2D_{2\frac{1}{2}}-y^4D^\circ_{3\frac{1}{2}}$	(0.00*w*) 1.49	(**0. 11**, 0.34, 0.57) --- 1.54, 1.77, **2. 00**
36	4, 179. 81	15		23, 917. 81	$b^2D_{1\frac{1}{2}}-y^2F^\circ_{2\frac{1}{2}}$	(0.00*w*) 1.25 A[3]	(**0. 03**, 0.09) 0.77, - 0.83, 0.89, **0. 94**
45	4, 161. 20	20	15	24, 024. 78	$a^2F_{2\frac{1}{2}}-z^4F^\circ_{1\frac{1}{2}}$	(0.00*w*) 1.09	(**0. 23**, 0.69) 0.17, - 0.63, 1.09, **1. 54**
43	4, 156. 24	15	15	24, 053. 45	$a^2P_{0\frac{1}{2}}-z^4F^\circ_{1\frac{1}{2}}$	(0.00) 0.70	(0.13) **0. 27**, 0.53
45	4, 150. 97	10	8	24, 083. 99	$a^2F_{3\frac{1}{2}}-z^4F^\circ_{2\frac{1}{2}}$	(0.00) 1.26	(**0. 06**, 0.17, 0.29) --- 1.20, 1.31, **1. 43**
31	4, 149. 22	75	50	24, 094. 14	$a^2F_{3\frac{1}{2}}-z^2D^\circ_{3\frac{1}{2}}$	(0.00) 1.15	(0.00) 1.14
46	4, 131. 31	1		24, 198. 60	$a^4P_{2\frac{1}{2}}-z^4D^\circ_{1\frac{1}{2}}$		
46	4, 123. 38	1		24, 245. 13	$a^4P_{1\frac{1}{2}}-z^4D^\circ_{0\frac{1}{2}}$		
47	4, 110. 05	3		24, 323. 77	$a^2P_{1\frac{1}{2}}-z^2D^\circ_{1\frac{1}{2}}$	(1.04) 0.69, **1. 38**	(0.27, **0. 80**) 0.53, **1. 07** 1.60
42	4, 096. 63	4	2	24, 403. 44	$a^2D_{2\frac{1}{2}}-z^4G^\circ_{3\frac{1}{2}}$	(0.00*w*) 0.81 A[1]	(**0. 11**, 0.32, 0.54) **0. 44**, 0.66, 0.88, ---
43	4, 090. 52	10	5	24, 439. 89	$a^2P_{1\frac{1}{2}}-z^4F^\circ_{2\frac{1}{2}}$	(0.00*w*) 0.81 A[1]	(**0. 15**, 0.46) **0. 57**, 0.88, 1.18, 1.49
46	4, 085. 68	5	5	24, 468. 85	$a^4P_{0\frac{1}{2}}-z^4D^\circ_{0\frac{1}{2}}$	(1.34) 1.33	(1.33) 1.33
46	4, 077. 05	3		24, 520. 64	$a^4P_{1\frac{1}{2}}-z^4D^\circ_{1\frac{1}{2}}$		
46	4, 071. 09	4	2	24, 556. 54	$a^4P_{2\frac{1}{2}}-z^4D^\circ_{2\frac{1}{2}}$	(0.52) 1.45	(0.11, 0.34, **0. 57**) --- 1.26, **1. 48**, 1. 72, ---
48	4, 050. 32	15	15	24, 682. 46	$a^2F_{2\frac{1}{2}}-z^2D^\circ_{1\frac{1}{2}}$	(0.00*w*) 1.23 A[3]	(**0. 03**, 0.09) 0.77, 0.83, 0.89, **0. 94**
48	4, 048. 68	25	15	24, 692. 46	$a^2F_{3\frac{1}{2}}-z^2D^\circ_{2\frac{1}{2}}$	(0.00) 1.20	(**0. 03**, 0.09, 0.14) **1. 00**, 1.06, 1.11, ---
47	4, 045. 63	15	10	24, 711. 07	$a^2P_{0\frac{1}{2}}-z^2D^\circ_{1\frac{1}{2}}$	(0.00) 0.58	(0.07) 0.73, **0. 87**
46	4, 040. 24	4	2	24, 744. 04	$a^4P_{0\frac{1}{2}}-z^4D^\circ_{1\frac{1}{2}}$	(0.69) **0. 46**, 1.90	(0.73) **0. 47**, 1.93
49	4, 034. 84	0		24, 777. 15	$a^2G_{3\frac{1}{2}}-z^4D^\circ_{2\frac{1}{2}}$		
45	4, 034. 10	5	2	24, 781. 70	$a^2F_{3\frac{1}{2}}-z^4F^\circ_{3\frac{1}{2}}$	(0.29) 1.20	(--- 0.24, **0. 33**) --- 1.10, **1. 19**, 1.29, ---
45	4, 031. 35	2		24, 798. 60	$a^2F_{2\frac{1}{2}}-z^4F^\circ_{2\frac{1}{2}}$		
31	4, 029. 68	20	15	24, 808. 88	$a^2F_{2\frac{1}{2}}-z^2F^\circ_{3\frac{1}{2}}$	(0.00) 1.59 A[3]	(**0. 14**, 0.43, 0.71) --- 1.28, 1.57, **1. 86**
46	4, 024. 45	12	5	24, 841. 12	$a^4P_{2\frac{1}{2}}-z^4D^\circ_{3\frac{1}{2}}$	(0.00*w*) 1.25	(**0. 09**, 0.26, 0.43) **1. 00**, 1.17, 1.34, ---
46	4, 018. 38	10	4	24, 878. 64	$a^4P_{1\frac{1}{2}}-z^4D^\circ_{2\frac{1}{2}}$	(0.00*w*) 0.89	(**0. 18**, 0.54) **0. 83**, 1.19, 1.55, 1.92

TABLE 2.—*Wave lengths in the spark spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities B. S.	Intensities King	ν	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
50	4,002.95	2		24,974.54	$b^2P_{1\frac12}-w^2D^\circ_{1\frac12}$		
51	3,998.98	30	20	24,999.33	$a^2D_{2\frac12}-z^2F^\circ_{2\frac12}$	(0.75) 1.08	(0.17, 0.51, **0.86**) --- 0.69, **1.03**, 1.37, ---
47	3,991.14	40	30	25,048.44	$a^2P_{1\frac12}-z^2D^\circ_{2\frac12}$	(0.00) 1.00 A[1]	(**0.07**, 0.20) **1.00**, 1.13, 1.27, 1.40
52	3,984.76	4	20	25,088.54	$b^4F_{2\frac12}-z^4G^\circ_{2\frac12}$		
50	3,982.01	3		25,105.87	$b^2P_{1\frac12}-w^2D^\circ_{2\frac12}$		
51	3,958.24	50	25	25,256.63	$a^2D_{1\frac12}-z^2F^\circ_{2\frac12}$	(0.00) 0.91	(**0.03**, 0.09) 0.77, 0.83, 0.89, **0.94**
53	3,941.92	3		25,361.20	$a^4P_{2\frac12}-y^2D^\circ_{2\frac12}$		
45	3,936.07	7	2	25,398.89	$a^2F_{3\frac12}-z^4F^\circ_{4\frac12}$	(0.00*w*) 1.78	(**0.10**, 0.29, ---) --- 1.62, 1.81, **2.00**
48	3,934.80	20	10	25,407.08	$a^2F_{2\frac12}-z^2D^\circ_{2\frac12}$	(0.56) 1.04	(0.17, 0.51, **0.86**) 0.34, 0.69, **1.03**, 1.37, 1.71
52	3,934.14	20	15	25,411.35	$b^4F_{1\frac12}-z^4G^\circ_{2\frac12}$	(0.00) 1.10	(**0.09**, 0.26) 0.31, 0.49, 0.66, **0.83**
50	3,929.54	8		25,441.09	$b^2P_{0\frac12}-w^2D^\circ_{1\frac12}$	(0.00) 1.00	(0.07) 0.73, **0.87**
54	3,923.92	1		25,477.53	$b^2D_{2\frac12}-x^4D^\circ_{3\frac12}$		
55	3,922.36	1		25,487.66	$b^2P_{1\frac12}-x^2P^\circ_{1\frac12}$		
56	3,915.94	25	15	25,529.45	$a^2D_{1\frac12}-z^4F^\circ_{1\frac12}$	(0.22) 0.74	(0.20, **0.60**) 0.20, **0.60**, 1.00
57	3,914.36	7		25,539.75	$b^2F_{2\frac12}-w^2D^\circ_{1\frac12}$	(0.00) 0.85	(**0.03**, 0.09) 0.77, 0.83, 0.89, **0.94**
52	3,903.77	1		25,609.03	$b^4F_{3\frac12}-z^4G^\circ_{3\frac12}$		
57	3,881.97	7		25,752.84	$b^2F_{3\frac12}-w^2D^\circ_{2\frac12}$		
58	3,874.37	1		25,803.36	$a^2H_{4\frac12}-y^2F^\circ_{3\frac12}$		
59	3,855.43	3		25,930.12	$a^2D_{2\frac12}-z^2D^\circ_{1\frac12}$		
60	3,853.07	2		25,946.00	$b^4P_{2\frac12}-z^2P^\circ_{1\frac12}$		
52	3,843.03	30		26,013.78	$b^4F_{2\frac12}-z^4G^\circ_{3\frac12}$	(0.00) 0.95	(**0.02**, 0.07, 0.11) **0.87**, 0.92, 0.96, ---
56	3,838.28	5		26,045.97	$a^2D_{2\frac12}-z^4F^\circ_{2\frac12}$		
51	3,836.76	60		26,056.29	$a^2D_{2\frac12}-z^2F^\circ_{3\frac12}$	(0.00) 1.12	(**0.03**, 0.09, 0.14) **1.00**, 1.06, 1.11, ---
54	3,833.87	2		26,075.93	$b^2D_{2\frac12}-x^4D^\circ_{3\frac12}$		
52	3,832.94	1		26,082.26	$b^4F_{4\frac12}-z^4G^\circ_{4\frac12}$		
61	3,827.51	1		26,119.26	$c^2D_{2\frac12}-y^2G^\circ_{3\frac12}$		
	3,827.27	1		26,120.90			
62	3,823.72	1		26,145.15	$a^2P_{1\frac12}-z^4D^\circ_{1\frac12}$		
63	3,823.41	3		26,147.27	$a^2F_{3\frac12}-z^4D^\circ_{2\frac12}$		
60	3,819.84	2		26,171.71	$b^4P_{1\frac12}-z^2P^\circ_{1\frac12}$		
64	3,818.78	1		26,178.97	$b^2G_{3\frac12}-x^4D^\circ_{3\frac12}$		
59	3,817.59	12		26,187.13	$a^2D_{1\frac12}-z^2D^\circ_{1\frac12}$	(0.00) 0.72	(0.00) 0.80
65	3,814.97	2		26,205.11	$b^4F_{3\frac12}-z^2F^\circ_{2\frac12}$		
54	3,813.98	0		26,211.91	$b^2D_{1\frac12}-x^4D^\circ_{2\frac12}$		
62	3,807.41	2		26,257.15	$a^2P_{0\frac12}-z^4D^\circ_{0\frac12}$		
56	3,800.73	5		26,303.29	$a^2D_{1\frac12}-z^4F^\circ_{2\frac12}$	(0.00) 1.30	(**0.11**, 0.34) 0.69, 0.91, 1.14, **1.37**
66	3,796.47	20		26,332.81	$a^2G_{4\frac12}-z^2G^\circ_{3\frac12}$	(0.00) 1.62 A[2]	(**0.11**, 0.33, ---) --- 1.44, 1.67, **1.89**
60	3,792.32	2		26,361.62	$b^4P_{0\frac12}-z^2P^\circ_{1\frac12}$		
67	3,782.72	5		26,428.52	$c^2D_{1\frac12}-y^2P^\circ_{0\frac12}$	(0.00) 0.83	(0.07) 0.73, **0.87**
63	3,782.24	4		26,431.88	$a^2F_{3\frac12}-z^4D^\circ_{3\frac12}$		
62	3,772.06	4		26,503.21	$a^2P_{1\frac12}-z^4D^\circ_{2\frac12}$	(0.00) 1.40	(**0.02**, 0.06) 1.31, 1.35, 1.35, 1.39, **1.43**
63	3,771.98	2		26,503.77	$a^2F_{2\frac12}-z^4D^\circ_{1\frac12}$		
62	3,767.89	5		26,532.54	$a^2P_{0\frac12}-z^4D^\circ_{1\frac12}$		
52	3,766.83	25	30	26,540.01	$b^4F_{3\frac12}-z^4G^\circ_{4\frac12}$	(0.00) 1.04	(**0.03**, 0.10, ---) **0.94**, 1.01, 1.07, ---
67	3,757.80	8		26,603.78	$c^2D_{2\frac12}-y^2P^\circ_{1\frac12}$	(0.00) 1.18	(**0.07**, 0.20) (**1.00**, 113, 1.27, 1.40
65	3,756.96	1		26,609.73	$b^4F_{2\frac12}-z^2F^\circ_{2\frac12}$		
66	3,751.60	75	30	26,647.74	$a^2G_{3\frac12}-z^2G^\circ_{3\frac12}$	(0.00) 0.91	(0.00) 0.89
59	3,750.65	6		26,654.50	$a^2D_{2\frac12}-z^2D^\circ_{2\frac12}$	(0.00) 1.15	(0.00) 1.20
68	3,745.97	40		26,687.80	$b^2G_{4\frac12}-y^2G^\circ_{4\frac12}$	(0.00) 1.07	(0.00) 1.11
56	3,738.13	5		26,743.77	$a^2D_{2\frac12}-z^4F^\circ_{3\frac12}$	(0.00) 1.32	(**0.02**, 0.06, 0.10) --- 1.22, 1.26, **1.29**
68	3,731.26	35	10	26,793.01	$b^2G_{3\frac12}-y^2G^\circ_{3\frac12}$	(0.00) 0.87	(0.00) 0.89
65	3,729.74	5		26,803.92	$b^4F_{4\frac12}-z^2F^\circ_{3\frac12}$	(0.00) 1.68	(**0.10**, 0.29, ---) --- 1.62, 1.81, **2.00**
68	3,727.72	10		26,818.45	$b^2G_{3\frac12}-y^2G^\circ_{4\frac12}$	(0.00*w*) 1.44	(**0.11**, 0.33, ---) --- 1.44, 1.67, **1.89**

TABLE 2.—*Wave lengths in the spark spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities B. S.	Intensities King	ν	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
63	3, 721. 69	2		26, 861. 90	$a^2F_{2\frac{1}{2}}-z^4D^0_{2\frac{1}{2}}$		
69	3, 718. 86	6		26, 882. 34	$b^4F_{2\frac{1}{2}}-z^4F^0_{1\frac{1}{2}}$	(0. 00*w*) 1. 43	(**0. 31**, 0.94) 0.09, 0.71, 1. 34, **1. 97**
70	3, 717. 02	2		26, 895. 65	$b^4P_{1\frac{1}{2}}-y^4D^0_{1\frac{1}{2}}$		
59	3, 714. 77	15	6	26, 911. 94	$a^2D_{1\frac{1}{2}}-z^2D^0_{2\frac{1}{2}}$	(0. 00*w*) 1. 31	(**0. 20**, 0.60) 0.60, 1.00, 1. 40, **1. 80**
65	3, 711. 95	1		26, 932. 38	$b^4F_{1\frac{1}{2}}-z^2F^0_{1\frac{1}{2}}$		
71	3, 710. 47	1		26, 943. 12	$c^2D_{2\frac{1}{2}}-x^2D^0_{2\frac{1}{2}}$		
72	3, 709. 27	60	30	26, 951. 84	$a^2F_{3\frac{1}{2}}-y^2D^0_{2\frac{1}{2}}$	(0. 00) 1. 08	(**0. 03**, 0.09, 0.14) **1. 00**, 1. 06, 1. 11, ---
66	3, 698. 17	100	40	27, 032. 74	$a^2G_{4\frac{1}{2}}-z^2G^0_{4\frac{1}{2}}$	(0. 00) 1. 13	(0. 00) 1. 11
52	3, 697. 49	20	10	27, 037. 71	$b^4F_{4\frac{1}{2}}-z^4G^0_{3\frac{1}{2}}$	(0. 00) 1. 15	(**0. 03**, 0. 09, 0. 15, ---) **1. 00**, 1. 06, 1. 12, ---
73	3, 692. 60	1		27, 073. 51	$a^4P_{1\frac{1}{2}}-z^2S^0_{0\frac{1}{2}}$		
63	3, 682. 67	2		27, 146. 51	$a^2F_{2\frac{1}{2}}-z^4D^0_{3\frac{1}{2}}$		
71	3, 679. 64	1		27, 168. 86	$c^2D_{1\frac{1}{2}}-x^2D^0_{1\frac{1}{2}}$		
74	3, 678. 91	10		27, 174. 25	$b^2D_{2\frac{1}{2}}-y^2P^0_{1\frac{1}{2}}$	(0. 00) 1. 12	(**0. 07**, 0.20) **1. 00**, 1.13, 1. 27, 1. 40
69	3, 674. 74	40	40	27, 205. 09	$b^4F_{1\frac{1}{2}}-z^4F^0_{1\frac{1}{2}}$	(0. 39) 0. 58	(0. 00) 0. 40
75	3, 672. 65	2		27, 220. 57	$a^4F_{3\frac{1}{2}}-z^4G^0_{2\frac{1}{2}}$		
72	3, 671. 28	20	10	27, 230. 73	$a^2F_{2\frac{1}{2}}-y^2D^0_{1\frac{1}{2}}$	(0. 00) 0. 93	(**0. 03**, 0.09) 0.77, 0.83, 0. 89, **0. 94**
69	3, 668. 46	8	5	27, 251. 66	$b^4F_{3\frac{1}{2}}-z^4F^0_{2\frac{1}{2}}$	(0. 00*w*) 1. 55	(**0. 10**, 0. 31, 0. 52) --- 1. 34, 1. 55, **1. 76**
76	3, 637. 40	1		27, 259. 54	$a^2P_{0\frac{1}{2}}-y^2D^0_{1\frac{1}{2}}$		
65	3, 667. 06	3		27, 262. 07	$b^4F_{3\frac{1}{2}}-z^2F^0_{3\frac{1}{2}}$	(0. 00) 1. 19	(--- 0. 24, **0. 33**) --- 1. 10, **1. 19**, 1. 29, ---
74	3, 662. 14	8		27, 298. 69	$b^2D_{1\frac{1}{2}}-y^2P^0_{0\frac{1}{2}}$	(0. 00) 0. 82	(0. 07) 0. 73, **0. 87**
77	3, 661. 33	4		27, 304. 73	$b^2D_{2\frac{1}{2}}-x^2D^0_{1\frac{1}{2}}$		
76	3, 660. 92	3		27, 307. 79	$a^2P_{1\frac{1}{2}}-y^2D^0_{2\frac{1}{2}}$		
66	3, 655. 56	7		27, 347. 83	$a^2G_{3\frac{1}{2}}-z^2G^0_{4\frac{1}{2}}$	(0. 00*w*) 1. 57	(**0. 11**, 0. 33 ---) --- 1. 44, 1. 67, **1. 89**
71	3, 651. 50	2		27, 378. 23	$c^2D_{1\frac{1}{2}}-x^2D^0_{2\frac{1}{2}}$	(0. 00) 1. 60	(**0. 20**, 0.60) 0.60, 1.00, 1. 40, **1. 80**
78	3, 650. 73	7		27, 384. 01	$a^2S_{0\frac{1}{2}}-w^2P^0_{0\frac{1}{2}}$	(0. 68) 1. 34	(0. 67) 1. 33
69	3, 636. 46	8	5	27, 491. 46	$b^4F_{4\frac{1}{2}}-z^4F^0_{3\frac{1}{2}}$	(0. 00) 1. 54	(**0. 05**, 0. 14, ---) --- 1. 48, 1. 57, **1. 67**
77	3, 633. 49	10		27, 513. 93	$b^2D_{2\frac{1}{2}}-z^2D^0_{2\frac{1}{2}}$	(0. 00) 1. 18	(0. 00) 1. 20
79	3, 630. 03	10	10	27, 540. 16	$b^4F_{2\frac{1}{2}}-z^2D^0_{1\frac{1}{2}}$	(0. 00*w*) 1. 70	(**0. 11**, 0.34) 0.69, 0.91, 1. 14, **1. 37**
80	3, 629. 12	1		27, 547. 06	$b^2G_{4\frac{1}{2}}-z^2H^0_{4\frac{1}{2}}$		
69	3, 614. 79	18	40	27, 656. 26	$b^4F_{2\frac{1}{2}}-z^4F^0_{2\frac{1}{2}}$	(0. 00) 1. 04	(0. 00) 1. 03
72	3, 613. 43	2		27, 666. 65	$a^2F_{2\frac{1}{2}}-y^2D^0_{2\frac{1}{2}}$		
75	3, 613. 08	12	40	27, 669. 35	$a^4F_{2\frac{1}{2}}-z^4G^0_{2\frac{1}{2}}$	(0. 86) 0. 94	(0.23, 0.69, **1. 14**) --- 0. 34, **0. 80**, 1. 06 ---
78	3, 612. 34	3		27, 675. 02	$a^2S_{0\frac{1}{2}}-w^2P^0_{1\frac{1}{2}}$	(0. 37) 0. 53	(0. 33) **1. 00**, 1. 67
80	3, 611. 90	15	8	27, 678. 39	$b^2G_{3\frac{1}{2}}-z^2H^0_{4\frac{1}{2}}$	(0. 00) 1. 06	(**0. 01**, 0. 03 ---) --- 0. 94, 0. 96, **0. 98**
81	3, 607. 39	7	5	27, 713. 00	$b^4P_{2\frac{1}{2}}-z^4S^0_{1\frac{1}{2}}$	(0. 00*w*) 1. 33	(**0. 20**, 0.60) **1. 00**, 1. 40, 1. 80, 2. 20
82	3, 599. 91	7		27, 770. 58	$c^2D_{2\frac{1}{2}}-x^2F^0_{3\frac{1}{2}}$	(0. 00) 1. 02	(**0. 03**, 0.09, 0.14) **1. 00**, 1. 06, 1. 11, ---
83	3, 588. 80	2		27, 856. 55	$a^4P_{2\frac{1}{2}}-z^2P^0_{1\frac{1}{2}}$	(0. 00) 1. 54	(**0. 13**, 0.40) 1.20, 1.47, 1. 73, **2. 00**
79	3, 588. 32	6		27, 860. 27	$b^4F_{3\frac{1}{2}}-z^2D^0_{2\frac{1}{2}}$	(0. 00) 1. 50	(**0. 02**, 0. 06, 0. 10) --- 1. 22, 1. 26, **1. 29**
79	3, 587. 98	7	10	27, 862. 91	$b^4F_{1\frac{1}{2}}-z^2D^0_{1\frac{1}{2}}$	(0. 26) 0. 52	(0.20, **0. 60**) 0.20, **0. 60**, 1.00
74	3, 582. 08	2		27, 908. 80	$b^2D_{1\frac{1}{2}}-y^2P^0_{1\frac{1}{2}}$		
81	3, 578. 22	7	4	27, 938. 91	$b^4P_{1\frac{1}{2}}-z^4S^0_{1\frac{1}{2}}$	(0. 25) **1. 81**	(0.13, **0. 40**) 1.60, **1. 87**, 2. 13
69	3, 576. 88	20	40	27, 949. 38	$b^4F_{3\frac{1}{2}}-z^4F^0_{3\frac{1}{2}}$	(0. 00) 1. 25	(0. 00) 1. 24
69	3, 573. 09	8	8	27, 979. 02	$b^4F_{1\frac{1}{2}}-z^4F^0_{2\frac{1}{2}}$	(**0. 31**, 0.96) ---, 0.67, 1. 35, **2. 01**	(**0. 31**, 0.94) 0.09, 0.71, 1. 34, **1. 97**
75	3, 572. 47	30	100	27, 983. 88	$a^4F_{1\frac{1}{2}}-z^4G^0_{2\frac{1}{2}}$	(0. 00*w*) 0. 93 A[2]	(**0. 09**, 0.26) 0.31, 0.49, 0. 66, **0. 83**
84	3, 568. 14	4		28, 017. 83	$a^2F_{3\frac{1}{2}}-z^2G^0_{3\frac{1}{2}}$	(0. 81) 1. 05	(--- 0.64, **0. 89**) --- 0. 76, **1. 02**, 1. 27, ---
77	3, 565. 41	5		28, 039. 29	$b^2D_{1\frac{1}{2}}-x^2D^0_{1\frac{1}{2}}$	(0. 00) 0. 84	(0. 00) 0. 80

TABLE 2.—*Wave lengths in the spark spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities B. S.	Intensities King	ν	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
70	3, 561. 11	1		28, 073. 17	$b^4P_{2\frac{1}{2}}-y^4D^\circ_{3\frac{1}{2}}$		
85, 69	3, 556. 61	30	60	28, 108. 66	$\{a^2D_{2\frac{1}{2}}-z^4D^\circ_{3\frac{1}{2}}$ $b^4F_{4\frac{1}{2}}-z^4F^\circ_{3\frac{1}{2}}\}$	(0. 00) 1. 31	(0. 00) 1. 33
81	3, 554. 09	7		28, 128. 59	$b^4P_{0\frac{1}{2}}-z^4S^\circ_{1\frac{1}{2}}$	(0. 37) **1. 55**, 2. 39	(0. 33) **1. 67**, 2. 33
75	3, 551. 94	18	40	28, 145. 62	$a^4F_{3\frac{1}{2}}-z^4G^\circ_{3\frac{1}{2}}$	(0. 69) 1. 14	-- 0. 64, **0. 89**) --- 0. 86, **1. 11**, 1. 37, ---
86	3, 549. 51	10		28, 164. 88	$b^4P_{2\frac{1}{2}}-z^4P^\circ_{1\frac{1}{2}}$	(0. 00) 1. 44	(0. 07, 0. 20) **1. 40**, 1.54, 1. 67, 1. 80
80	3, 542. 65	25	10	28, 219. 42	$b^2G_{4\frac{1}{2}}-z^2H^\circ_{5\frac{1}{2}}$	(0. 00) 1. 11	(**0. 01**, 0. 03, ---) **1. 00**, 1. 02, 1. 04, ---
77	3, 539. 05	4		28, 248. 13	$b^2D_{1\frac{1}{2}}-x^2D^\circ_{2\frac{1}{2}}$	(0. 00) 1. 59	(**0. 20**, 0. 60) 0. 60, 1. 00, 1. 40, **1. 80**
79	3, 536. 94	5		28, 264. 98	$b^4F_{2\frac{1}{2}}-z^2D_{2\frac{1}{2}}$	(0. 00) 1. 12	(0. 09, 0. 26, **0. 43**) --- 0. 94, **1. 11**, 1. 28, ---
87	3, 530. 85	6		28, 313. 73	$b^2G_{4\frac{1}{2}}-x^2F^\circ_{3\frac{1}{2}}$	(0. 00) 1. 06	(**0. 02**, 0. 05, ---) **1. 00**, 1. 03, 1. 06, ---
86	3, 529. 99	5		28, 320. 63	$b^4P_{1\frac{1}{2}}-z^4P^\circ_{0\frac{1}{2}}$	(0. 41) 1. 09	(0. 47) **1. 27**, 2. 20
93	3, 527. 42	7		28, 341. 26	$b^2D_{2\frac{1}{2}}-x^2F^\circ_{3\frac{1}{2}}$	(0. 00) 1. 06	(**0. 03**, 0. 09, 0. 14) **1. 00**, 1. 06, 1. 11, ---
69	3, 525. 81	8	10	28, 354. 20	$b^4F_{2\frac{1}{2}}-z^4F^\circ_{3\frac{1}{2}}$	(0. 00) 1. 53	(**0. 10**, 0. 31, 0. 52) --- 1. 34, 1. 55, **1. 76**
94, 85	3, 520. 87	5		28, 393. 98	$\{a^2D_{2\frac{1}{2}}-z^4D^\circ_{3\frac{1}{2}}$ $a^4P_{2\frac{1}{2}}-y^4F^\circ_{1\frac{1}{2}}\}$	(0. 00) 1. 73	
87	3, 514. 64	4		28, 444. 31	$b^2G_{3\frac{1}{2}}-x^2F^\circ_{3\frac{1}{2}}$		
83	3, 512. 67	3		28, 460. 26	$a^4P_{1\frac{1}{2}}-z^2P^\circ_{0\frac{1}{2}}$		
88	3, 511. 55	2		28, 469. 34	$c^2D_{2\frac{1}{2}}-y^4P^\circ_{1\frac{1}{2}}$		
89	3, 510. 46	7	4	28, 478. 18	$a^2D_{2\frac{1}{2}}-y^2D^\circ_{1\frac{1}{2}}$	(0.00*w*) 1. 55	(**0. 20**, 0. 60) 0. 60, 1. 00, 1. 40, **1. 80**
90	3, 507. 66	4		28, 500. 91	$a^4P_{1\frac{1}{2}}-y^4D^\circ_{0\frac{1}{2}}$	(0. 81) 0. 96, **2. 48**	(0. 87) 0. 87, **2. 60**
86	3, 506. 48	2		28, 510. 50	$b^4P_{0\frac{1}{2}}-z^4P^\circ_{0\frac{1}{2}}$		
86	3, 506. 04	4		28, 514. 08	$b^4P_{2\frac{1}{2}}-z^4P^\circ_{2\frac{1}{2}}$	(0. 00) 1. 70	(0. 00) 1. 60
75	3, 505. 67	12	20	28, 517. 09	$a^4F_{4\frac{1}{2}}-z^4G^\circ_{4\frac{1}{2}}$	(0. 80) 1. 27	(--- 0. 57, **0. 73**) --- 1. 09, **1. 25**, 1. 42, ---
91	3, 505. 47	15	10	28, 518. 72	$a^2H_{5\frac{1}{2}}-y^2G^\circ_{4\frac{1}{2}}$	(0. 00) 1. 13	(**0. 01**, 0. 03, ---) **1. 00**, 1. 02, 1. 04, ---
82	3, 500. 15	4		28, 562. 06	$c^2D_{1\frac{1}{2}}-x^2F^\circ_{2\frac{1}{2}}$	(0. 00) 0. 94	(**0. 03**, 0. 09) 0. 77, 0. 83, 0. 89, **0. 94**
69	3, 499. 58	8	6	28, 566. 72	$b^4F_{3\frac{1}{2}}-z^4F^\circ_{1\frac{1}{2}}$	(0. 00) 1. 48	(**0. 05**, 0. 14, ---) --- 1. 48, 1. 57, **1. 67**
90, 86	3, 497. 90	12		28, 580. 43	$\{b^4P_{0\frac{1}{2}}-z^4P^\circ_{1\frac{1}{2}}$ $a^4P^\circ_{2\frac{1}{2}}-y^4D^\circ_{1\frac{1}{2}}\}$	(0. 36) 1. 33, **2. 26**	{(**0. 20**, 0. 60) -1. 00, 1. 40, 1. 80, **2. 20**
79	3, 497. 00	2		28, 587. 76	$b^4F_{1\frac{1}{2}}-z^2D^\circ_{2\frac{1}{2}}$		
75	3, 496. 18	50	200	28, 594. 50	$a^4F_{2\frac{1}{2}}-z^4G^\circ_{3\frac{1}{2}}$	(0. 00) 1. 00	(**0. 02**, 0. 07, 0. 11) **0. 87**, 0. 92, 0. 96, ---
83	3, 485. 31	5		28, 683. 67	$a^4P_{0\frac{1}{2}}-z^2P^\circ_{0\frac{1}{2}}$	(1. 05) 1. 72	(1. 00) 1. 67
93, 92	3, 483. 54	12	30	28, 698. 25	$\{a^2P_{1\frac{1}{2}}-z^2S^\circ_{0\frac{1}{2}}$ $b^2D_{2\frac{1}{2}}-x^2F^\circ_{2\frac{1}{2}}\}$	(0. 34) **0. 98**, 1. 63	(0. 33) **1. 00**, **1. 67**
94	3, 481. 44	2		28, 715. 56	$a^4P_{1\frac{1}{2}}-y^4F^\circ_{1\frac{1}{2}}$		
84	3, 481. 14	35	80	28, 718. 03	$a^2F_{3\frac{1}{2}}-z^2G^\circ_{4\frac{1}{2}}$	((0. 00) 1. 09	(**0. 02**, 0. 05, --- **1. 00**, 1. 03, 1. 06---
90	3, 480. 40	5	5	28, 724. 14	$a^4P_{0\frac{1}{2}}-y^4D^\circ_{0\frac{1}{2}}$	(1. 30) 1. 44	(1. 33) 1. 33
84	3, 479. 39	30	60	28, 732. 47	$a^2F_{2\frac{1}{2}}-z^2G^\circ_{3\frac{1}{2}}$	(0. 00) 0. 90	(**0. 02**, 0. 05, 0. 08) --- 0. 90, 0. 94, **0. 97**
89	3, 479. 02	5	10	28, 735. 53	$a^2D_{1\frac{1}{2}}-y^2D^\circ_{1\frac{1}{2}}$	(0. 00) 0. 90	(0. 00) 0. 80
86	3, 478. 50	3	2	28, 739. 82	$b^4P_{1\frac{1}{2}}-z^4P^\circ_{2\frac{1}{2}}$	(0. 00) 1. 47	(**0. 07**, 0. 20) **1. 40**, 1. 54, 1. 67, 1. 80
95	3, 478. 29	4	5	28, 741. 56	$a^4F_{3\frac{1}{2}}-z^2F^\circ_{2\frac{1}{2}}$	(0. 00) 1. 93	(**0. 19**, 0. 57, 0. 95)--- 1. 43, 1. 81, **2. 19**
87	3, 471. 14	8	100	28, 800. 76	$b^2G_{3\frac{1}{2}}-x^2F^\circ_{2\frac{1}{2}}$	(0. 00) 0. 93	(**0. 02**, 0. 05, 0. 08) --- 0. 90, 0. 94, **0. 97**
94	3, 469. 94	4		28, 810. 72	$a^4P_{2\frac{1}{2}}-y^4F^\circ_{2\frac{1}{2}}$	(1. 20) 1. 43	(0. 29, 0. 86, **1. 43**)--- 0. 74, **1. 31**, 1. 89,---
91	3, 463. 02	35	30	28, 868. 29	$a^2H_{4\frac{1}{2}}-y^2G^\circ_{3\frac{1}{2}}$	(0. 00) 0. 95	(**0. 01**, 0. 03, ---) --- 0. 94, 0. 96, **0. 98**
91	3, 459. 95	3		28, 893. 91	$a^2H_{4\frac{1}{2}}-y^2G^\circ_{4\frac{1}{2}}$		
90	3, 458. 93	10	10	28, 902. 43	$a^4P_{1\frac{1}{2}}-y^4D^\circ_{1\frac{1}{2}}$	(1.05) 0.63, **1. 37**, 2.02	(0. 27, **0. 80**) 0. 93, **1. 47**, 2. 00

TABLE 2.—*Wave lengths in the spark spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities B. S.	Intensities King	ν	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
89	3,457.56	12	30	28,913.88	$a^2D_{2\frac{1}{2}}-y^2D^0_{3\frac{1}{2}}$	(0.00) 1.20	(0.00) 1.20
94	3,454.57	4	3	28,938.91	$a^4P_{0\frac{1}{2}}-y^4F^0_{1\frac{1}{2}}$		
97	3,443.57	7	3	29,031.34	$a^2G_{3\frac{1}{2}}-y^4F^0_{2\frac{1}{2}}$	(0.00*w*) 0.64	(**0.07**, 0.21, 0.35) **0.54**, 0.68, 0.82,--
75	3,438.23	100	400	29,076.43	$a^4F_{3\frac{1}{2}}-z^4G^0_{4\frac{1}{2}}$	(0.00) 1.11	(**0.03**, 0.10, ---) **0.94**, 1.01, 1.07,--
92	3,437.16	10	20	29,085.73	$a^2P_{0\frac{1}{2}}-z^2S^0_{0\frac{1}{2}}$	(0.65) 1.28	(0.67) 1.33
90	3,433.90	8	4	29,113.09	$a^4P_{2\frac{1}{2}}-y^4D^0_{2\frac{1}{2}}$	(1.07) 1.42	(0.11, 0.34, **0.57**) --- 1.26, **1.48**, 1.72,---
90	3,432.41	7	5	29,125.73	$a^4P_{0\frac{1}{2}}-y^4D^0_{1\frac{1}{2}}$	(0.85) **0.00**, 1.54	(0.73) **0.47**, 1.93
94	3,431.57	6	5	29,132.86	$a^4P_{1\frac{1}{2}}-y^4F^0_{2\frac{1}{2}}$	(**0.29**, 0.91) **0.00**, ---	(**0.35**, 1.06) **0.03**, 0.68, 1.38, 2.09
98	3,430.53	30	50	29,141.69	$b^4F_{4\frac{1}{2}}-z^4D^0_{3\frac{1}{2}}$	(0.00) 1.19	(**0.05**, 0.14, ---) **1.00**, 1.10, 1.19---
95	3,424.82	7	10	29,190.27	$a^4F_{2\frac{1}{2}}-z^2F^0_{2\frac{1}{2}}$	(0.37) **0.84**	(0.09, 0.26, **0.43**) --- 0.77, **0.94**, 1.12, --
99	3,424.64	1		29,191.81	$b^4P_{1\frac{1}{2}}-x^4D^0_{0\frac{1}{2}}$		
	3,423.82	3*l*		29,198.80			
95	3,419.10	5	6	29,239.11	$a^4F_{4\frac{1}{2}}-z^2F^0_{3\frac{1}{2}}$	(0.00) 1.82	(**0.10**, 0.29, ---) --- 1.62, 1.81, **2.00**
97	3,414.65	12	6	29,277.21	$a^2G_{4\frac{1}{2}}-y^4F^0_{3\frac{1}{2}}$	(0.00) 0.78	(**0.06**, 0.19, ---) **0.67**, 0.80, 0.92, --
100	3,413.39	5	4	29,288.02	$a^4P_{2\frac{1}{2}}-y^2F^0_{2\frac{1}{2}}$	(1.29) 1.40	(0.37, 1.11, **1.86**) --- 0.49, **1.23**, 1.97, --
98	3,410.26	20	60	29,314.90	$b^4F_{3\frac{1}{2}}-z^4D^0_{2\frac{1}{2}}$	(0.00) 1.12	(**0.07**, 0.20, 0.33) **0.91**, 1.04, 1.17,---
101	3,408.09	10	8	29,333.56	$a^2G_{3\frac{1}{2}}-y^4D^0_{2\frac{1}{2}}$	(0.00) 0.47	(**0.24**, 0.72, 1.21) 0.16, **0.32**, 0.65,--
98	3,404.84	12	50	29,361.56	$b^4F_{2\frac{1}{2}}-z^4D^0_{1\frac{1}{2}}$	(0.00) 0.88	(**0.09**, 0.26) **0.77**, 0.94, 1.12, 1.29
94	3,403.69	8	10	29,371.48	$a^4P_{2\frac{1}{2}}-y^4F^0_{3\frac{1}{2}}$	(0.00) 0.54	(**0.18**, 0.54, 0.90) **0.35**, 0.70, 1.06, --
102	3,402.87	7	6	29,378.56	$a^2H_{5\frac{1}{2}}-z^2H^0_{4\frac{1}{2}}$	(0.00) 1.52	(**0.09**, 0.27, ---) ---1.54, 1.73, **1.91**
99	3,402.52	1		29,381.58	$b^4P_{0\frac{1}{2}}-x^4D^0_{0\frac{1}{2}}$		
98	3,399.36	10	40	29,408.90	$b^4F_{1\frac{1}{2}}-z^4D^0_{0\frac{1}{2}}$	(0.00) 0.57	(0.20) 0.20, **0.60**
93	3,396.66	6	2	29,432.27	$b^2D_{1\frac{1}{2}}-x^2F^0_{2\frac{1}{2}}$	(0.00) 0.95	(**0.03**, 0.09) 0.77, 0.83, 0.89, **0.94**
90	3,396.34	7	8	29,435.04	$a^4P_{1\frac{1}{2}}-y^4D^0_{2\frac{1}{2}}$	(**0.30**, 0.90) 0.60	(**0.18**, 0.54) **0.83**, 1.19, 1.55, 1.92
99	3,394.63	3	2	29,449.87	$b^4P_{1\frac{1}{2}}-x^4D^0_{1\frac{1}{2}}$	(0.00) 1.58	(0.27, **0.80**) 0.93, **1.47**, 2.00
103	3,393.12	10	25	29,462.97	$a^4F_{2\frac{1}{2}}-z^4F^0_{1\frac{1}{2}}$	(0.00) 1.46	(**0.31**, 0.94) 0.09, 0.71, 1.34, **1.97**
75	3,391.96	100	400	29,473.05	$a^4F_{4\frac{1}{2}}-z^4G^0_{5\frac{1}{2}}$	(0.00) 1.13	(**0.03**, 0.09, ---) **1.60**, 1.06, 1.12, ---
95	3,388.29	15	80	29,504.97	$a^4F_{1\frac{1}{2}}-z^2F^0_{2\frac{1}{2}}$	(**0.22**, 0.60) 1.51	(**0.23**, 0.69) 0.17, 0.63, 1.09, **1.54**
104	3,387.87	12	40	29,508.63	$a^2G_{3\frac{1}{2}}-y^2F^0_{2\frac{1}{2}}$	(0.00) 0.67	(**0.02**, 0.05, 0.08) --- 0.90, 0.94, **0.97**
97	3,378.30	5	4	29,592.22	$a^2G_{3\frac{1}{2}}-y^4F^0_{3\frac{1}{2}}$		
98	3,377.45	6	10	29,599.66	$b^4F_{3\frac{1}{2}}-z^4D^0_{3\frac{1}{2}}$	(0.55) 1.30	(--- 0.48, **0.67**) --- 1.14, **1.33**, 1.52, ---
100	3,376.25	7	8	29,610.18	$a^4P_{1\frac{1}{2}}-y^2F^0_{2\frac{1}{2}}$	(0.34) **0.00**, 1.00	(**0.44**, 1.31) 0.42, **0.46**, 1.30, 2.17
105	3,374.71	15	30	29,623.70	$a^4P_{2\frac{1}{2}}-z^4S^0_{1\frac{1}{2}}$	(0.00*w*) 1.35	(**0.20**, 0.60) **1.00**, 1.40, 1.80, 2.20
104	3,373.42	8	15	29,635.03	$a^2G_{4\frac{1}{2}}-y^2F^0_{3\frac{1}{2}}$	(0.00) 0.94	(**0.02**, 0.05, ---) **1.00**, 1.03, 1.06, ---
99	3,369.27	3	2	29,671.53	$b^4P_{2\frac{1}{2}}-x^4D^0_{2\frac{1}{2}}$	(0.40) 1.48	(0.11, 0.34, **0.57**) --- 1.26, **1.48**, 1.72, ---
98	3,367.81	5	7	29,684.39	$b^4F_{1\frac{1}{2}}-z^4D^0_{1\frac{1}{2}}$	(0.00, **1.13**) **0.79**, 1.53	(0.40, **1.20**) 0.00, **0.80**, 1.60
98	3,363.81	5	8	29,719.69	$b^4F_{2\frac{1}{2}}-z^4D^0_{2\frac{1}{2}}$	(0.76) 1.20	(0.17, 0.51, **0.86**) --- 0.86, **1.20**, 1.54,---
100	3,362.70	4	4	29,729.50	$a^4P_{2\frac{1}{2}}-y^2F^0_{3\frac{1}{2}}$	(0.00) 0.00*w*	(**0.23**, 0.69, 1.14) **0.00**, 0.46, 0.91, ---
102	3,359.96	12	10	29,753.74	$a^2H_{4\frac{1}{2}}-z^2H^0_{4\frac{1}{2}}$	(0.00) 0.93	(0.00) 0.91

TABLE 2.—*Wave lengths in the spark spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities B. S.	Intensities King	ν	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
103	3, 357. 26	15	50	29, 777. 67	$a^4F_{1\frac{1}{2}}-z^4F^{\circ}_{1\frac{1}{2}}$	(0. 36) 0. 53	(0. 00) 0. 40
103	3, 356. 08	18	60	29, 788. 14	$a^4F_{3\frac{1}{2}}-z^4F^{\circ}_{2\frac{1}{2}}$	(0. 00*w*) 1. 56	(**0. 10**, 0. 31, 0. 52) --- 1. 34, 1. 55, **1. 76**
106	3, 354. 39	7	10	29, 803. 14	$a^2P_{1\frac{1}{2}}-z^2P^{\circ}_{1\frac{1}{2}}$	(0. 00) 1. 33	(0. 00) 1. 33
101	3, 344. 80	15	15	29, 888. 59	$a^2G_{4\frac{1}{2}}-y^4D^{\circ}_{3\frac{1}{2}}$	(0. 00) 0. 57	(**0. 16**, 0. 48, ---) **0. 00** 0. 32, 0. 63, ---
99	3, 343. 81	4		29, 897. 44	$b^4P_{1\frac{1}{2}}-x^4D^{\circ}_{2\frac{1}{2}}$	(0. 00) 1. 06	(**0. 18**, 0. 54) **0. 83**, 1. 19, 1. 55, 1. 92
103	3, 340. 55	15	50	29, 926. 61	$a^4F_{4\frac{1}{2}}-z^4F^{\circ}_{3\frac{1}{2}}$	(0. 00) 1. 52	(0. 05, 0. 14, ---) --- 1. 48, 1. 57, **1. 67**
105	3, 338. 41	10	12	29, 945. 80	$a^4P_{1\frac{1}{2}}-z^4S^{\circ}_{1\frac{1}{2}}$	(0. 00) 1. 82	(0. 13, **0. 40**) 1. 60, **1. 87**, 2. 13
104	3, 337. 93	2	1	29, 950. 10	$a^2G_{3\frac{1}{2}}-y^2F^{\circ}_{3\frac{1}{2}}$		
107	3, 334. 62	9	15	29, 979. 83	$a^2D_{2\frac{1}{2}}-z^2G^{\circ}_{3\frac{1}{2}}$		
90	3, 334. 25	10	15	29, 983. 16	$a^4P_{2\frac{1}{2}}-y^4D^{\circ}_{3\frac{1}{2}}$	(0. 00) 0. 71 A[1]	(**0. 09**, 0. 26, 0. 43) **1. 00**, 1. 17, 1. 34, ---
98	3, 331. 90	2		30, 004. 31	$b^4F_{2\frac{1}{2}}-z^4D^{\circ}_{3\frac{1}{2}}$		
98	3, 327. 67	2		30, 042. 45	$b^4F_{1\frac{1}{2}}-z^4D^{\circ}_{2\frac{1}{2}}$		
102	3, 326. 81	15	10	30, 050. 21	$a^2H_{5\frac{1}{2}}-z^2H^{\circ}_{5\frac{1}{2}}$	(0. 00) 1. 09	(0. 00) 1. 09
106	3, 322. 99	10	20	20, 084. 75	$a^2P_{1\frac{1}{2}}-z^2P^{\circ}_{0\frac{1}{2}}$	(0. 38) 1. 00, **1. 68**	(0. 33) 1. 00, **1. 67**
108	3, 319. 03	8	15	30, 120. 65	$a^4F_{2\frac{1}{2}}-z^2D^{\circ}_{1\frac{1}{2}}$	(0. 00) 1. 47	(**0. 11**, 0. 34) 0. 69, 0. 91, 1. 14, **1. 37**
109	3, 318. 52	7	6	30, 125. 28	$a^2P_{1\frac{1}{2}}-y^4D^{\circ}_{0\frac{1}{2}}$	(0. 62) 0. 66, **1. 34**	(0. 67) 0. 67, **2. 00**
110	3, 314. 49	10	12	30, 161. 90	$a^2F_{2\frac{1}{2}}-z^2P^{\circ}_{1\frac{1}{2}}$	(0. 00*w*) 0. 00*w*	(**0. 24**, 0. 71) **0. 14**, 0. 62, 1. 09, 1. 57
105	3, 313. 70	8	8	30, 169. 10	$a^4P_{0\frac{1}{2}}-z^4S^{\circ}_{1\frac{1}{2}}$	(0. 36) **1. 55**, 2. 15	(0. 33) **1. 67**, 2. 33
106	3, 311. 34	4	4	30, 190. 60	$a^2P_{0\frac{1}{2}}-z^2P^{\circ}_{1\frac{1}{2}}$	(0. 00) 1. 56	(0. 33) 1. 00 **1. 67**
101	3, 309. 90	4	2	30, 203. 73	$a^2G_{3\frac{1}{2}}-y^4D^{\circ}_{3\frac{1}{2}}$		
103	3, 306. 27	25	80	30, 236. 89	$a^4F_{2\frac{1}{2}}-z^4F^{\circ}_{3\frac{1}{2}}$	(0. 00) 1. 00	(0. 00) 1. 03
95	3, 305. 15	15	40	30, 247. 13	$a^4F_{2\frac{1}{2}}-z^2F^{\circ}_{3\frac{1}{2}}$	(0. 00) 1. 25	(**0. 06**, 0. 17, 0. 29) --- 1. 20, 1. 31, **1. 43**
99, 96	3, 302. 66	7*l*	4	30, 269. 94	$\{d^2D_{1\frac{1}{2}}-w^2F^{\circ}_{2\frac{1}{2}}$; $b^4F_{2\frac{1}{2}}-x^4D^{\circ}_{3\frac{1}{2}}\}$	(0. 00) 1. 29	{(**0. 09**, 0. 26, 0. 43) **1. 00**, 1. 17, 1. 34, ---
111	3, 296. 41	7	4	30, 327. 33	$a^4P_{1\frac{1}{2}}-z^4P^{\circ}_{0\frac{1}{2}}$	(0. 42) 1. 34	(0. 47) **1. 27**, 2. 20
112	3, 295. 03	1		30, 340. 03	$a^2P_{1\frac{1}{2}}-y^4F^{\circ}_{1\frac{1}{2}}$		
111, 108	3, 288. 81	10	8	30, 397. 41	$\{a^4P_{1\frac{1}{2}}-z^4P^{\circ}_{1\frac{1}{2}}$; $a^4F_{3\frac{1}{2}}-z^2D^{\circ}_{2\frac{1}{2}}\}$	(0. 00) 1. 73	(0. 00) **1. 73**
113	3, 287. 31	3	2	30, 411. 28	$b^4F_{1\frac{1}{2}}-y^2D^{\circ}_{1\frac{1}{2}}$		
111	3, 285. 89	4	2	30, 424. 42	$a^4P_{2\frac{1}{2}}-z^4P^{\circ}_{2\frac{1}{2}}$	(0. 00) 1. 61	(0. 00) 1. 60
102	3, 285. 77	3		30, 425. 53	$a^2H_{4\frac{1}{2}}-z^2H^{\circ}_{5\frac{1}{2}}$	(0. 00) 1. 60	(**0. 09**, 0. 27, ---) --- 1. 54, 1. 73, **1. 91**
108	3, 284. 72	20	80	30, 435. 26	$a^4F_{1\frac{1}{2}}-z^2D^{\circ}_{1\frac{1}{2}}$	(0. 31) 0. 58	(0. 20, **0. 60**) 0. 20, **0. 60**, 1. 00
114	3, 282. 84	12	4	30, 452. 68	$c^2D_{2\frac{1}{2}}-w^2D^{\circ}_{2\frac{1}{2}}$	(0. 00) 1. 19	(0. 00) 1. 20
106	3, 280. 75	3		30, 472. 09	$a^2P_{0\frac{1}{2}}-z^2P^{\circ}_{0\frac{1}{2}}$	(0. 00) 0. 62	(0. 00) 0. 67
103	3, 279. 26	65	125	30, 485. 93	$a^4F_{3\frac{1}{2}}-z^4F^{\circ}_{3\frac{1}{2}}$	(0. 00) 1. 28	(0. 00) 1. 24
115	3, 278. 89	2		30, 489. 37	$z^2P^{\circ}_{0\frac{1}{2}}-e^2D_{1\frac{1}{2}}$		
109	3, 276. 37	1		30, 512. 82	$a^2P_{0\frac{1}{2}}-y^4D^{\circ}_{0\frac{1}{2}}$		
116	3, 275. 65	1		30, 519. 53	$a^2H_{4\frac{1}{2}}-x^2F^{\circ}_{3\frac{1}{2}}$		
113	3, 275. 15	2	2	30, 524. 19	$b^4F_{2\frac{1}{2}}-y^2D^{\circ}_{2\frac{1}{2}}$	(0. 00) 1. 12	(0. 09, 0. 26, **0. 43**) --- 0. 94, **1. 11**, 1. 28, ---
103	3, 273. 04	75	150	30, 543. 86	$a^4F_{4\frac{1}{2}}-z^4F^{\circ}_{4\frac{1}{2}}$	(0. 00) 1. 30	(0. 00) 1. 33
103	3, 272. 21	8	40	30, 551. 61	$a^4F_{1\frac{1}{2}}-z^4F^{\circ}_{2\frac{1}{2}}$	(**0. 33**, 1. 00) ---, 1. 37, **2. 04**	(**0. 31**, 0. 94) 0. 09, 0. 71, 1. 34, **1. 97**
117	3, 271. 13	7	8	30, 561. 70	$a^2D_{1\frac{1}{2}}-z^2S^{\circ}_{0\frac{1}{2}}$	(0. 57) **0. 00**, 1. 24	(0. 60) **0. 20**, 1. 40
111	3, 264. 81	6	4	30, 620. 86	$a^4P_{0\frac{1}{2}}-z^4P^{\circ}_{1\frac{1}{2}}$	(0. 46) 1. 31	(0. 47) **1. 27**, 2. 20
118	3, 256. 53	1		30, 698. 71	$a^2F_{2\frac{1}{2}}-y^4F^{\circ}_{1\frac{1}{2}}$		
114	3, 250. 44	20	35	30, 756. 22	$c^2D_{1\frac{1}{2}}-w^2D^{\circ}_{1\frac{1}{2}}$	(0. 00) 0. 98	(0. 00) 0. 80
119	3, 242. 18	3	2	30, 834. 58	$c^2D_{2\frac{1}{2}}-x^2P^{\circ}_{1\frac{1}{2}}$	(0. 00) 1. 24	(**0. 07**, 0. 20) **1. 00**, 1. 13, 1. 27, 1. 40
108	3, 241. 01	25	40	30, 845. 71	$a^4F_{2\frac{1}{2}}-z^2D^{\circ}_{2\frac{1}{2}}$	(0. 15) 1. 09	(0. 09, 0. 26, **0. 43**) --- 0. 94, **1. 11**, 1. 28, ---
120	3, 237. 54	1		30, 878. 76	$a^2F_{3\frac{1}{2}}-y^2F^{\circ}_{2\frac{1}{2}}$		
114	3, 236. 61	4		30, 887. 64	$c^2D_{1\frac{1}{2}}-w^2D^{\circ}_{2\frac{1}{2}}$	(0. 00) 1. 51	(**0. 20**, 0. 60) 0. 60, 1. 00, 1. 40, **1. 80**
121	3, 236. 17	1		30, 891. 85	$b^2D_{2\frac{1}{2}}-w^2D^{\circ}_{1\frac{1}{2}}$		
103	3, 231. 69	30	70	30, 934. 66	$a^4F_{2\frac{1}{2}}-z^4F^{\circ}_{3\frac{1}{2}}$	(0. 00*w*) 1. 55	(**0. 10**, 0. 31, 0. 52) --- 1. 34, 1. 55, **1. 76**
115	3, 229. 73	1*l*		30, 953. 43	$z^2P^{\circ}_{1\frac{1}{2}}-e^2D_{2\frac{1}{2}}$		
118	3, 228. 81	15	15	30, 962. 25	$a^2F_{3\frac{1}{2}}-y^4F^{\circ}_{3\frac{1}{2}}$	(0. 41) 1. 22	(--- 0. 24, **0. 33**) --- 1. 10, **1. 19**, 1. 29, ---

TABLE 2.—*Wave lengths in the spark spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities B. S.	Intensities King	ν	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
121	3, 222. 48	15	5	31, 023. 07	$b^2D_{2\frac{1}{2}}-w^2D^2_{2\frac{1}{2}}$	(0. 00) 1. 15	(0. 00) 1. 20
109	3, 218. 68	1		31, 059. 70	$a^2P_{1\frac{1}{2}}-y^4D^2_{2\frac{1}{2}}$		
103	3, 214. 19	40	60	31, 103. 08	$a^4F_{3\frac{1}{2}}-z^4F^4_{4\frac{1}{2}}$	(0. 00) 1. 53	(**0. 05**, 0. 14, ---) --- 1. 48, 1. 57, **1. 67**
118	3, 212. 85	6	8	31, 116. 06	$a^2F_{2\frac{1}{2}}-y^4F^2_{2\frac{1}{2}}$	(0. 45) 1. 00	(0. 09, 0. 26, **0. 43**) --- 0. 77, **0. 94**, 1. 12, ---
122	3, 210. 98	3		31, 134. 18	$a^4P_{2\frac{1}{2}}-x^4D^3_{1\frac{1}{2}}$		
108	3, 208. 32	4	4	31, 159. 99	$a^4F_{1\frac{1}{2}}-z^2D^2_{2\frac{1}{2}}$		
122	3, 204. 36	4		31, 198. 50	$a^4P_{1\frac{1}{2}}-x^4D^0_{0\frac{1}{2}}$		
123	3, 200. 67	2		31, 234. 46	$a^2P_{1\frac{1}{2}}-y^2F^2_{3\frac{1}{2}}$		
119	3, 197. 08	3		31, 269. 53	$c^2D_{1\frac{1}{2}}-x^2P^1_{1\frac{1}{2}}$		
120	3, 191. 93	12	10	31, 319. 98	$a^2F_{3\frac{1}{2}}-y^2F^3_{3\frac{1}{2}}$	(0. 00) 1. 14	(0. 00) 1. 14
124	3, 182. 86	35	60	31, 409. 23	$a^2D_{2\frac{1}{2}}-z^2P^1_{1\frac{1}{2}}$	(0. 00) 1. 02	(**0. 07**, 0.20) **1. 00**, 1. 13, 1. 27, 1. 40
125	3, 181. 94	7	10	31, 418. 31	$a^2F_{2\frac{1}{2}}-y^4D^2_{1\frac{1}{2}}$	(0. 60) ?	(0. 26, 0. 77, **1. 29**) --- 0. 60, **1. 12**, 1. 63, ---
122	3, 181. 58	8	10	31, 421. 86	$a^4P_{0\frac{1}{2}}-x^4D^0_{0\frac{1}{2}}$	(1. 30) 1. 40	(1. 33) 1. 33
122	3, 178. 10	15	10	31, 456. 27	$a^4P_{1\frac{1}{2}}-x^4D^1_{1\frac{1}{2}}$	(0. 78) 1. 48	(0. 27, **0. 80**) 0. 93, **1. 47**, 2. 00
125	3, 166. 29	8	12	31, 573. 60	$a^2F_{3\frac{1}{2}}-y^4D^3_{3\frac{1}{2}}$	(0. 55) 0. 83	(--- 0.71, **1. 00**) --- 1. 00, **1. 29**, 1. 57, ---
126	3, 165. 98	10	80	31, 576. 69	$a^4F_{4\frac{1}{2}}-z^4D^5_{3\frac{1}{2}}$		
122	3, 165. 45	7	10	31, 581. 97	$a^4P_{2\frac{1}{2}}-x^4D^2_{2\frac{1}{2}}$	(0. 44) 1. 44	(0. 11, 0.34, **0. 57**) --- 1. 26, **1. 48**, 1. 72, ---
120	3, 164. 32	20	25	31, 593. 25	$a^2F_{2\frac{1}{2}}-y^2F^2_{2\frac{1}{2}}$	(0. 29) 1. 00	(0. 00) 0. 86
121	3, 161. 01	2		31, 626. 33	$b^2D_{1\frac{1}{2}}-w^2D^1_{1\frac{1}{2}}$	(0. 00) 0. 85	(0. 00) 0. 80
119	3, 159. 12	5		31, 645. 25	$c^2D_{1\frac{1}{2}}-x^2P^0_{0\frac{1}{2}}$		
124	3, 157. 00	10	15	31, 666. 50	$a^2D_{1\frac{1}{2}}-z^2P^1_{1\frac{1}{2}}$	(0. 73) 1. 05	(0.27, **0. 80**) 0.53, **1.07**, 1. 60
118	3, 155. 95	1		31, 677. 04	$a^2F_{2\frac{1}{2}}-y^4F^3_{3\frac{1}{2}}$		
122	3, 155. 68	10	20	31, 679. 75	$a^4P_{0\frac{1}{2}}-x^4D^1_{1\frac{1}{2}}$	(0. 69) **0. 46**, 1. 89	(0. 73) **0. 47**, 1. 93
126	3, 138. 66	25	50	31, 851. 53	$a^4F_{3\frac{1}{2}}-z^4D^2_{2\frac{1}{2}}$	(0. 00) 1. 03	(**0. 07**, 0.20, 0.33) **0.91**, 1. 64, 1. 17, ---
122	3, 133. 49	25	20	31, 904. 08	$a^4P_{1\frac{1}{2}}-x^4D^2_{2\frac{1}{2}}$	(0. 00) 1. 05	(**0. 18**, 0. 54) **0. 83**, 1. 19, 1. 55, 1. 92
126	3, 129. 76	12	40	31, 942. 10	$a^4F_{2\frac{1}{2}}-z^4D^1_{1\frac{1}{2}}$	(0. 00) 0. 91	(**0. 09**, 0.26) **0. 77**, 0.94, 1.12, 1.29
124	3, 129. 16	10	25	31, 948. 23	$a^2D_{1\frac{1}{2}}-z^2P^0_{0\frac{1}{2}}$	(0. 00) 0. 85	(0.07) 0.73, **0. 87**
127	3, 128. 79	1	1	31, 952. 01	$a^2P_{1\frac{1}{2}}-z^4P^0_{0\frac{1}{2}}$		
126	3, 125. 92	12	40	31, 981. 34	$a^4F_{1\frac{1}{2}}-z^4D^0_{0\frac{1}{2}}$	(0. 00) 0. 50	(0. 20) 0. 20, **0. 60**
128	3, 125. 21	4	5	31, 988. 61	$a^2D_{1\frac{1}{2}}-y^4D^0_{0\frac{1}{2}}$	(0. 00) 0. 93	(0. 40) 0. 40, **1. 20**
135	3, 122. 61	1		32, 015. 24	$a^2F_{3\frac{1}{2}}-z^4P^2_{2\frac{1}{2}}$		
	3, 116. 68	4*l*		32, 076. 15			
129	3, 115. 73	2	1	32, 085. 93	$a^2G_{4\frac{1}{2}}-x^4D^3_{3\frac{1}{2}}$		
	3, 113. 92	7*b*, *l*		32, 104. 58			
128	3, 111. 15	2	3	32, 133. 16	$a^2D_{2\frac{1}{2}}-y^4D^2_{1\frac{1}{2}}$		
126	3, 110. 87	8	20	32, 136. 06	$a^4F_{3\frac{1}{2}}-z^4D^3_{3\frac{1}{2}}$	(0. 50) 1. 31	(--- 0. 48, **0. 67**) --- **1. 14**, **1. 33**, 1. 52,
130	3, 110. 52	1		32, 139. 67	$b^2D_{1\frac{1}{2}}-x^2P^1_{1\frac{1}{2}}$		
122	3, 106. 58	35	40	32, 180. 43	$a^4P_{2\frac{1}{2}}-x^4D^3_{3\frac{1}{2}}$	(0. 00) 1. 19	(**0. 09**, 0.26, 0.43) **1. 00**, 1. 17, 1. 34, ---
126	3, 099. 22	10	25	32, 256. 85	$a^4F_{1\frac{1}{2}}-z^4D^1_{1\frac{1}{2}}$	(1. 18) 0. 00, ?,	(0. 40, **1. 20**) 0. 00, **0. 80**, 1. 60
126	3, 095. 07	12	25	32, 300. 10	$a^4F_{2\frac{1}{2}}-z^4D^2_{2\frac{1}{2}}$	(0. 68) 1. 12	(0. 17, 0. 51, **0. 86**) --- 0. 86, **1. 20**, 1. 54, --
127	3, 091. 30	1		32, 339. 49	$a^2P_{0\frac{1}{2}}-z^4P^0_{0\frac{1}{2}}$		
	3, 089. 34	1*b*		32, 360. 01			
131	3, 089. 00	1	1	32, 363. 57	$a^2D_{2\frac{1}{2}}-y^4F^2_{2\frac{1}{2}}$		
127	3, 088. 28	1		32, 371. 11	$a^2P_{1\frac{1}{2}}-z^4P^2_{2\frac{1}{2}}$		
128	3, 086. 44	2		32, 390. 41	$a^2D_{1\frac{1}{2}}-y^4D^1_{1\frac{1}{2}}$		
	3, 081. 93	1*b*		32, 437. 81			
	3, 080. 05	1*b*		32. 457. 61			
132	3, 075. 55	1		32, 505. 09	$b^2P_{1\frac{1}{2}}-w^2P^0_{0\frac{1}{2}}$		
130	3, 074. 55	1		32, 515. 67	$b^2D_{1\frac{1}{2}}-x^2P^0_{0\frac{1}{2}}$		
	3, 073. 93	1*b*		32, 522. 23			
	3, 070. 18	0*b*		32, 561. 95			
	3, 068. 32	2*b*		32, 581. 69			
126	3, 068. 02	2		32, 584. 87	$a^4F_{2\frac{1}{2}}-z^4D^3_{3\frac{1}{2}}$		

TABLE 2.—*Wave lengths in the spark spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities B. S.	Intensities King	ν	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
	3,065.68	1*b*		32,609.75			
126	3,065.20	2	3	32,614.85	$a^4F_{1\frac{1}{2}}-z^4D^{\circ}_{2\frac{1}{2}}$		
131	3,064.64	3	3	32,620.81	$a^2D_{1\frac{1}{2}}-y^4F^{\circ}_{2\frac{1}{2}}$		
	3,063.63	3*b l*		32,631.56			
133	3,061.33	3	4	32,656.07	$a^4F_{3\frac{1}{2}}-y^2D^{\circ}_{2\frac{1}{2}}$	(0.00) 1.31 E_1	(**0.02**, 0.06, 0.10) --- 1.22, 1.26, **1.29**
	3,060.56	1*b*		32,664.29			
133	3,060.11	3	4	32,669.09	$a^4F_{2\frac{1}{2}}-y^2D^{\circ}_{1\frac{1}{2}}$	(0.00) 1.25 E_1	(**0.11**, 0.34) 0.69, 0.91, 1.14, **1.37**
134	3,057.22	5	2	32,699.98	$a^2G_{4\frac{1}{2}}-y^2G^{\circ}_{3\frac{1}{2}}$	(0.00) 1.59 E_1	(**0.11**, 0.33, ---) --- 1.44, 1.67, **1.89**
134	3,054.84	30	20	32,725.45	$a^2G_{4\frac{1}{2}}-y^2G^{\circ}_{4\frac{1}{2}}$	(0.00) 1.22 E_1	(0.00) 1.11
135	3,054.39	3		32,730.27	$a^2F_{2\frac{1}{2}}-z^4P^{\circ}_{2\frac{1}{2}}$		
136	3,048.42	2	1	32,794.37	$a^4P_{2\frac{1}{2}}-y^2G^{\circ}_{3\frac{1}{2}}$		
132	3,048.28	5	1	32,795.87	$b^2P_{1\frac{1}{2}}-w^2P^{\circ}_{1\frac{1}{2}}$		
	3,044.72	1*b*		32,834.22			
137	3,044.12	4	1	32,840.69	$a^2D_{2\frac{1}{2}}-y^2F^{\circ}_{2\frac{1}{2}}$	(0.00*w*) 1.00 E_1	(0.17, 0.51, **0.86**) 0.34, 0.69, **1.03**, 1.37, 1.71
	3,038.59	2		32,900.45			
128	3,036.50	7	5	32,923.10	$a^2D_{1\frac{1}{2}}-y^4D^{\circ}_{2\frac{1}{2}}$		
131 / 139	3,036.39	15	10	32,924.29	$a^2D_{2\frac{1}{2}}-y^4F^{\circ}_{3\frac{1}{2}}$ / $b^4P_{2\frac{1}{2}}-y^4P^{\circ}_{1\frac{1}{2}}$		
	3,033.45	1*b*		32,956.20			
132	3,032.00	3		32,971.96	$b^2P_{0\frac{1}{2}}-w^2P^{\circ}_{0\frac{1}{2}}$	(0.00) 0.48 E_1	(0.00) 0.67
133	3,030.91	10	15	32,983.82	$a^4F_{1\frac{1}{2}}-y^2D^{\circ}_{1\frac{1}{2}}$	(0.59) ?	(0.20, **0.60**) 0.20, **0.60**, 1.00
134	3,028.05	20	20	33,014.97	$a^2G_{3\frac{1}{2}}-y^2G^{\circ}_{3\frac{1}{2}}$	(0.00) 0.90	(0.00) 0.89
138	3,026.18	3*b*,*l*		33,035.37	$z^4F^{\circ}_{4\frac{1}{2}}-e^4F_{4\frac{1}{2}}$		
134	3,025.70	2	1	33,040.61	$a^2G_{3\frac{1}{2}}-y^2G^{\circ}_{4\frac{1}{2}}$		
139	3,025.16	3*b*	1	33,046.51	$b^4P_{1\frac{1}{2}}-y^4P^{\circ}_{0\frac{1}{2}}$		
138	3,024.72	3*b*		33,051.32	$z^4F^{\circ}_{2\frac{1}{2}}-e^4F_{1\frac{1}{2}}$		
140	3,021.97	1		33,081.39	$a^2P_{1\frac{1}{2}}-x^4D^{\circ}_{1\frac{1}{2}}$		
137	3,020.45	5	30	33,098.04	$a^2D_{1\frac{1}{2}}-y^2F^{\circ}_{2\frac{1}{2}}$	(0.00) 1.16	(**0.03**, 0.09) 0.77, 0.83, 0.89, **0.94**
133	3,019.84	3	15	33,104.72	$a^4F_{2\frac{1}{2}}-y^2D^{\circ}_{2\frac{1}{2}}$	(0.00) 1.07	(0.09, 0.26, **0.43**) --- 0.94, **1.11**, 1.28, ---
	3,019.50	1		33,108.45			
138	3,018.53	3*b*		33,119.09	$z^4F^{\circ}_{3\frac{1}{2}}-e^4F_{3\frac{1}{2}}$		
	3,018.08	2*b*		33,124.02			
141	3,015.86	2		33,148.40	$c^2D_{2\frac{1}{2}}-w^2F^{\circ}_{2\frac{1}{2}}$		
139	3,015.67	1		33,150.50	$b^4P_{1\frac{1}{2}}-y^4P^{\circ}_{1\frac{1}{2}}$		
142	3,013.66	0		33,172.61	$a^2F_{3\frac{1}{2}}-x^4D^{\circ}_{2\frac{1}{2}}$		
143	3,013.32	8	8	33,176.35	$a^2D_{2\frac{1}{2}}-z^4S^{\circ}_{1\frac{1}{2}}$	(0.00*w*) 0.00*w*	(**0.40**, 1.20) **0.00**, 0.80, 1.60, 2.40
140	3,010.28	2*b l*		33,209.85	$a^2P_{0\frac{1}{2}}-x^4D^{\circ}_{0\frac{1}{2}}$		
144	3,009.85	2	2	33,214.60	$a^4P_{0\frac{1}{2}}-y^2P^{\circ}_{0\frac{1}{2}}$		
139	3,008.13	3		33,233.59	$b^4P_{2\frac{1}{2}}-y^4P^{\circ}_{2\frac{1}{2}}$	(0.00) 1.71 E_1 90	(0.00) 1.60
137	3,003.73	15	20	33,282.26	$a^2D_{2\frac{1}{2}}-y^2F^{\circ}_{3\frac{1}{2}}$	(0.00) 1.23	(**0.03**, 0.09, 0.14) **1.00**, 1.06, 1.11,---
138	3,000.59	3*b*		33,317.09	$z^4F^{\circ}_{2\frac{1}{2}}-e^4F_{2\frac{1}{2}}$		
139	2,998.49	2	1	33,340.43	$b^4P_{0\frac{1}{2}}-y^4P^{\circ}_{1\frac{1}{2}}$	(0.00) 1.53 E_1	(0.47) **1.27**, 2.20
145	2,998.34	1		33,342.10	$b^4F_{1\frac{1}{2}}-z^2P^{\circ}_{1\frac{1}{2}}$		
	2,994.05	4*b*		33,389.86			
133	2,991.40	5	5	33,419.44	$a^4F_{1\frac{1}{2}}-y^2D^{\circ}_{2\frac{1}{2}}$	(0.00*w*) 2.24 E_1	(**0.40**, 1.20) 0.00, 0.80, 1.60, **2.40**
143	2,990.10	3	1	33,433.97	$a^2D_{1\frac{1}{2}}-z^4S^{\circ}_{1\frac{1}{2}}$	(1.44) 0.00*W* E_1	(0.60, **1.80**) 0.20, **1.40**, 2.60
146	2,988.74	4*b*		33,449.19	$y^2D^{\circ}_{2\frac{1}{2}}-e^2D_{2\frac{1}{2}}$	(0.00) 1.14 E_1	(0.00) 1.20
139	2,987.80	5	40	33,459.71	$b^4P_{1\frac{1}{2}}-y^4P^{\circ}_{2\frac{1}{2}}$	(0.00) 1.53 E_1	(**0.07**, 0.20) **1.40**, 1.54, 1.67, 1.80
128	2,981.02	12	25	33,535.81	$a^2D_{2\frac{1}{2}}-y^4D^{\circ}_{3\frac{1}{2}}$	(0.00) 1.64 E_1	(**0.11**, 0.34, 0.57) --- 1.54, 1.77, **2.00**
147	2,979.18	12	20	33,556.52	$b^4F_{2\frac{1}{2}}-y^4F^{\circ}_{1\frac{1}{2}}$	(0.00) 1.50 E_1	(**0.31**, 0.94) 0.09, 0.71, 1.34, **1.97**
147	2,978.07	12	40	33,569.02	$b^4F_{3\frac{1}{2}}-y^4F^{\circ}_{2\frac{1}{2}}$	(0.00) 1.45 E_1	(**0.10**, 0.31, 0.52) --- 1.34, 1.55, **1.76**
148	2,976.61	10	8	33,585.49	$a^2G_{4\frac{1}{2}}-z^2H^{\circ}_{4\frac{1}{2}}$	(0.58) 1.18 E_1	(--- 0.50, 0.71, **0.91**) 0.81, **1.01**, 1.21,---

TABLE 2.—*Wave lengths in the spark spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities B. S.	Intensities King	ν	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
144	2, 975. 16	1		33, 601. 86	$a^4P_{1\frac{1}{2}}-y^2P^\circ_{1\frac{1}{2}}$		
149	2, 973. 69	2		33, 618. 47	$a^4P_{2\frac{1}{2}}-x^2D^\circ_{2\frac{1}{2}}$		
192	2, 972. 79	0		33, 628. 64	$a^2D_{2\frac{1}{2}}-z^4P^\circ_{1\frac{1}{2}}$		
	2, 972. 50	0		33, 631. 92			
150	2, 969. 63	8	20	33, 664. 43	$b^4F_{1\frac{1}{2}}-y^4D^\circ_{0\frac{1}{2}}$	(0. 00) 0. 51	(0. 20) 0. 20, **0. 60**
147	2, 968. 95	12	30	33, 672. 14	$b^4F_{4\frac{1}{2}}-y^4F^\circ_{3\frac{1}{2}}$	(0. 00) 1. 42	(**0. 05**, 0. 14, ---)--- 1. 48, 1. 57, **1. 67**
146	2, 966. 27	2*b*		33, 702. 55	$y^2D^\circ_{1\frac{1}{2}}-e^2D_{1\frac{1}{2}}$		
151	2, 964. 55	4	1	33, 722. 11	$a^4F_{3\frac{1}{2}}-z^2G^\circ_{3\frac{1}{2}}$	(1. 03) 1. 38 E_1	(--- 0. 87, **1. 22**) --- 0. 71, **1. 06**, 1. 41, ---
150	2, 962. 69	12	30	33, 743. 28	$b^4F_{2\frac{1}{2}}-y^4D^\circ_{1\frac{1}{2}}$	(0. 00) 0. 95	(**0. 09**, 0. 26) **0. 77**, 0. 94, 1. 12, 1. 29
	2, 960. 57	1		33, 767. 44			
152	2, 955. 77	20	15	33, 822. 28	$b^2G_{3\frac{1}{2}}-w^2F^\circ_{2\frac{1}{2}}$	(0. 00) 1. 00	(**0. 02**, 0. 05, 0. 08) --- 0. 90, 0. 94, **0. 97**
138, 144	2, 955. 53	2*b*		33, 825. 04	$z^4F^\circ_{1\frac{1}{2}}-e^4F_{1\frac{1}{2}}$; $a^4P_{0\frac{1}{2}}-y^2P^\circ_{1\frac{1}{2}}$		
151	2, 952. 23	6	8	33, 862. 83	$a^4F_{4\frac{1}{2}}-z^2G^\circ_{4\frac{1}{2}}$	(0. 93) 1. 27 E_1	(--- 0. 78, **1. 00**) --- 1. 00, **1. 22**, 1. 44, ---
150	2, 951. 46	10	25	33, 871. 66	$b^4F_{3\frac{1}{2}}-y^4D^\circ_{2\frac{1}{2}}$	(0. 00) 1. 30 E_1	(**0. 07**, 0. 20, 0. 33) **0. 91**, 1. 04, 1. 17, ---
	2, 949. 81	2*b*		33, 890. 61			
148	2, 948. 94	12	20	33, 900. 60	$a^2G_{3\frac{1}{2}}-z^2H^\circ_{4\frac{1}{2}}$	(0. 00) 1. 00	(**0. 01**, 0. 03, ---) --- 0. 94, 0. 96, **0. 98**
	2, 946. 93	1*b*		33, 923. 73			
242	2, 946. 30	1*b*		33, 930. 98	$z^2G^\circ_{4\frac{1}{2}}-e^2G_{3\frac{1}{2}}$		
149	2, 945. 45	4	3	33, 940. 78	$a^4P_{1\frac{1}{2}}-x^2D^\circ_{2\frac{1}{2}}$	(0. 00*w*) 0. 00*w* E_1	(**0. 27**, 0. 80) **0. 40**, 0. 93, 1. 47, 2. 00
149	2, 944. 19	3		33, 955. 30	$a^4P_{0\frac{1}{2}}-x^2D^\circ_{1\frac{1}{2}}$	(0. 87) 0. 00*w* E_1	(0. 93) **0. 13**, 1. 73
192	2, 942. 26	1		33, 977. 57	$a^2D_{2\frac{1}{2}}-z^4P^\circ_{2\frac{1}{2}}$		
248	2, 941. 55	1		33, 985. 77	$z^2H^\circ_{5\frac{1}{2}}-e^2I_{5\frac{1}{2}}$		
	2, 940. 62	1*b*		33, 996. 52			
	2, 938. 82	1*b*		34, 017. 34			
153	2, 937. 74	4	1	34, 029. 85	$b^4F_{4\frac{1}{2}}-y^2F^\circ_{3\frac{1}{2}}$	(0. 00) 1. 64 E_1	(**0. 10**, 0. 29, ---) --- 1. 62, 1. 81, **2. 00**
153	2, 936. 31	12	20	34, 046. 42	$b^4F_{3\frac{1}{2}}-y^2F^\circ_{2\frac{1}{2}}$	(0. 00) 1. 66 E_1	(**0. 19**, 0. 57, 0. 95) --- 1. 43, 1. 81, **2. 19**
150	2, 934. 62	12	20	34, 066. 02	$b^4F_{1\frac{1}{2}}-y^4D^\circ_{1\frac{1}{2}}$	(0. 96) 0. 77 E_1	(0. 40, **1. 20**) 0. 00, **0. 80**, 1. 60
242	2, 931. 89	3*b*		34, 097. 74	$z^2G^\circ_{3\frac{1}{2}}-e^2G_{4\frac{1}{2}}$		
154	2, 931. 08	8*b*, *l*		34, 107. 17	$z^4G^\circ_{5\frac{1}{2}}-e^4F_{4\frac{1}{2}}$		
147	2, 929. 10	1		34, 130. 22	$b^4F_{3\frac{1}{2}}-y^4F^\circ_{3\frac{1}{2}}$		
152	2, 926. 99	25	20	34, 154. 82	$b^2G_{4\frac{1}{2}}-w^2F^\circ_{3\frac{1}{2}}$	(0. 00) 1. 05	(**0. 02**, 0. 05, ---)**1. 00**, 1. 03, 1. 06, ---
151	2, 925. 62	4	2	34, 170. 82	$a^4F_{2\frac{1}{2}}-z^2G^\circ_{3\frac{1}{2}}$	(0. 00) 0. 62 E_1	(**0. 07**, 0. 21, 0. 35) **0. 54**, 0. 68, 0. 82, ---
155	2, 924. 63	8	2	34, 182. 38	$b^2D_{2\frac{1}{2}}-w^2F^\circ_{3\frac{1}{2}}$	(0. 00) 1. 00 E_1	(**0. 03**, 0. 09, 0. 14) **1. 00**, 1. 06, 1. 11, ---
	2, 922. 93	1*b*		34, 202. 26			
	2, 921. 14	1*b*		34, 223. 22			
	2, 920. 03	3*b*		34, 236. 23			
148	2, 918. 24	18	30	34, 257. 23	$a^2G_{4\frac{1}{2}}-z^2H^\circ_{5\frac{1}{2}}$	(0. 00) 0. 94	(**0. 01**, 0. 03,--) **1. 00**, 1. 02, 1. 04---
150	2, 916. 63	7	8	34, 276. 14	$b^4F_{2\frac{1}{2}}-y^4D^\circ_{2\frac{1}{2}}$	(0. 00*w*) 1. 17 E_1	(0. 17, 0. 51, **0. 86**) 0. 51, 0. 86, **1. 20**, 1. 54, 1. 89
150	2, 915. 98	15	40	34, 283. 77	$b^4F_{4\frac{1}{2}}-y^4D^\circ_{3\frac{1}{2}}$	(0. 00) 1. 41 E_1	(**0. 05**, 0. 14,---) **1. 00**, 1. 10, 1. 19, ---
	2, 914. 71	1*b*		34, 298. 71			
156	2, 910. 26	8	8	34, 351. 16	$a^2G_{4\frac{1}{2}}-x^2F^\circ_{3\frac{1}{2}}$	(0. 00) 1. 00 E_1	(**0. 02**, 0. 05,---) **1. 00**, 1. 03, 1. 06, ---
	2, 907. 99	3*b*		34, 378. 09			
157	2, 907. 37	6	5	34, 385. 30	$a^2F_{3\frac{1}{2}}-y^2G^\circ_{3\frac{1}{2}}$	(0. 68) 1. 02 E_1	(--- 0. 64, **0. 89**) --- 0. 76, **1. 02**, 1. 27, ---
157	2, 905. 22	15	25	34, 410. 87	$a^2F_{3\frac{1}{2}}-y^2G^\circ_{4\frac{1}{2}}$	(0. 00) 1. 07 E_1	(**0. 02**, 0. 05, ---) **1. 00**, 1. 03, 1. 06, ---
151	2, 904. 22	1	1	34, 422. 60	$a^4F_{3\frac{1}{2}}-z^2G^\circ_{4\frac{1}{2}}$		
248	2, 903. 70	15*b*, *l*		34, 428. 76	$z^2H^\circ_{5\frac{1}{2}}-e^2I_{6\frac{1}{2}}$	(0. 00) 1. 05 E_1	(**0. 01**, 0. 02, **0. 03**, ---) **1. 00**, 1. 01, 1. 03, ---

TABLE 2.—*Wave lengths in the spark spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities B. S.	Intensities King	ν	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
158	2, 902. 24	2	1	34, 446. 07	$a^4P_{2\frac{1}{2}}-x^2F^{\circ}_{3\frac{1}{2}}$		
153	2, 901. 81	3	6	34, 451. 18	$b^4F_{2\frac{1}{2}}-y^2F^{\circ}_{2\frac{1}{2}}$		
155	2, 901. 60	5	4	34, 453. 67	$b^2D_{1\frac{1}{2}}-w^2F^{\circ}_{3\frac{1}{2}}$	(0. 00 0. 72 E_1	(**0. 03**, 0. 09) 0. 77, 0. 83, 0. 89, **0. 94**
153	2, 898. 72	7	12	34, 487. 90	$b^4F_{3\frac{1}{2}}-y^2F^{\circ}_{3\frac{1}{2}}$	(0. 00*w*) 1. 14 E_1	(--- 0. 24, **0. 33**)---- 1. 10, **1. 19**, 1. 29, ---
	2, 897. 72	1		34, 499. 81			
154	2, 895. 32	6*b*, *l*		34, 528. 40	$z^4G^{\circ}_{1\frac{1}{2}}-e^4F_{3\frac{1}{2}}$	(0. 00) 1. 12 E_1	(**0. 03**, 0. 10, ---) **0. 94**, 1. 01, 1. 07, ---
147	2, 894. 78	1		34, 534, 84	$b^4F_{2\frac{1}{2}}-y^4F^{\circ}_{3\frac{1}{2}}$		
	2, 891. 99	3*b*		34, 568. 15			
	2, 891. 75	1		34, 571. 03			
150	2, 889. 41	5	3	34, 599. 02	$b^4F_{1\frac{1}{2}}-y^4D^{\circ}_{2\frac{1}{2}}$	(0. 00*w*) 2. 03 E_1	(**0. 09**, 1. 46) 0. 09, 0. 88, 1. 86, **2. 83**
159	2, 888. 04	5	6	34, 615. 43	$a^2P_{1\frac{1}{2}}-y^2P^{\circ}_{0\frac{1}{2}}$	(0. 00) 1. 51 E_1	(0. 33) 1. 00, **1. 67**
242	2, 886. 71	3*b*		34, 631. 38	$z^2G^{\circ}_{3\frac{1}{2}}-e^2G_{3\frac{1}{2}}$	(0. 00) 0. 00*W* E_1	(0. 00) 0. 89
248	2, 884. 57	7*b*		34, 657. 07	$z^2H^{\circ}_{4\frac{1}{2}}-e^2I_{5\frac{1}{2}}$	(0. 00) 1. 15 E_1	(**0. 01**, 0. 02, 0. 03, ---) --- 0. 96, 0. 97, **0. 98**
156	2, 883. 79	3	3	34, 666. 45	$a^2G_{3\frac{1}{2}}-x^2F^{\circ}_{3\frac{1}{2}}$	(0. 57) 1. 21 E_1	(--- 0. 64, **0. 89**) --- 0. 76, **1. 02**, 1. 27, ---
160	2, 882. 08	5	3	34, 687. 02	$\left\{\begin{matrix} a^2D_{1\frac{1}{2}}-x^4D^{\circ}_{0\frac{1}{2}} \\ a^2D_{2\frac{1}{2}}-x^4D^{\circ}_{1\frac{1}{2}} \end{matrix}\right\}$		
	2, 880. 14	1		34, 710. 38			
150	2, 877. 56	10	10	34, 741. 49	$b^4F_{3\frac{1}{2}}-y^4D^{\circ}_{3\frac{1}{2}}$	(0. 00*w*) 1. 26 E_1	(--- 0. 48, **0. 67**) --- 1. 14, **1. 33**, 1. 52, ---
	2, 874. 22	3*b*		34, 781. 86			
158	2, 872. 52	3	2	34, 802. 45	$a^4P_{2\frac{1}{2}}-x^2F^{\circ}_{2\frac{1}{2}}$	(1. 60) 0. 00*W* E_1	(0. 37, 1. 11, **1. 86**) 0. 26 **0. 49**, **1. 23**, 1. 97, 2. 71
161	2, 871. 85	1		34, 810. 57	$a^4F_{1\frac{1}{2}}-z^2S^{\circ}_{0\frac{1}{2}}$		
162	2, 869. 80	12	40	34, 835. 43	$a^4P_{2\frac{1}{2}}-y^4P^{\circ}_{1\frac{1}{2}}$	(0. 00) 1. 47 E_1	(**0. 07**, 0. 20) **1. 40**, 1. 54 1. 67, 1. 80
	2, 867. 42	1		34, 864. 35			
	2, 865. 93	1*b*		34, 882. 47			
147	2, 865. 61	5	8	34, 886. 36	$b^4F_{4\frac{1}{2}}-y^4F^{\circ}_{4\frac{1}{2}}$	(0. 00) 1. 35 E_1	(0. 00) 1. 33
153	2, 865. 09	3	2	34, 892. 70	$b^4F_{2\frac{1}{2}}-y^2F^{\circ}_{3\frac{1}{2}}$		
	2, 864. 19	1*b*		34, 903. 66			
154	2, 859. 61	4*b*		34, 959. 56	$z^4G^{\circ}_{3\frac{1}{2}}-e^4F_{2\frac{1}{2}}$	(0. 00) 0. 87 E_1	(**0. 02**, 0. 07, 0. 11) **0. 87**, 0. 92, 0. 96, ---
	2, 858. 33	1*b*		34, 975. 21			
	2, 857. 33	3*b*, *l*		34, 987. 45			
159	2, 856. 05	5	1	35, 003. 14	$a^2P_{0\frac{1}{2}}-y^2P^{\circ}_{0\frac{1}{2}}$	(0. 00) 0. 44 E_1	(0. 00) 0. 67
156	2, 854. 42	7	3	35, 023. 12	$a^2G_{3\frac{1}{2}}-x^2F^{\circ}_{2\frac{1}{2}}$	(0. 00) 0. 83 E_1	(**0. 02**, 0. 05, 0. 08) --- 0. 90, 0. 94, **0. 97**
240	2, 853. 66	2*b*		35, 032. 45	$z^2D^{\circ}_{2\frac{1}{2}}-e^2F_{3\frac{1}{2}}$	(0. 00) 1. 17 E_1	(**0. 03**, 0. 09, 0. 14) **1. 00**, 1. 06, 1. 11, ---
162	2, 851. 98	12	40	35, 053. 08	$a^4P_{1\frac{1}{2}}-y^4P^{\circ}_{0\frac{1}{2}}$	(0. 00) 1. 47 E_1	(0. 47) **1. 27**, 2. 20
154	2, 851. 28	1*b*		35, 061. 69	$z^4G^{\circ}_{4\frac{1}{2}}-e^4F_{4\frac{1}{2}}$		
	2, 849. 10	1*b*		35, 088. 52			
157	2, 848. 17	8	15	35, 099. 97	$a^2F_{2\frac{1}{2}}-y^2G^{\circ}_{3\frac{1}{2}}$	(0. 00) 0. 93 E_1	(**0. 02**, 0. 05, 0. 08) --- 0. 90, 0. 94, **0. 97**
158	2, 846. 16	2		35, 124. 76	$a^4P_{1\frac{1}{2}}-x^2F^{\circ}_{2\frac{1}{2}}$		
162	2, 844. 57	15	50	35, 144. 39	$a^4P_{2\frac{1}{2}}-y^4P^{\circ}_{2\frac{1}{2}}$	(0. 00) 1. 58 E_1	(0. 00) 1. 60
162	2, 843. 53	10	10	35, 157. 24	$a^4P_{1\frac{1}{2}}-y^4P^{\circ}_{1\frac{1}{2}}$	(0. 00) 1. 68 E_1	(0. 00) 1. 73
163	2, 841. 38	1		35, 183. 84	$b^4F_{3\frac{1}{2}}-z^4P^{\circ}_{2\frac{1}{2}}$		
164	2, 839. 34	10	8	35, 209. 12	$a^2F_{3\frac{1}{2}}-x^2D^{\circ}_{2\frac{1}{2}}$	(0. 00). 1. 10 E_1	(**0. 03**, 0. 09, 0. 14) **1. 00**, 1. 06, 1. 11, ---
159	2, 838. 00	5	4	35, 225. 75	$a^2P_{1\frac{1}{2}}-y^2P^{\circ}_{1\frac{1}{2}}$	(0. 00) 0. 90 E_1	(0. 00) 1. 33
165	2, 835. 00	1		35, 263. 02	$d^2D_{1\frac{1}{2}}-w^2P^{\circ}_{1\frac{1}{2}}$		
166	2, 834. 38	5	3	35, 270. 73	$a^2F_{3\frac{1}{2}}-z^2H^{\circ}_{4\frac{1}{2}}$		
162	2, 833. 90	8	6	35, 276. 71	$a^4P_{0\frac{1}{2}}-y^4P^{\circ}_{0\frac{1}{2}}$	(0. 00) 2. 51 E_1	(0. 00) 2. 67
	2, 832. 81	3		35, 290. 28			
	2, 831. 54	2*b*		35, 306. 11			
249	2, 829. 38	0		35, 333. 06	$z^2H^{\circ}_{5\frac{1}{2}}-e^2H_{4\frac{1}{2}}$		
167	2, 827. 52	3	8	35, 356. 30	$a^2P_{1\frac{1}{2}}-x^2D^{\circ}_{1\frac{1}{2}}$		
162	2, 825. 54	15	30	35, 381. 08	$a^4P_{0\frac{1}{2}}-y^4P^{\circ}_{1\frac{1}{2}}$	(0. 00) 1. 52 E_1	(0. 47) **1. 27**, 2. 20
160	2, 824. 56	2*b*		35, 393. 35	$a^2D_{1\frac{1}{2}}-x^4D^{\circ}_{2\frac{1}{2}}$		
	2, 824. 08	1*b*		35, 399. 37			
240	2, 821. 09	1*b*		35, 436. 88	$z^2D^{\circ}_{1\frac{1}{2}}-e^2F_{2\frac{1}{2}}$		
154	2, 819. 31	3*l*		35, 459. 25	$z^4G^{\circ}_{3\frac{1}{2}}-e^4F_{3\frac{1}{2}}$		
162	2, 818. 76	20	20	35, 466. 17	$a^4P_{1\frac{1}{2}}-y^4P^{\circ}_{2\frac{1}{2}}$	(0. 00) 1. 44 E_1	(**0. 07**, 0. 20) **1. 40**, 1. 54, 1. 67, 1. 80

TABLE 2.—*Wave lengths in the spark spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities B. S.	Intensities King	ν	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
163	2, 816. 77	3*b*		35, 491. 31	$b^4F_{1\frac{1}{2}}-z^4P^\circ_{0\frac{1}{2}}$		
167	2, 810. 91	15	15	35, 565. 21	$a^2P_{1\frac{1}{2}}-x^2D^\circ_{2\frac{1}{2}}$	(0. 00) 1. 18 E_1	(**0. 07**, 0. 20) **1. 00**, 1. 13, 1. 27, 1. 40
168	2, 809. 40	2		35, 584. 33	$a^2F_{2\frac{1}{2}}-y^2P^\circ_{1\frac{1}{2}}$		
169	2, 808. 15	3	2	35, 600. 17	$a^4F_{2\frac{1}{2}}-z^2P^\circ_{1\frac{1}{2}}$		
	2, 807. 86	3		35, 603. 84			
159, 170	{2, 807. 13	3*b*		35, 613. 10	{$a^2S_{0\frac{1}{2}}-v^2P^\circ_{0\frac{1}{2}}$ / $a^2P_{0\frac{1}{2}}-y^2P^\circ_{1\frac{1}{2}}$}	}	
154	2, 806. 68	5		35, 618. 81	$z^4G^\circ_{2\frac{1}{2}}-e^4F_{1\frac{1}{2}}$		
241	2, 805. 71	2*b*		35, 631. 13	$z^2F^\circ_{3\frac{1}{2}}-e^2F_{3\frac{1}{2}}$		
	2, 804. 78	1*b*		35, 642. 94			
	2, 800. 10	2		35, 702. 51			
164	2, 799. 16	8	5	35, 715. 50	$a^2F_{2\frac{1}{2}}-x^2D^\circ_{1\frac{1}{2}}$	(0. 00) 1. 05 E.	(**0. 03**, 0. 09) 0. 77 0. 83 0. 89, **0. 94**
	2, 798. 71	1		35, 720. 24			
160	2, 797. 78	3*b*		35, 732. 11	$a^2D_{2\frac{1}{2}}-x^4D^\circ_{3\frac{1}{2}}$		
167	2, 796. 92	10	12	35, 743. 10	$a^2P_{0\frac{1}{2}}-x^2D^\circ_{1\frac{1}{2}}$	(0. 00) 0. 84 E_1	(0. 07) 0. 73, **0. 87**
173	2, 796. 32	2*b*		35, 750. 77	$b^2P_{1\frac{1}{2}}-v^2D^\circ_{1\frac{1}{2}}$		
	2, 793. 12	2		35, 791. 73			
249	2, 786. 95	6*b*, *l*		35, 870. 96	$z^2H^\circ_{5\frac{1}{2}}-e^2H_{5\frac{1}{2}}$	(0. 00) 1. 11 E_1	(0. 00) 1. 09
154	2, 785. 90	4*b*		35, 884. 48	$z^4G^\circ_{3\frac{1}{2}}-e^4F_{2\frac{1}{2}}$		
	2, 785. 33	1*b*		35, 891. 82			
169	2, 783. 56	5	4	35, 914. 64	$a^4F_{1\frac{1}{2}}-z^2P^\circ_{1\frac{1}{2}}$		
164	2, 782. 84	2		35, 923. 93	$a^2F_{2\frac{1}{2}}-x^2D^\circ_{2\frac{1}{2}}$		
	2, 781. 61	2		35, 939. 82			
	2, 777. 05	3*b*		35, 998. 83			
249	2, 776. 59	3*b*		36, 004. 79	$z^2H^\circ_{4\frac{1}{2}}-e^2H_{4\frac{1}{2}}$		
171	2, 774. 15	12	15	36, 036. 46	$a^2F_{3\frac{1}{2}}-x^2F^\circ_{3\frac{1}{2}}$	(0. 00) 1. 15 E_1	(0. 00) 1. 14
	2, 772. 56	2*b*		36, 057. 12			
172	2, 768. 84	15		36, 105. 57	$a^4F_{3\frac{1}{2}}-y^4F^\circ_{2\frac{1}{2}}$		
172	2, 768. 73	15		36, 107. 00	$a^4F_{4\frac{1}{2}}-y^4F^\circ_{3\frac{1}{2}}$		
	2, 767. 45	1*b*		36, 123. 70			
	2, 766. 82	1*b*		36, 131. 92			
172	2, 766. 41	1		36, 137. 28	$a^4F_{2\frac{1}{2}}-y^4F^\circ_{1\frac{1}{2}}$		
169	2, 761. 89	6	5	36, 196. 41	$a^4F_{1\frac{1}{2}}-z^2P^\circ_{0\frac{1}{2}}$	(0. 00) 0. 00*w* E_1	(0. 13) **0. 27**, 0. 53
173	2, 760. 10	3*b*		36, 219. 89	$b^2P_{0\frac{1}{2}}-v^2D^\circ_{1\frac{1}{2}}$		
174	2, 758. 80	20	80	36, 236. 96	$a^4F_{1\frac{1}{2}}-y^4D^\circ_{0\frac{1}{2}}$	(0. 00*w*) 0. 56	(0. 20) 0. 20, **0. 60**
	2, 754. 39	2*b*		36, 294. 97			
175	2, 754. 23	2	2	36, 297. 08	$b^4F_{2\frac{1}{2}}-x^4D^\circ_{1\frac{1}{2}}$	(0. 00) 0. 99 E_1	(**0. 09**, 0. 26) **0. 77**, 0. 94, 1. 12, 1. 29
	2, 753. 25	3*b*		36, 310. 00			
184	2, 752. 57	2*b*		36, 318. 97	$b^2F_{2\frac{1}{2}}-v^2D^\circ_{1\frac{1}{2}}$		
174	2, 752. 21	20	150	36, 323. 72	$a^4F_{2\frac{1}{2}}-y^4D^\circ_{1\frac{1}{2}}$	(0. 00) 1. 00	(**0. 09**, 0. 26) **0. 77**, 0. 94, 1. 12, 1. 29
175	2, 750. 95	4	3	36, 340. 36	$b^4F_{3\frac{1}{2}}-x^4D^\circ_{2\frac{1}{2}}$	(0. 00) 0. 93 E_1	(**0. 07**, 0. 20, 0. 33) **0. 91**, 1. 04, 1. 17, ---
176	2, 750. 44	1		36, 347. 09	$a^2D_{2\frac{1}{2}}-y^2G^\circ_{3\frac{1}{2}}$		
	2, 749. 85	2		36, 354. 89			
241	2, 748. 89	2		36, 367. 59	$z^2F^\circ_{2\frac{1}{2}}-e^2F_{2\frac{1}{2}}$		
154	2, 747. 66	1*b*		36, 383. 86	$z^4G^\circ_{2\frac{1}{2}}-e^4F_{3\frac{1}{2}}$		
174	2, 745. 86	20	100	36, 407. 71	$a^4F_{3\frac{1}{2}}-y^4D^\circ_{2\frac{1}{2}}$	(0. 00) 1. 24	(**0. 07**, 0. 20, 0. 33) **0. 91**, 1. 04, 1. 17, ---
	2, 744. 49	3*b*		36, 425. 89			
172	2, 742. 54	20	125	36, 451. 79	$a^4F_{1\frac{1}{2}}-y^4F^\circ_{1\frac{1}{2}}$		
177	2, 741. 54	8	15	36, 464. 95	$a^4F_{4\frac{1}{2}}-y^2F^\circ_{3\frac{1}{2}}$	(0. 00) 1. 52 E_1	(**0. 10**, 0. 29, ---)----- 1. 62, 1. 81, **2. 00**
178	2, 740. 49	8	8	36, 478. 92	$a^2D_{1\frac{1}{2}}-y^2P^\circ_{0\frac{1}{2}}$	(0. 00) 0. 68 E_1	(0. 07) 0. 73, **0. 87**
175	2, 740. 33	6	4	36, 481. 18	$b^4F_{4\frac{1}{2}}-x^4D^\circ_{3\frac{1}{2}}$		
173	2, 739. 77	1		36, 488. 64	$b^2P_{1\frac{1}{2}}-v^2D^\circ_{2\frac{1}{2}}$		
179	2, 738. 40	1		36, 506. 89	$y^2F^\circ_{2\frac{1}{2}}-f^2F_{2\frac{1}{2}}$		
172	2, 734. 84	20	150	36, 554. 41	$a^4F_{2\frac{1}{2}}-y^4F^\circ_{2\frac{1}{2}}$	(0. 00) 1. 08 E_1	(0. 00) 1. 03
177	2, 732. 72	15	80	36, 582. 77	$a^4F_{3\frac{1}{2}}-y^2F^\circ_{2\frac{1}{2}}$	(0. 00) 1. 50 E_1	(**0. 19**, 0. 57, 0. 95)--- 1. 43, 1. 81, **2. 19**
175	2, 729. 93	3		36, 620. 15	$b^4F_{1\frac{1}{2}}-x^4D^\circ_{1\frac{1}{2}}$		
174	2, 728. 56	2		36, 638. 54	$a^4F_{1\frac{1}{2}}-y^4D^\circ_{1\frac{1}{2}}$		
170	2, 726. 99	3 *b*		36, 659. 63	$a^2S_{0\frac{1}{2}}-v^2P^\circ_{1\frac{1}{2}}$		(0. 00) 1. 24
172	2, 726. 48	15	125	36, 666. 49	$a^4F_{3\frac{1}{2}}-y^4F^\circ_{3\frac{1}{2}}$	(0. 00) 1. 20 E_1	(**0. 05**, 0. 14, 0. 24, 0. 33) **1. 00**, 1. 10, 1. 19, ---
174	1, 722. 62	25	150	36, 718. 47	$a^4F_{4\frac{1}{2}}-y^4D^\circ_{3\frac{1}{2}}$	(0. 00) 1. 45 E_1	
180	2, 721. 37	2		36, 735. 33	$a^2F_{3\frac{1}{2}}-y^4P^\circ_{2\frac{1}{2}}$		

TABLE 2.—*Wave lengths in the spark spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities B. S.	Intensities King	ν	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
181	2,720.36	5	2	36,748.97	$a^2P_{1\frac{1}{2}}-x^2F^\circ_{2\frac{1}{2}}$		
178	2,714.22	10	20	36,832.10	$a^2D_{2\frac{1}{2}}-y^2P^\circ_{1\frac{1}{2}}$	(0.00) 1.08 E_1	(**0.07**, 0.20) **1.00**, 1.13, 1.27, 1.40
174	2,712.38	10	25	36,857.08	$a^4F_{2\frac{1}{2}}-y^4D^\circ_{2\frac{1}{2}}$	(0.00*w*) 1.04 E_1	(0.17, 0.51, **0.86**) 0.51, 0.86, **1.20**, 1.54, 1.89
172	2,711.48	12	50	36,869.32	$a^4F_{1\frac{1}{2}}-y^4F^\circ_{2\frac{1}{2}}$	(0.00) 1.89 E_1	(**0.31**, 0.94) 0.09, 0.71, 1.34, **1.97**
175	2,706.38	4		36,938.79	$b^4F_{3\frac{1}{2}}-x^4D^\circ_{3\frac{1}{2}}$		
182	2,704.66	4		36,962.28	$a^2D_{2\frac{1}{2}}-x^2D^\circ_{1\frac{1}{2}}$		
183	2,703.25	3		36,981.56	$b^2P_{1\frac{1}{2}}-v^2F^\circ_{2\frac{1}{2}}$		
	2,702.93	1		36,985.93			
177	2,700.12	18	100	37,024.42	$a^4F_{3\frac{1}{2}}-y^2F^\circ_{3\frac{1}{2}}$	(0.00) 1.23 E_1	(0.00) 1.24
177	2,699.59	6	15	37,031.69	$a^4F_{2\frac{1}{2}}-y^2F^\circ_{2\frac{1}{2}}$	(0.00) 1.20 E_1	(0.09, 0.26, **0.43**) 0.60, 0.77, **0.94**, 1.12, 1.29
178	2,695.42	8	3	37,088.98	$a^2D_{1\frac{1}{2}}-y^2P^\circ_{1\frac{1}{2}}$	(0.59) 1.09 E_1	(0.27, **0.80**) 0.53, **1.07**, 1.60
171	2,694.05	10	20	37,107.84	$a^2F_{2\frac{1}{2}}-x^2F^\circ_{2\frac{1}{2}}$	(0.00) 0.83 E_1	(0.00) 0.86
172	2,693.52	9	30	37,115.14	$a^4F_{2\frac{1}{2}}-y^4F^\circ_{3\frac{1}{2}}$	(0.00) 1.64 E_1	(**0.10**, 0.31, 0.52) --- 1.34, 1.55, **1.76**
185	2,692.60	6	5	37,127.82	$a^4P_{2\frac{1}{2}}-w^2D^\circ_{2\frac{1}{2}}$	(0.76) 1.39 E_1	(0.20, 0.60, **1.00**) 0.60, 1.00, **1.40**, 1.80, 2.20
184	2,692.00	6		37,136.10	$b^2F_{3\frac{1}{2}}-v^2D^\circ_{2\frac{1}{2}}$	(0.00) 1.23 E_1	(**0.03**, 0.09, 0.14) **1.00**, 1.06, 1.11, ---
182, 174	2,689.47	6	5	37,171.03	$\{a^2D_{2\frac{1}{2}}-x^2D^\circ_{2\frac{1}{2}}\}$ $\{a^4F_{1\frac{1}{2}}-y^4D^\circ_{2\frac{1}{2}}\}$		
174	2,681.75	5	2	37,278.03	$a^4F_{3\frac{1}{2}}-y^4D^\circ_{3\frac{1}{2}}$		
	2,680.94	1*b*		37,289.29			
172	2,678.59	25	150	37,322.00	$a^4F_{4\frac{1}{2}}-y^4F^\circ_{4\frac{1}{2}}$	(0.00) 1.45 E_1	(0.00) 1.33
	2,673.84	1*b*		37,388.30			
	2,673.56	1		37,392.21			
182	2,670.94	10		37,428.89	$a^2D_{1\frac{1}{2}}-x^2D^\circ_{2\frac{1}{2}}$	(0.00) 1.56 E_1	(**0.20**, 0.60) 0.60, 1.00, 1.40, **1.80**
185, 180	2,669.48	8	4	37,449.36	$\{a^2F_{2\frac{1}{2}}-y^4P^\circ_{2\frac{1}{2}}\}$ $\{a^4P_{1\frac{1}{2}}-w^2D^\circ_{2\frac{1}{2}}\}$		
177	2,667.77	12	20	37,473.36	$a^4F_{2\frac{1}{2}}-y^2F^\circ_{3\frac{1}{2}}$	(0.00) 1.43 E_1	(**0.06**, 0.17, 0.29) --- 1.20, 1.31, **1.43**
	2,666.56	1		37,490.36			
186	2,665.19	3		37,509.64	$a^4P_{2\frac{1}{2}}-x^2P^\circ_{1\frac{1}{2}}$		
187	2,662.57	3		37,546.54	$b^2F_{2\frac{1}{2}}-v^2F^\circ_{2\frac{1}{2}}$		
	2,652.92	1		37,683.11			
188	2,650.37	12	8	37,719.37	$a^4F_{3\frac{1}{2}}-z^4P^\circ_{2\frac{1}{2}}$	(0.00) 0.54 E_1	(**0.18**, 0.54, 0.90) **0.35**, 0.70, 1.06, ---
	2,649.80	2		37,763.96			
	2,644.88	1		37,797.65			
188	2,643.40	6	4	37,818.82	$a^4F_{2\frac{1}{2}}-z^4P^\circ_{1\frac{1}{2}}$		
186	2,642.51	2		37,831.55	$a^4P_{1\frac{1}{2}}-x^2P^\circ_{1\frac{1}{2}}$		
	2,639.73	3*b*		37,871.39			
172	2,639.07	12	30	37,880.86	$a^4F_{3\frac{1}{2}}-y^4F^\circ_{4\frac{1}{2}}$	(0.00) 1.52 E_1	(**0.05**, 0.14, ---) --- 1.48, 1.57, **1.67**
	2,637.62	1*b*		37,901.68			
189	2,630.91	15	40	37,998.35	$a^2D_{2\frac{1}{2}}-x^2F^\circ_{3\frac{1}{2}}$	(0.00) 0.98 E_1	(**0.03**, 0.09, 0.14) **1.00**, 1.06, 1.11, ---
	2,629.52	1*b*		38,018.43			
	2,628.89	1		38,027.54			
186	2,626.98	3		38,055.19	$a^4P_{0\frac{1}{2}}-x^2P^\circ_{1\frac{1}{2}}$		
188	2,626.41	4		38,063.45	$a^4F_{1\frac{1}{2}}-z^4P^\circ_{0\frac{1}{2}}$		
188	2,621.60	3		38,132.88	$a^4F_{1\frac{1}{2}}-z^4P^\circ_{1\frac{1}{2}}$		
188	2,619.20	3		38,168.22	$a^4F_{2\frac{1}{2}}-z^4P^\circ_{2\frac{1}{2}}$		
252	2,618.89	2		38,172.73	$d^2D_{2\frac{1}{2}}-v^2D^\circ_{2\frac{1}{2}}$		
252	2,615.59	4		38,220.89	$d^2D_{1\frac{1}{2}}-v^2D^\circ_{1\frac{1}{2}}$		
187	2,609.74	5		38,306.56	$b^2F_{3\frac{1}{2}}-v^2F^\circ_{3\frac{1}{2}}$	(0.00) 1.24 E_1	(0.00) 1.14
190	2,604.99	2		38,376.41	$b^4F_{3\frac{1}{2}}-z^2D^\circ_{2\frac{1}{2}}$		
	2,604.73	1		38,380.24			
191	2,604.19	3		38,388.20	$a^2D_{2\frac{1}{2}}-y^4P^\circ_{1\frac{1}{2}}$		
	2,602.95	1		38,406.48			
186	2,601.27	3		38,431.29	$a^4P_{0\frac{1}{2}}-x^2P^\circ_{0\frac{1}{2}}$		
	2,598.16	2		38,477.29			
189	2,589.02	15		38,613.12	$a^2D_{1\frac{1}{2}}-x^2F^\circ_{2\frac{1}{2}}$	(0.00) 1.06 E_1	(**0.03**, 0.09) 0.77, 0.83, 0.89, **0.94**
191	2,586.85	4		38,645.50	$a^2D_{1\frac{1}{2}}-y^4P^\circ_{1\frac{1}{2}}$		
193	2,586.40	1		38,652.22	$b^4F_{4\frac{1}{2}}-z^2H^\circ_{5\frac{1}{2}}$		

TABLE 2.—*Wave lengths in the spark spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities B. S.	Intensities King	ν	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
	2, 583.99	2		38, 688.27			
191	2, 583.38	15		38, 697.40	$a^2D_{2\frac{1}{2}}-y^4P^\circ_{2\frac{1}{2}}$	(0.83) 1.49 E_1	(0.20, 0.60, **1.60**) 0.60, 1.00, **1.40**, 1.80, 2.20
243	2, 581.71	2		38, 722.44	$z^2F^\circ_{3\frac{1}{2}}-e^2G_{4\frac{1}{2}}$		
	2, 580.61	2*b*		38, 738.94			
	2, 579.73	1*b*		38, 752.15			
250	2, 578.39	3		38, 772.29	$y^2G^\circ_{3\frac{1}{2}}-f^2G_{3\frac{1}{2}}$		
	2, 573.64	2		38, 843.85			
195	2, 571.42	50		38, 877.38	$\{a^4F_{3\frac{1}{2}}-x^4D^\circ_{2\frac{1}{2}}$ $a^4F_{2\frac{1}{2}}-x^4D^\circ_{1\frac{1}{2}}\}$		
195	2, 568.85	40		38, 916.27	$a^4F_{4\frac{1}{2}}-x^4D^\circ_{3\frac{1}{2}}$		
195	2, 567.62	20		38, 934.91	$a^4F_{1\frac{1}{2}}-x^4D^\circ_{0\frac{1}{2}}$		
247	2, 567.05	7		38, 943.56	$a^2P_{1\frac{1}{2}}-w^2D^\circ_{1\frac{1}{2}}$	(0.75) 1.15 E_1	(0.27, **0.80**) 0.53, **1.07**, 1.60
247	2, 558.36	1*b*		39, 075.83	$a^2P_{1\frac{1}{2}}-w^2D^\circ_{2\frac{1}{2}}$		
	2, 557.54	1*b*		39, 088.36			
	2, 554.18	2*b*		39, 139.77			
196	2, 553.06	2		39, 156.94	$b^2D_{1\frac{1}{2}}-w^2P^\circ_{0\frac{1}{2}}$		
	2, 552.59	2		39, 164.15			
195	2, 550.71	18		39, 193.02	$a^4F_{1\frac{1}{2}}-x^4D^\circ_{1\frac{1}{2}}$	(1.26) 1.22 E_1	(0.40, **1.20**) 0.00, **0.80**, 1.60
194	2, 543.66	1		39, 301.63	$a^2F_{2\frac{1}{2}}-w^2D^\circ_{1\frac{1}{2}}$		
197	2, 543.04	3*b*		39, 311.22	$z^2G^\circ_{4\frac{1}{2}}-f^2F_{3\frac{1}{2}}$		
195	2, 542.09	18		39, 325.90	$a^4F_{2\frac{1}{2}}-x^4D^\circ_{2\frac{1}{2}}$	(0.82) 1.29 E_1	(0.17, 0.51, **0.86**) 0.51, 0.86, **1.20**, 1.54, 1.89
198	2, 540.87	3*b*		39, 344.79	$d^2D_{2\frac{1}{2}}-v^2F^\circ_{3\frac{1}{2}}$		
197	2, 539.37	2		39, 368.03	$z^2G^\circ_{3\frac{1}{2}}-f^2F_{2\frac{1}{2}}$		
250, 194	2, 535.15	5		39, 433.55	$\{y^2G^\circ_{4\frac{1}{2}}-f^2G_{4\frac{1}{2}}$ $a^2F_{2\frac{1}{2}}-w^2D^\circ_{2\frac{1}{2}}\}$		
198	2, 534.16	2*b*		39, 448.96	$d^2D_{1\frac{1}{2}}-v^2F^\circ_{2\frac{1}{2}}$		
199	2, 533.65	4		39, 456.90	$a^2P_{1\frac{1}{2}}-x^2P^\circ_{1\frac{1}{2}}$		
195	2, 532.47	20		39, 475.28	$a^4F_{3\frac{1}{2}}-x^4D^\circ_{3\frac{1}{2}}$	(0.60) 1.39 E_1	(0.10, 0.29, 0.48, **0.67**) 1.14, **1.33**, 1.52, ---
	2, 528.99	3		39, 528.60			
	2, 522.52	2*b*		39, 630.98			
195	2, 521.90	5		39, 640.72	$a^4F_{1\frac{1}{2}}-x^4D^\circ_{2\frac{1}{2}}$		
	2, 520.01	1*b*		39, 670.45			
	2, 513.50	2*b*		39, 773.19			
	2, 510.01	2*l*		39, 828.49			
199	2, 509.77	3		39, 832.29	$a^2P_{1\frac{1}{2}}-x^2P^\circ_{0\frac{1}{2}}$		
199	2, 509.01	2		39, 844.36	$a^2P_{0\frac{1}{2}}-x^2P^\circ_{1\frac{1}{2}}$		
195	2, 503.98	4		39, 924.39	$a^4F_{2\frac{1}{2}}-x^4D^\circ_{3\frac{1}{2}}$		
	2, 503.59	1		39, 930.61			
200	2, 501.38	1*b*		39, 965.88	$b^4F_{2\frac{1}{2}}-x^2F^\circ_{2\frac{1}{2}}$		
201	2, 496.48	15		40, 044.33	$a^2G_{3\frac{1}{2}}-w^2F^\circ_{2\frac{1}{2}}$	(0.00) 0.90 E_1	(**0.02**, 0.05, 0.08) --- 0.90, 0.94, **0.97**
	2, 489.83	2*b*		40, 151.27			
201	2, 487.28	20		40, 192.43	$a^2G_{4\frac{1}{2}}-w^2F^\circ_{3\frac{1}{2}}$	(0.00) 1.06 E_1	(**0.02**, 0.05, ---) **1.00**, 1.03, 1.06, ---
199	2, 485.60	3		40, 219.59	$a^2P_{0\frac{1}{2}}-x^2P^\circ_{0\frac{1}{2}}$		
	2, 484.42	2*b*		40, 238.70			
200	2, 481.35	5		40, 288.48	$b^4F_{1\frac{1}{2}}-x^2F^\circ_{2\frac{1}{2}}$		
202	2, 480.16	2		40, 307.81	$b^4F_{2\frac{1}{2}}-y^4P^\circ_{2\frac{1}{2}}$		
	2, 471.42	2		40, 450.34			
	2, 471.06	1		40, 456.23			
	2, 470.62	1		40, 463.44			
201	2, 467.97	2*b*		40, 506.88	$a^2G_{3\frac{1}{2}}-w^2F^\circ_{3\frac{1}{2}}$		
	2, 467.24	1*b*		40, 518.87			
203	2, 465.37	8		40, 549.60	$a^2D_{2\frac{1}{2}}-w^2D^\circ_{1\frac{1}{2}}$		
203	2, 457.43	20		40, 680.60	$a^2D_{2\frac{1}{2}}-w^2D^\circ_{2\frac{1}{2}}$	(0.00) 1.30 E_1	(0.00) 1.20
204	2, 454.61	4		40, 727.34	$a^4F_{1\frac{1}{2}}-y^2P^\circ_{0\frac{1}{2}}$		
205	2, 454.21	4		40, 733.97	$b^2P_{1\frac{1}{2}}-v^2P^\circ_{0\frac{1}{2}}$		
203	2, 449.83	20		40, 806.79	$a^2D_{1\frac{1}{2}}-w^2D_{1\frac{1}{2}}$	(0.00) 0.99 E_1	(0.00) 0.80
206	2, 443.41	1		40, 914.01	$a^4F_{3\frac{1}{2}}-x^2D^\circ_{2\frac{1}{2}}$		
203	2, 441.97	12		40, 938.13	$a^2D_{1\frac{1}{2}}-w^2D^\circ_{2\frac{1}{2}}$		
	2, 439.22	2*b*		40, 984.28			
	2, 438.26	1*b*		41, 000.41			
204	2, 436.94	1		41, 022.62	$a^4F_{2\frac{1}{2}}-y^2P^\circ_{1\frac{1}{2}}$		
207	2, 434.55	8		41, 062.89	$a^2D_{2\frac{1}{2}}-x^2P^\circ_{1\frac{1}{2}}$		

TABLE 2.—*Wave lengths in the spark spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities B. S.	Intensities King	ν	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
	2, 433. 25	3*b*		41, 084. 83			
208	2, 432. 26	3		41, 101. 72	$c^2D_{2\frac{1}{2}}-v^2D^\circ_{1\frac{1}{2}}$		
	2, 431. 71	1		41, 110. 84			
206	2, 429. 12	1		41, 154. 67	$a^4F_{2\frac{1}{2}}-x^2D^\circ_{1\frac{1}{2}}$		
205	2, 426. 38	7		41, 201. 14	$b^2P_{0\frac{1}{2}}-v^2P^\circ_{0\frac{1}{2}}$		
	2, 425. 73	1		41, 212. 18			
	2, 423. 29	3*b*		41, 253. 68			
	2, 422. 24	3		41, 271. 56			
207	2, 419. 37	10		41, 320. 51	$a^2D_{1\frac{1}{2}}-x^2P^\circ_{1\frac{1}{2}}$		
	2, 417. 40	2*b*		41, 354. 18			
206	2, 416. 89	2		41, 362. 91	$a^4F_{2\frac{1}{2}}-x^2D^\circ_{2\frac{1}{2}}$		
	2, 414. 23	2		41, 408. 48			
209	2, 413. 85	3		41, 415. 00	$a^2F_{3\frac{1}{2}}-w^2F^\circ_{2\frac{1}{2}}$		
	2, 412. 40	1		41, 439. 89			
206	2, 410. 67	1		41, 469. 62	$a^4F_{1\frac{1}{2}}-x^2D^\circ_{1\frac{1}{2}}$		
208	2, 406. 83	7		41, 535. 78	$c^2D_{1\frac{1}{2}}-v^2D^\circ_{1\frac{1}{2}}$		
	2, 403. 86	1*b*		41, 587. 09			
	2, 403. 28	1*b*		41, 614. 44			
	2, 402. 58	1*b*		41, 626. 57			
	2, 401. 44	1*b*		41, 629. 00			
	2, 400. 62	1		41, 643. 22			
210	2, 398. 97	5		41, 671. 86	$b^2D_{2\frac{1}{2}}-v^2D^\circ_{1\frac{1}{2}}$		
207	2, 397. 57	5		41, 696. 19	$a^2D_{1\frac{1}{2}}-x^2P^\circ_{0\frac{1}{2}}$		
211	2, 393. 35	2		41, 769. 70	$a^2P_{1\frac{1}{2}}-w^2F^\circ_{2\frac{1}{2}}$		
205	2, 392. 66	10		41, 781. 75	$b^2P_{1\frac{1}{2}}-v^2P^\circ_{1\frac{1}{2}}$		
208	2, 389. 52	8		41, 836. 64	$c^2D_{2\frac{1}{2}}-vD^\circ_{2\frac{1}{2}}$		
	2, 388. 21	1		41, 859. 59			
209	2, 387. 17	15		41, 877. 83	$a^2F_{3\frac{1}{2}}-w^2F^\circ_{3\frac{1}{2}}$		
	2, 382. 32	2		41, 963. 08			
	2, 378. 68	1*b*		42, 027. 29			
209	2, 372. 92	12		42, 129. 29	$a^2F_{2\frac{1}{2}}-w^2F^\circ_{2\frac{1}{2}}$		
	2, 371. 38	1*b*		42, 156. 65			
	2, 370. 14	5*b*		42, 178. 70			
	2, 368. 99	2*b*		42, 199. 18			
	2, 367. 63	1*b*		42, 223. 41			
205	2, 366. 22	3		42, 248. 57	$b^2P_{0\frac{1}{2}}-v^2P^\circ_{1\frac{1}{2}}$		
	2, 365. 61	1*b*		42, 259. 46			
208	2, 364. 95	2		42, 271. 26	$c^2D_{1\frac{1}{2}}-v^2D^\circ_{2\frac{1}{2}}$		
251	2, 364. 58	2		42, 277. 87	$y^2F^\circ_{2\frac{1}{2}}-f^2G_{3\frac{1}{2}}$		
212	2, 363. 84	4		42, 291. 10	$b^4F_{2\frac{1}{2}}-w^2D^\circ_{2\frac{1}{2}}$		
	2, 362. 97	1*b*		42, 306. 67			
213	2, 361. 76	10		42, 328. 35	$c^2D_{2\frac{1}{2}}-v^2F^\circ_{3\frac{1}{2}}$		
	2, 359. 08	5*b*		42, 376. 43			
210	2, 357. 45	25		42, 405. 73	$\left\{\begin{matrix} b^2D_{2\frac{1}{2}}-v^2D^\circ_{2\frac{1}{2}} \\ b^2D_{1\frac{1}{2}}-v^2D^\circ_{1\frac{1}{2}} \end{matrix}\right\}$		
	2, 354. 51	2*b*		42, 458. 67			
212	2, 353. 21	6		42, 482. 13	$b^4F_{1\frac{1}{2}}-w^2D^\circ_{1\frac{1}{2}}$		
214	2, 351. 69	12		42, 509. 58	$b^2G_{3\frac{1}{2}}-v^2D^\circ_{2\frac{1}{2}}$		
251	2, 350. 91	3		42, 523. 69	$y^2F^\circ_{3\frac{1}{2}}-f^2G_{4\frac{1}{2}}$		
	2, 350. 22	3*b*		42, 536. 17			
209	2, 347. 13	4		42, 592. 16	$a^2F_{2\frac{1}{2}}-w^2F^\circ_{3\frac{1}{2}}$		
212	2, 345. 93	1		42, 613. 95	$b^4F_{1\frac{1}{2}}-w^2D^\circ_{2\frac{1}{2}}$		
	2, 342. 33	3*b*		42, 679. 44			
	2, 341. 74	1*b*		42, 690. 19			
	2, 339. 39	2*b*		42, 733. 07			
	2, 338. 93	1		42, 741. 47			
213	2, 337. 76	1		42, 762. 86	$c^2D_{1\frac{1}{2}}-v^2F^\circ_{2\frac{1}{2}}$		
	2, 335. 63	2*b*		42, 801. 86			
	2, 331. 57	3*b*		42, 876. 38			
215	2, 330. 38	18		42, 898. 27	$b^2D_{2\frac{1}{2}}-v^2F^\circ_{3\frac{1}{2}}$		
216	2, 324. 77	15		43, 001. 78	$b^2G_{3\frac{1}{2}}-v^2F^\circ_{3\frac{1}{2}}$		
213	2, 324. 48	5		43, 007. 15	$c^2D_{2\frac{1}{2}}-v^2F^\circ_{3\frac{1}{2}}$		
	2, 321. 87	5		43, 055. 49			
210	2, 317. 27	15		43, 140. 95	$b^2D_{1\frac{1}{2}}-v^2D^\circ_{2\frac{1}{2}}$		
	2, 308. 10	6		43, 312. 33			
	2, 307. 31	1*b*		43, 327. 16			

TABLE 2.—*Wave lengths in the spark spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities B. S.	Intensities King	ν	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
217	2, 306. 78	2*b*		43, 337. 11	$z^2D^\circ_{2\frac{1}{2}}-f^2F_{3\frac{1}{2}}$		
217	2, 302. 52	2*b*		43, 417. 28	$z^2D^\circ_{1\frac{1}{2}}-f^2F_{2\frac{1}{2}}$		
	2, 301. 61	4*b*		43, 434. 45			
	2, 300. 42	3*b*		43, 456. 91			
216	2, 295. 53	10		43, 549. 48	$b^2G_{4\frac{1}{2}}-v^2F^\circ_{3\frac{1}{2}}$		
215	2, 294. 08	12		43, 577. 00	$b^2D_{2\frac{1}{2}}-v^2F^\circ_{3\frac{1}{2}}$		
218, 215	2, 291. 15	15		43, 632. 73	$\left\{\begin{matrix} b^2D_{1\frac{1}{2}}-v^2F^\circ_{2\frac{1}{2}} \\ a^2D_{1\frac{1}{2}}-w^2F^\circ_{2\frac{1}{2}} \end{matrix}\right\}$		
216	2, 288. 63	2		43, 680. 76	$b^2G_{3\frac{1}{2}}-v^2F^\circ_{3\frac{1}{2}}$		
253	2, 288. 00	1		43, 692. 74	$z^4D^\circ_{3\frac{1}{2}}-f^4F_{4\frac{1}{2}}$		
	2, 283. 18	2		43, 784. 94			
	2, 281. 47	2*b*		43, 817. 83			
218	2, 280. 36	5		43, 839. 16	$a^2D_{2\frac{1}{2}}-w^2F^\circ_{3\frac{1}{2}}$		
	2, 276. 69	5*b*		43, 909. 91			
219	2, 275. 39	3*b*		43, 934. 99	$z^2F^\circ_{3\frac{1}{2}}-f^2F_{3\frac{1}{2}}$		
	2, 275. 07	1*b*		43, 941. 17			
	2, 268. 15	2		44, 075. 19			
	2, 265. 02	4		44, 136. 08			
	2, 262. 67	2		44, 181. 87			
	2, 261. 20	4, Ti?		44, 210. 59			
	2, 257. 88	4*b*		44, 275. 59			
219	2, 254. 20	3*b*		44, 347. 86	$z^2F^\circ_{2\frac{1}{2}}-f^2F_{2\frac{1}{2}}$		
	2, 253. 33	1*b*		44, 364. 98			
	2, 252. 38	2*b*		44, 383. 69			
220	2, 250. 44	3		44, 421. 95	$a^4F_{3\frac{1}{2}}-w^2D^\circ_{2\frac{1}{2}}$		
	2, 247. 54	1		44, 479. 26			
	2, 245. 38	4, Fe?		44, 522. 04			
	2, 240. 90	1*B*		44, 611. 04			
	2, 239. 67	3*B*		44, 635. 54			
221	2, 235. 10	5		44, 726. 80	$z^4F^\circ_{4\frac{1}{2}}-f^4F_{4\frac{1}{2}}$		
220	2, 234. 42	1		44, 740. 40	$a^4F_{1\frac{1}{2}}-w^2D^\circ_{1\frac{1}{2}}$		
221	2, 233. 48	5		44, 759. 24	$z^4F^\circ_{3\frac{1}{2}}-f^4F_{3\frac{1}{2}}$		
221	2, 231. 86	2		44, 791. 71	$z^4F^\circ_{2\frac{1}{2}}-f^4F_{2\frac{1}{2}}$		
	2, 231. 00	4, Ti?		44, 808. 98			
221	2, 229. 74	1*b*		44, 834. 30	$z^4F^\circ_{1\frac{1}{2}}-f^4F_{1\frac{1}{2}}$		
	2, 228. 12	2*b*		44, 866. 90			
	2, 226. 64	0		44, 896. 71			
	2, 223. 33	2*b*		44, 963. 55			
219	2, 221. 91	1*b*		44, 992. 28	$z^2F^\circ_{2\frac{1}{2}}-f^2F_{3\frac{1}{2}}$		
	2, 221. 38	1*b*		45, 003. 01			
	2, 220. 22	4*b*		45, 026. 53			
	2, 218. 46	1*b*		45, 062. 24			
222	2, 214. 59	2		45, 140. 98	$a^4P_{1\frac{1}{2}}-w^2P^\circ_{1\frac{1}{2}}$		
	2, 212. 92	1*b*		15, 175. 04			
220	2, 212. 44	0		45, 184. 84	$a^4F_{1\frac{1}{2}}-w^2D^\circ_{2\frac{1}{2}}$		
	2, 206. 97	3*b*		45, 296. 82			
223	2, 206. 31	4*b*		45, 310. 37	$b^4F_{1\frac{1}{2}}-u^2F^\circ_{2\frac{1}{2}}$		
221	2, 199. 17	1*b*		45, 457. 47	$z^4F^\circ_{2\frac{1}{2}}-f^4F_{3\frac{1}{2}}$		
224	2, 193. 84	0*b*		45, 567. 89	$a^4F_{1\frac{1}{2}}-x^2P^\circ_{1\frac{1}{2}}$		
	2, 192. 75	3		45, 590. 54			
	2, 192. 02	1*b*		45, 605. 72			
	2, 191. 16	3*b*		45, 623. 62			
	2, 187. 77	1*b*		45, 694. 30			
225	2, 184. 80	5*b*		45, 756. 42	$a^2H_{4\frac{1}{2}}-v^2F^\circ_{3\frac{1}{2}}$		
226	2, 182. 81	5*b*		45, 798. 12	$z^4G^\circ_{5\frac{1}{2}}-f^4F_{4\frac{1}{2}}$		
	2, 178. 86	2		45, 881. 14			
	2, 176. 69	0		45, 926. 87			
	2, 176. 39	1*b*		45, 933. 20			
224	2, 175. 81	4*b*		45, 945. 45	$a^4F_{1\frac{1}{2}}-x^2P^\circ_{0\frac{1}{2}}$		
	2, 170. 20	0		46, 064. 20			
	2, 167. 78	3		46, 115. 62			
	2, 166. 54	2*b*		46, 142. 01			
226	2, 165. 24	4*b*		46, 169. 71	$z^4G^\circ_{4\frac{1}{2}}-f^4F_{3\frac{1}{2}}$		
	2, 162. 16	1*b*		46, 235. 47			
	2, 159. 96	2*b*		46, 282. 56			
	2, 159. 67	0		46, 288. 77			

TABLE 2.—*Wave lengths in the spark spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities B. S.	Intensities King	ν	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
	2,159.19	4		46,299.06			
	2,157.98	2*b*		46,325.02			
	2,154.07	1*b*		46,409.09			
	2,153.26	1*b*		46,426.55			
226	2,152.89	4*b*		46,434.53	$z^4G^0_{3\frac{1}{2}}-f^4F_{2\frac{1}{2}}$		
227	2,151.02	6		46,474.89	$a^2P_{1\frac{1}{2}}-w^2P^0_{0\frac{1}{2}}$		
228	2,145.24	1		46,600.10	$b^4P_{2\frac{1}{2}}-v^2D^0_{2\frac{1}{2}}$		
	2,144.86	0		46,608.36			
	2,144.33	1		46,619.87			
226	2,144.01	4*b*		46,626.83	$z^4G^0_{2\frac{1}{2}}-f^4F_{1\frac{1}{2}}$		
	2,142.71	1		46,654.46			
	2,141.43	3		46,683.00			
227	2,137.67	7		46,765.10	$a^2P_{1\frac{1}{2}}-w^2P^0_{1\frac{1}{2}}$		
	2,136.80	1		46,784.14			
227	2,133.28	7		46,861.32	$a^2P_{0\frac{1}{2}}-w^2P^0_{0\frac{1}{2}}$		
	2,131.15	1		46,908.16			
	2,129.93	2*B*		46,935.02			
	2,126.56	2		47,009.39			
	2,125.06	3*b*, *l*		47,042.57			
	2,124.58	1		47,053.19			
226	2,122.41	1		47,101.30	$z^4G^0_{3\frac{1}{2}}-f^4F_{3\frac{1}{2}}$		
229	2,121.18	1*b*		47,128.60	$c^2D_{2\frac{1}{2}}-v^2P^0_{1\frac{1}{2}}$		
227	2,120.12	5		47,152.16	$a^2P_{0\frac{1}{2}}-w^2P^0_{1\frac{1}{2}}$		
	2,119.71	2		47,161.29			
	2,113.10	1		47,308.79			
230	2,109.66	12		47,385.92	$b^2D_{1\frac{1}{2}}-v^2P^0_{0\frac{1}{2}}$		
	2,108.40	2 *b*, *l*		47,414.24			
	2,103.17	5*b*		47,532.13			
	2,101.55	1		47,568.77			
	2,099.30	1		47,619.74			
	2,097.02	5*b*		47,671.51			
230	2,095.80	15		47,699.26	$b^2D_{2\frac{1}{2}}-v^2P^0_{1\frac{1}{2}}$		
	2,091.75	2		47,791.60			
	2,083.80	1*b*		47,973.91			
	2,081.81	1		48,019.76			
	2,080.99	5*b*		48,038.68			
	2,076.29	2		48,147.41			
	2,074.90	3		48,179.66			
	2,074.03	6*b*		48,199.86			
231	2,068.09	3		48,338.29	$a^2D_{1\frac{1}{2}}-w^2P^0_{1\frac{1}{2}}$		
232	2,067.08	4		48,361.90	$z^2G^0_{4\frac{1}{2}}-g^2G_{4\frac{1}{2}}$		
244	2,065.35	3		48,402.41	$z^4G^0_{5\frac{1}{2}}-e^4H_{5\frac{1}{2}}$		
	2,064.37	0		48,425.38			
230	2,063.89	6		48,436.64	$b^2D_{1\frac{1}{2}}-v^2P^0_{1\frac{1}{2}}$		
244	2,061.85	6		48,484.56	$z^4G^0_{5\frac{1}{2}}-e^4H_{6\frac{1}{2}}$		
	2,061.35	5*b*		48,496.32			
245	2,057.96	1*b*		48,576.19	$z^2H^0_{5\frac{1}{2}}-f^2H_{4\frac{1}{2}}$		
	2,055.42	3		48,636.21			
	2,054.30	2		48,662.73			
	2,051.83	1*b*		48,721.30			
232	2,051.21	4		48,736.02	$z^2G^0_{3\frac{1}{2}}-g^2G_{3\frac{1}{2}}$		
	2,050.85	0		48,744.57			
	2,048.19	0		48,807.87			
	2,046.94	0		48,837.67			
	2,044.43	0		48,897.62			
	2,041.98	0*b*		48,956.28			
	2,040.52	0		48,991.31			
	2,040.11	0*b*		49,001.15			
244	2,039.84	1		49,007.64	$z^4G^0_{4\frac{1}{2}}-e^4H_{4\frac{1}{2}}$		
232	2,037.58	1		49,061.98	$z^2G^0_{3\frac{1}{2}}-g^2G_{4\frac{1}{2}}$		
233	2,030.73	6		49,227.46	$a^2G_{3\frac{1}{2}}-v^2F^0_{2\frac{1}{2}}$		
245	2,029.81	3*b*		49,248.31	$z^2H^0_{4\frac{1}{2}}-f^2H_{4\frac{1}{2}}$		
	2,028.03	1		49,292.99			
245	2,026.61	5*b*		49,327.52	$z^2H^0_{5\frac{1}{2}}-f^2H_{5\frac{1}{2}}$		
244	2,025.33	4		49,358.69	$z^4G^0_{4\frac{1}{2}}-e^4H_{5\frac{1}{2}}$		

TALBE 2.—*Wave lengths in the spark spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities B. S.	Intensities King	ν	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
	2,021.36	0*b*		49,455.62			
	2,019.65	0		49,497.49			
	2,016.52	0		49,574.30			
233	2,015.86	5		49,590.53	$a^2G_{4\frac{1}{2}}-v^2F^{\circ}_{3\frac{1}{2}}$		
	2,013.21	0		49,655.80			
244	2,012.66	0		49,669.36	$z^4G^{\circ}_{3\frac{1}{2}}-e^4H_{3\frac{1}{2}}$		
	2,012.03	0		49,684.92			
233	2,003.18	0		49,904.39	$a^2G_{3\frac{1}{2}}-v^2F^{\circ}_{3\frac{1}{2}}$		
244	2,001.90	4		49,938.79	$z^4G^{\circ}_{3\frac{1}{2}}-e^4H_{4\frac{1}{2}}$		
245	1,999.43	1*b*		49,998.25	$z^2H^{\circ}_{4\frac{1}{2}}-f^2H_{5\frac{1}{2}}$		
234	1,996.05	6		50,082.89	$a^2F_{2\frac{1}{2}}-v^2D^{\circ}_{1\frac{1}{2}}$		
234	1,995.24	7		50,103.21	$a^2F_{3\frac{1}{2}}-v^2D^{\circ}_{2\frac{1}{2}}$		
235	1,994.91	1		50,111.50	$a^2P_{0\frac{1}{2}}-v^2D^{\circ}_{1\frac{1}{2}}$		
	1,990.70	0		50,217.44			
235	1,981.21	2		50,457.91	$a^2P_{1\frac{1}{2}}-v^2D^{\circ}_{2\frac{1}{2}}$		
244	1,975.90	3		50,593.46	$z^4G^{\circ}_{2\frac{1}{2}}-e^4H_{3\frac{1}{2}}$		
	1,961.37	2		50,968.14			
236	1,949.65	2		51,274.43	$a^2F_{3\frac{1}{2}}-v^2F^{\circ}_{3\frac{1}{2}}$		
236	1,948.23	1		51,311.79	$a^2F_{2\frac{1}{2}}-v^2F^{\circ}_{2\frac{1}{2}}$		
237	1,947.46	1		51,332.07	$a^2D_{2\frac{1}{2}}-v^2D^{\circ}_{1\frac{1}{2}}$		
237	1,937.64	3		51,592.40	$a^2D_{1\frac{1}{2}}-v^2D^{\circ}_{1\frac{1}{2}}$		
237	1,920.76	5		52,062	$a^2D_{2\frac{1}{2}}-v^2D^{\circ}_{2\frac{1}{2}}$		
237	1,911.32	4		52,319	$a^2D_{1\frac{1}{2}}-v^2D^{\circ}_{2\frac{1}{2}}$		
238	1,902.78	3		52,554	$a^2D_{2\frac{1}{2}}-v^2F^{\circ}_{3\frac{1}{2}}$		
238	1,893.52	1		52,811	$a^2D_{1\frac{1}{2}}-v^2F^{\circ}_{2\frac{1}{2}}$		
246	1,887.07	1		52,992	$z^2F^{\circ}_{3\frac{1}{2}}-g^2G_{4\frac{1}{2}}$		
238	1,878.53	4		53,233	$a^2D_{2\frac{1}{2}}-v^2F^{\circ}_{3\frac{1}{2}}$		
246	1,861.71	0		53,714	$z^2F^{\circ}_{2\frac{1}{2}}-g^2G_{3\frac{1}{2}}$		
239	1,767.85	0		56,565	$a^2D_{1\frac{1}{2}}-v^2P^{\circ}_{0\frac{1}{2}}$		
239	1,743.53	0		57,354	$a^2D_{2\frac{1}{2}}-v^2P^{\circ}_{1\frac{1}{2}}$		

TABLE 3.—*Key to the term combinations of Zr II*

Even terms \ Odd terms	$z^4G°$	$z^4F°$	$y^4F°$	$z^4D°$	$y^4D°$	$x^4D°$	$z^4P°$	$y^4P°$	$z^4S°$	$z^2H°$	$z^2G°$	$y^2G°$	$z^2F°$	$y^2F°$	$x^2F°$	$w^2F°$	$r^2F°$	$z^2D°$	$y^2D°$	$x^2D°$	$w^2D°$	$v^2D°$	$z^2P°$	$y^2P°$	$x^2P°$	$w^2P°$	$v^2P°$	$z^2S°$
e^4H	244																											
a^4F	75	103	172	126	174	195	188				151		95	177				108	133	206	220		169	204	224			161
b^4F	52	69	147	98	150	175	163	202		193			65	153	200	223		79	113	190	212		145					
e^4F	154	138																										
f^4F	226	221																										
a^4P			94	46	90	122	111	162	105			136	24	100	158				53	149	185		83	144	186	222		73
b^4P				20	70	99	86	139	81				11						41			228	60					
e^2I										248																		
a^2H		8								102	23	91		58	116		225											
e^2H										249																		
f^2H										245																		
a^2G	13	26	97	49	101	129				148	66	134	17	104	156	201	233	39										
b^2G			29		34	64				80	9	68	4	37	87	152	216					214						
e^2G											242		243															
f^2G												250		251														
g^2G											232		246															
a^2F	19	45	118	63	125	142	135	180		166	84	157	31	120	171	209	236	48	72	164	194	234	110	168				
b^2F								44		21	1*a*	15			33		187			18	57	184						
e^2F													241					240										
f^2F											197		219	179				217										
a^2D	42	56	131	85	128	160	192	191	143		107	176	51	137	189	218	238	59	89	182	203	237	124	178	207	231	239	117
b^2D		3	30	6	28	54								36	93	155	215		7	77	121	210	22	74	130	196	230	
c^2D			25		38			88				61		32	82	141	213		5	71	114	208	14	67	119		229	
d^2D																96	198					252				165		
e^2D																			146				115					
a^2P		43	112	62	109	140	127						40	123	181	211		47	76	167	247	235	106	159	199	227		92
b^2P								35							27		183			16	50	173	2	12	55	132	205	1
a^2S																									10	78	170	

2. THE ZEEMAN EFFECTS

Following the term designations of the lines in Table 2 are the observed Zeeman effects. For the most part these have been taken from the lists published by Moore and have proved of inestimable worth in unraveling not only Zr II, but also Zr I. Some of his published patterns, however, are in error because of overlapping of close lines. In such instances the observed patterns given in the table are those derived from the more recent observations made in the Brace Laboratory and at the Bureau of Standards, as stated above. In some instances, too, the new measurements have given improved values for patterns marked uncertain by Moore, and these also have been included in Table 2. For comparison with the observed Zeeman effects, the final column of Table 2 contains the theoretical pattern for weak fields as calculated according to Landé. These theoretical patterns have been taken from the Tables of Theoretical Zeeman Effects, published recently by Kiess and Meggers.[16]

Except for lines observed with the E_1 spectrograph, inspection of the table shows that there is good agreement between the observed and theoretical Zeeman effects for all lines which are simple triplets and for complex patterns whose components are separated by ½ a or more, a being the normal triplet separation. For complex lines whose components are separated by less than ½ a the agreement between the observed and calculated patterns is only qualitative. For some lines with components close to the undisturbed position a definite widening was noticed, and this is indicated in the table by a letter w following the pattern. Many of the apparent triplets are unresolved patterns with the strongest theoretical components either on the inside or on the outside, of the types designated as A^1 and A^2 by Back.[17] Such designations in Table 2 were derived from the recent observations described above. For lines of such types the rule noted by Russell[18] for Ti and by Meggers[19] for Yt was found to hold, namely, that the observed Zeeman effect is increased or decreased by one-fourth the separation between the strongest and weakest components of the theoretical pattern.

For the Zeeman effects observed with the prism spectrograph there is only qualitative agreement between the observed and theoretical patterns. No complex patterns were resolved and the only ones measured were either triplets or quartets. However, a few complex patterns on the verge of resolution were noted and these are indicated in Table 2 by the letter W. These observations were made after the lines had been classified and have served the purpose of checking the term combinations which have been assigned. They are published here to illustrate the possibilities and limitations of the E_1 spectrograph, or similar instrument, in Zeeman effect work. One is led to the conclusion that, of themselves, these observations are not sufficiently accurate to establish the identity spectral terms.

In general the g values of the terms appear to be normal, being those required by Landé's theory for weak fields. For two terms, however, $z^4F_{1\frac{1}{2}}$ and $y^2F_{2\frac{1}{2}}$, abnormal g values were noted. Combinations involving these terms and having observed Zeeman effects are given in Table 4. The calculated patterns in the last column are based on the observed and not on the theoretical g values of the two terms.

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[16] B. S. Jour. Research, 1, p. 641; 1928.
[17] Zeit. für Physik, 15, p. 206; 1923.
[18] Astrophys. J., 66, p. 308; 1927.
[19] B. S. Jour. Research, 2, p. 745; 1929.

TABLE 4.—*Zeeman effects from anomalous g values*

Term combination	λ	Observed Zeeman effect	Calculated Zeeman effect
$a^4F_{1\frac{1}{2}}-z^4F^{\circ}_{1\frac{1}{2}}$	3,357.26	(0.36) 0.53	(0.15, **0.40**) 0.25, **0.55**, 0.85
$b^4F_{1\frac{1}{2}}-z^4F^{\circ}_{2\frac{1}{2}}$	3,674.74	(0.39) 0.58	
$a^4F_{2\frac{1}{2}}-z^4F^{\circ}_{1\frac{1}{2}}$	3,393.12	(0.00) 1.46	(**0.16**, 0.49) 0.54, 0.86, 1.19, **1.52**
$b^4F_{2\frac{1}{2}}-z^4F^{\circ}_{1\frac{1}{2}}$	3,718.86	(0.00) 1.43	
$a^2F_{2\frac{1}{2}}-z^4F^{\circ}_{1\frac{1}{2}}$	4,161.20	(0.00) 1.09 A[2]	(**0.07**, 0.23) 0.62, 0.78, 0.93, **1.09**
$a^2D_{1\frac{1}{2}}-z^4F^{\circ}_{1\frac{1}{2}}$	3,915.94	(0.22) 0.74	(0.05, **0.15**) 0.65, **0.75**, 0.85
$a^2P_{0\frac{1}{2}}-z^4F^{\circ}_{1\frac{1}{2}}$	4,156.24	(0.00) 0.70	(0.02) 0.68, **0.72**
$b^4F_{3\frac{1}{2}}-y^2F^{\circ}_{2\frac{1}{2}}$	2,936.31	(0.00) 1.66	(**0.13**, 0.39, 0.65) 0.58, 0.84, 1.11, 1.37, 1.63, **1.89**
$a^4F_{3\frac{1}{2}}-y^2F^{\circ}_{2\frac{1}{2}}$	2,732.72	(0.00) 1.50	
$a^4F_{2\frac{1}{2}}-y^2F^{\circ}_{2\frac{1}{2}}$	2,699.59	(0.00) 1.20	(0.03, 0.08, **0.13**) 0.90, 0.95, **1.00**, 1.05, 1.11
$a^2G_{3\frac{1}{2}}-y^2F^{\circ}_{2\frac{1}{2}}$	3,387.87	(0.00) 0.67	(**0.04**, 0.13, 0.22) **0.67**, 0.76, 0.84, 0.93, 1.02, 1.10
$b^2G_{3\frac{1}{2}}-y^2F^{\circ}_{2\frac{1}{2}}$	4,293.14	(0.00) 0.66 A[1]	
$a^2F_{2\frac{1}{2}}-y^2F^{\circ}_{3\frac{1}{2}}$	3,164.32	(0.29) 1.00	(0.06, 0.18, **0.30**) 0.68, 0.80, **0.92**, 1.03, 1.15
$a^2D_{2\frac{1}{2}}-y^2F^{\circ}_{3\frac{1}{2}}$	3,044.12	(0.00*w*) 1.00	(0.11, 0.34, **0.56**) 0.64, 0.86, **1.09**, 1.31, 1.54
$a^2D_{1\frac{1}{2}}-y^2F^{\circ}_{2\frac{1}{2}}$	3,020.45	(0.00) 1.16	(**0.09**, 0.26) 0.71, 0.89, 1.06, **1.24**
$b^2D_{1\frac{1}{2}}-y^2F^{\circ}_{2\frac{1}{2}}$	4,179.81	(0.00) 1.25 A[2]	
$c^2D_{1\frac{1}{2}}-y^2F^{\circ}_{2\frac{1}{2}}$	4,337.63	(0.00) 1.20	

	g values	
	Observed	Theoretical
$z^4F^{\circ}_{1\frac{1}{2}}$	0.700	0.400
$y^2F^{\circ}_{2\frac{1}{2}}$	.975	.857

Among the Zr Zeeman effects are two complex patterns which beautifully illustrate the power of a magnetic field to resolve two very close or coincident lines which have not been resolved with the most powerful gratings used in observing them. The lines in question are at wave lengths 4,457.42 and 4,282.21 A. Each belongs to both Zr I and Zr II, and represents the term combinations given in Table 5.

TABLE 5.—*Zeeman effects of coincident lines of Zr I and Zr II*

λ	Terms	Theoretical Zeeman effect	Observed Zeeman effect
4,457.42	$^5P_2-^5D_1$	(**0.00**, 0.33) 1.50, 1.83, **2.17**	(0.00, **1.30**) **1.33**, 2.17
	$^4P_{0\frac{1}{2}}-^4D_{0\frac{1}{2}}$	(1.33) 1.33	
[1] 4,282.21	$^5F_2-^5F_3$	(**0.00**, 0.25, 0.50) 0.75, 1.00, 1.25, 1.50, **1.75**	(0.00) **0.87**, 1.54, **1.77**
	$^2F_{2\frac{1}{2}}-^2F_{2\frac{1}{2}}$	(0.00) 0.86	

[1] From the apparent wave lengths of the *n* components the wave length of the Zr I line comes out 4,282.18 A.

3. INTERPRETATION OF THE OBSERVED TERMS

The present accepted explanation of the terms of a spectrum is that they are the resultants of the interaction of the valence electrons of an atom in the various configurations they can assume. The neutral Zr atom in its unexcited state has two 4_3 and two 5_1 electrons external to the krypton shell, the configuration of these electrons being designated by the symbol $4d^2\ 5s^2$. The singly ionized atom has lost one of the *s* electrons, whence the configuration of the unexcited state, corresponding to its minimum energy stage, is designated as $4d^2 \cdot 5s$. But the difference in energy between the binding of an electron in a 5_1 orbit and a 4_3 orbit is small, so that stages of low energy may also result from the configurations $4d^3$ and $4d\ 5s^2$. The terms which result from these three configurations are shown in Table 6. As the present analysis shows all have been found for Zr II.

When the ion Zr^+ absorbs energy an electron is removed from one of the configurations just described to a higher orbit of the *ns*, *np*, *nd*, *nf*, etc., types, and new electron configurations ensue. The terms resulting from these excited configurations are also shown in Table 6. The most conspicuous of these terms are those which arise when the dislodged electron enters a 5_2 orbit. All the terms coming from the configurations $4d^2\ 5p$ and $4d\ 5s\ 5p$ have been found, as Table 6 shows. It is the combinations of these odd terms of the middle group with the terms of the low configurations that account for nearly all the strong lines of the spectrum.

TABLE 6.—*Theoretical and observed terms of Zr II*

Electron configuration	Theoretical terms	Observed terms	Limit in Zr III
$4d^2 \cdot 5s$	$^4F, {}^2F$ $^4P, {}^2P$ ^2G ^2D ^2S	a^4F, a^2F a^4P, a^2P b^2G a^2D a^2S	$4d^3F$ $4d^3P$ $4d^1G$ $4d^1D$ $4d^1S$
$4d^3$	$^4F, {}^4P, {}^2H, {}^2G, {}^2F, {}^2D, {}^2P, {}^2D$	$b^4F, b^4P, a^2H, a^2G, b^2F, b^2D, b^2P, c^2D$	
$4d \cdot 5s^2$	^2D	d^2D	$5s^3D, 5s^1D$
$4d^2 \cdot 5p$	$^4G^0, {}^4F^0, {}^4D^0, {}^2G^0, {}^2F^0, {}^2D^0$ $^4D^0\ {}^4P^0\ {}^4S^0, {}^2D^0, {}^2P^0, {}^2S^0$ $^2H^0, {}^2G^0, {}^2F^0$ $^2F^0, {}^2D^0, {}^2P^0$ $^2P^0$	$z^4G^0, z^4F^0, z^4D^0, z^2G^0, z^2F^0, z^2D^0$ $y^4D^0, y^4P^0, z^4S^0, y^2D^0, y^2P^0, z^2S^0$ z^2H^0, y^2G^0, y^2F^0 x^2F^0, x^2D^0, z^2P^0 x^2P^0	$4d^3F$ $4d^3P$ $4d^1G$ $4d^1D$ $4d^1S$
$4d \cdot 5s \cdot 5p$	$^4F^0, {}^4D^0, {}^4P^0, {}^2F^0, {}^2D^0, {}^2P^0$ $^2F^0, {}^2D^0, {}^2P^0$	$y^4F^0, x^4D^0, z^4P^0, v^2F^0, v^2D^0, v^2P^0$ w^2F^0, w^2D^0, w^2P^0	$5s^3D$ $5s^1D$
$4d^2 \cdot 6s$	$^4F, {}^2F$ $^4P, {}^2P$ ^2G ^2D ^2S	e^4F, e^2F e^2G e^2D	$4d^3F$ $4d^3P$ $4d^1G$ $4d^1D$ $4d^1S$
$4d^2 \cdot 5d$	$^4H, {}^4G, {}^4F, {}^4D, {}^4P, {}^2H, {}^2G, {}^2F, {}^2D, {}^2P$ $^4F, {}^4D, {}^4P\ {}^2F, {}^2D, {}^2P$ $^2I, {}^2H, {}^2G, {}^2F, {}^2D$ $^2G, {}^2F, {}^2D, {}^2P, {}^2S$ ^2D	$e^4H, f^4F, f^2H, g^2G, f^2F$ e^2I, e^2H, f^2G	$4d^3F$ $4d^3P$ $4d^1G$ $4d^1D$ $4d^1S$

With increase in energy of the ion the dislodged electron may enter the 5_3 and 6_1 orbits. The configurations $4d^2\ 6s$ and $4d^2\ 5d$ give high groups of terms of the same type and parity as those of the low configurations. In the case of the $4d^2\ 5d$ configuration all the terms will appear which have been excluded from the $4d^3$ group because of Pauli's restriction. These high terms will combine with those of the middle group, and, because of their electronic origin, will be in Rydberg sequence with corresponding terms of the low groups. The combinations between the high and middle terms will, in general yield faint lines which appear nebulous. The high terms are not easy to identify and as Table 6 shows, only a few of those theoretically possible have actually been found.

As the current electron recedes from the core of the Zr^+ ion, there comes a stage when it is completely removed and the atom is doubly ionized with its two remaining outer electrons forming the configurations $4d^2$ or $4d\ 5s$. From these arise the lowest and metastable terms of Zr III. These terms, which belong to the triplet and singlet systems, have all been found, as is shown in a previous paper by Kiess and Lang.[20] They are the limiting terms of Zr III from which

[20] B. S. Jour. Research, 5, p. 305; 1930.

the terms of Zr II may be found by adding to them the $4d$, $5s$, $5p$, $5d$, etc., electrons.

The minimum energy that the singly ionized Zr atom can absorb is represented by the transition $4d^2\,5s \longrightarrow 4d^2\,5p$. The lowest term belonging to the group arising from the $4d^2\,5p$ configuration is $z^4G°$, although the components of both $z^4F°$ and $z^2D°$ overlap it. The chief lines of the term combination a^4F–$z^4G°$, therefore, constitute not only the resonance lines of Zr II, but also the *raies ultimes*, according to the rules enunciated by Meggers, Kiess, and Walters,[21] and subsequently elaborated by Laporte and Meggers,[22] and by Russell.[23] These are the lines which were selected empirically as the *raies ultimes* by de Gramont as stated above.

In spectra resulting from systems of one or two outer electrons the coordination of term groups with electron configurations is fairly simple. The spectra of systems with three or more electrons are generally complex and the assignment of terms to their proper configurations is attended with some uncertainty. There are, however, certain guiding principles which may be of service in making the assignments. In general, a complex term will exhibit $\Delta\nu$'s of the same order of magnitude as its parent term. All the quartet terms of Zr II will arise from triplet terms of Zr III; but of the doublet terms some will arise from singlet terms and some from triplet terms of Zr III. Inspection of Table 1 shows that the $\Delta\nu$'s of the doublet terms fall into two groups, those under 467 cm^{-1}, and those over 610 cm^{-1}.

Another guide in the assignment of terms to their proper electron configurations is to be found in the multiplet intensities. Here the lack of quantitative intensity measurements for spectrum lines is felt, but for limited regions of the spectrum in which there is no very great change in the sensitivity of the photographic plate qualitative estimates prove satisfactory. The intensities of multiplets resulting from combinations between a triad of high terms and a common lower term will differ, that being strongest for which the change in the term quantum numbers, ΔL, is the same as the change Δk in the azimuthal quantum number of the current electron. For example, the triad of odd terms $z^4G°$, $z^4F°_2$ and $z^4D°$ of the $4d^2\,5p$ configuration combines with the term a^4F ($4d^2\,5s$), and also with the term b^4F ($4d^3$). In the first case the electron change is $5p \rightarrow 5s$, $\Delta k = -1$, and the multiplet $a^4F \leftarrow z^4G°$ for which $\Delta L = -1$, is strongest. In the second case the electron change is $5p \rightarrow 4d$, $\Delta k = +1$, and the multiplet $b^4F \leftarrow z^4D°$ for which $\Delta L = +1$, is strongest. This principle, due to Kronig,[24] represents an extension of Sommerfeld's qualitative intensity rule, and was first actually tested by Laporte,[25] several years ago, on the Zr II multiplets here discussed.

A check on the correctness of the term assignments is furnished by the irregular doublet law according to which the values of $\sqrt{\nu/R}$ for corresponding terms of isoelectronic systems should differ by a constant. Here ν is the distance separating a term from its limit and R is the Rydberg number. The only system isoelectronic with Zr^+ whose spectrum has been almost completely worked out is the neutral Yt atom. The analysis of Yt I is due to Meggers and Rus-

[21] J. Opt. Soc. Am. & Rev. Sci. Inst., **9**, p. 372; 1924.
[22] J. Opt. Soc. Am. & Rev. Sci. Inst., **11**, p. 460; 1925.
[23] Astrophys. J., **66** p. 212; 1927.
[24] Zeit. für Physik, **33**, p. 261; 1925.
[25] J. Opt. Soc. Am., **13**, p. 18; 1926.

sell [26] who established for it nearly all the terms required theoretically for the low and middle groups. From their work were derived the data entered in Table 7 for comparison with Zr II. The differences in the fifth column of Table 7 run as smoothly as can be expected and indicate a close parallelism between the term structures of Yt I and Zr II, although the relative importance of the corresponding terms in their respective spectra differs considerably. Thus, the lowest term of Yt I is ^{2}D coming from $4d\ 5s^2$, the configurations $4d^2\ 5s$ and $4d^3$ yielding metastable terms of less prominence. In Zr II, however, the lowest term, ^{4}F, and the more prominent metastable terms come from the configurations $4d^2\ 5s$ and $4d^3$, respectively, the term d^2D coming from $4d\ 5s^2$ being doubtful and relatively inconspicuous. And in like manner similar comparisons may be made between the odd terms of the middle groups arising from the configurations $4d\ 5s\ 5p$ and $4d^2\ 5s$, the former yielding the more prominent terms in Yt I, the latter in Zr II.

TABLE 7.—*Values of $\sqrt{\nu/R}$ for Yt I and Zr II*

Electron configuration	Term	Limit	Yt I	Δ	Zr II
$4d^2 \cdot 5s$	$^4F_{4\frac{1}{2}}$	$4d^2, {}^3F_4$	0.684	*0.333*	1.017
	$^4P_{2\frac{1}{2}}$	$4d^2, {}^3F_2$	.694	*.326*	1.020
	$^2G_{4\frac{1}{2}}$	$4d^2, {}^1G_4$	.684	*.278*	.962
	$^2F_{3\frac{1}{2}}$	$4d^2, {}^3F_4$	.655	*.338*	.993
	$^2D_{2\frac{1}{2}}$	$4d^2, {}^1D_2$	.694	*.317*	1.011
	$^2P_{1\frac{1}{2}}$	$4d^2, {}^3P_2$	.667	*.361*	1.028
$4d^2 \cdot 5p$	$^4G^0_{5\frac{1}{2}}$	$4d^2, {}^3F_4$	.549	*.325*	.874
	$^4F^0_{4\frac{1}{2}}$	$4d^2, {}^3F_4$	.529	*.340*	.869
	$^4D^0_{3\frac{1}{2}}$	$4d^2, {}^3F_4$	.516	*.347*	.863
	$^2G^0_{4\frac{1}{2}}$	$4d^2, {}^3F_4$	.515	*.336*	.851
	$^2F^0_{3\frac{1}{2}}$	$4d^2, {}^3F_4$	.513	*.363*	.876
	$^2D^0_{2\frac{1}{2}}$	$4d^2, {}^3F_4$	.511	*.362*	.873
	$^4D^0_{3\frac{1}{2}}$	$4d^2, {}^3P_2$	.539	*.336*	.875
	$^4P^0_{2\frac{1}{2}}$	$4d^2, {}^3P_2$	.529	*.344*	.873
	$^4S^0_{1\frac{1}{2}}$	$4d^2, {}^3P_2$	.536	*.341*	.877
	$^2D^0_{2\frac{1}{2}}$	$4d^2, {}^3P_2$	.501	*.398*	.899
	$^2P^0_{1\frac{1}{2}}$	$4d^2, {}^3P_2$			.886
	$^2S^0_{0\frac{1}{2}}$	$4d^2, {}^3P_2$	.555	*.337*	.892
	$^2H^0_{5\frac{1}{2}}$	$4d^2, {}^1G_4$	.539	*.279*	.818
	$^2G^0_{4\frac{1}{2}}$	$4d^2, {}^1G_4$	.533	*.293*	.826
	$^2F^0_{3\frac{1}{2}}$	$4d^2, {}^1G_4$	.495	*.348*	.843
	$^2F^0_{3\frac{1}{2}}$	$4d^2, {}^1D_2$	.535	*.287*	.822
	$^2D^0_{2\frac{1}{2}}$	$4d^2, {}^1D_2$	.543	*.283*	.826
	$^2P^0_{1\frac{1}{2}}$	$4d^2, {}^1D_2$	.538	*.319*	.857
$4d \cdot 5s \cdot 5p$	$^4F^0_{4\frac{1}{2}}$	$4d\ 5s, {}^3D_3$	.599	*.327*	.926
	$^4D^0_{3\frac{1}{2}}$	$4d\ 5s, {}^3D_3$	.592	*.326*	.918
	$^4P^0_{2\frac{1}{2}}$	$4d\ 5s, {}^3D_3$	.576	*.351*	.927
	$^2F^0_{3\frac{1}{2}}$	$4d\ 5s, {}^3D_3$	.554	*.273*	.827
	$^2D^0_{2\frac{1}{2}}$	$4d\ 5s, {}^3D_3$	.600	*.233*	.833
	$^2P^0_{1\frac{1}{2}}$	$4d\ 5s, {}^3D_3$	.532	*.272*	.804
	$^2F^0_{3\frac{1}{2}}$	$4d\ 5s, {}^1D_2$	.545	*.314*	.859
	$^2D^0_{2\frac{1}{2}}$	$4d\ 5s, {}^1D_2$	.546	*.330*	.876
	$^2P^0_{1\frac{1}{2}}$	$4d\ 5s, {}^1D_2$	.517	*.318*	.835

4. SERIES AND IONIZATION POTENTIAL

Among the terms of Table 1, there are eight sequences of two members each available for calculating series limits. Four of the term sequences arise from the migration of the *s* electron, and four from the *d* electron. Experience with other spectra shows, however, that term sequences coming from the *d* electron, when represented by a simple Rydberg formula, give results out of harmony with those for

[26] B. S. Jour. Research, **2**, p. 733; 1929.

series resulting from the *s* electron. This is accounted for theoretically by the firm binding of the lowest *d* electron in its orbit. The values derived for the series limits of Zr II, and also the value of the ionization potential of Zr^+, are based, therefore, on the series, coming from the *s* electron. The component series, however, have different limits in the low and metastable terms of Zr III. The manner in which the individual series approach their limits has been given by Hund.[27] In Table 8 results are given for 10 series which converge to the different components of ^3F, ^1G, and ^1D, respectively, of Zr III, the relative positions of which are known from the analysis of Zr III referred to above. The individual values for the separation of the lowest terms of Zr II and Zr III agree as well as can be expected from the limited data available and their mean, 113,175 cm^{-1}, is adopted as the value of $a^3F_2-a^4F_{1\frac{1}{2}}$. From this an ionization potential of 13.97 volts is derived for the ion Zr^+.

TABLE 8.—*Series limits of Zr II*

Term	$a^2D_{1\frac{1}{2}}$	$a^2D_{2\frac{1}{2}}$	$a^2F_{2\frac{1}{2}}$	$a^2F_{3\frac{1}{2}}$	$b^2G_{3\frac{1}{2}}$	$b^2G_{4\frac{1}{2}}$	$a^4F_{1\frac{1}{2}}$	$a^4F_{2\frac{1}{2}}$	$a^4F_{3\frac{1}{2}}$	$a^4F_{4\frac{1}{2}}$
Distance from limit, cm^{-1}	111, 820	111, 696	108, 528	107, 944	101, 284	101, 308	113, 460	113, 392	113, 460	113, 428
Reduction to $^3F_2$, Zr III	−3, 392	−3, 392	−682	−1, 487	−2, 534	−2, 534	0	0	−682	−1, 487
Reduction to $^4F_{1\frac{1}{2}}$, Zr II	+4, 248	+4, 505	+5, 753	+6, 468	+14,060	+14, 190	0	+315	+763	+1, 323
$a^3F_2-a^4F_{1\frac{1}{2}}$	112, 676	112, 809	113, 599	112, 925	112, 810	112, 964	113, 460	113, 707	113, 541	113, 264

Mean $(a^3F_2-a^4F_{1\frac{1}{2}})=113,175$
Ionization potential$=113,175\times1.2345\times10^{-4}=13.97v$

IV. IONIZED ZIRCONIUM IN THE SUN

Zirconium is present in the sun in both its neutral and ionized states. In the recent Revision of Rowland's Preliminary Table of Solar Spectrum Wave-Lengths [28] by St. John and his collaborators 238 dark lines are assigned to Zr^+. These include nearly all the strong lines and many of the fainter ones listed in Table 2 down to wave length 2,975 A, which marks the limit of transparency of the earth's atmosphere to solar radiation. The method used in identifying Fraunhofer lines with those of terrestrial elements was that of coincidences; that is, the direct comparison of solar wave lengths with those of emission lines observed in the laboratory. That this method of identification has its limitations is shown by the fact that of the 20,000 lines recorded by Rowland only 57 per cent have had their chemical origins assigned in the Revision of Rowland.

Perhaps the chief reason why the method of coincidences has not been more fruitful in establishing the identity of the solar lines is that most of the elements of astrophysical importance have not had their spectra measured with the same order of precision as that applied to the sun's spectrum. In the case of the fainter lines, therefore, which constitute a great majority of the 43 per cent remaining unidentified, direct comparisons of wave lengths are often uncertain and must await improved laboratory wave lengths. As stated above, however, the wave lengths entered in Table 2 are the results of new measure-

[27] Linienspektren und periodisches System der Elemente, p. 184, Julius Springer, Berlin; 1927.
[28] Carnegie Institution of Washington, Publ. No. 396; 1928.

ments made at the National Bureau of Standards in the second order of the large concave grating, and are regarded as sufficiently accurate to warrant the assignment of additional lines to the spectrum of singly ionized zirconium. The new identifications which have thus been made, by the method of coincidences, are presented in Table 9.

TABLE 9.—*Identification of Fraunhofer lines with Zr^+*

Observed		Solar			Observed		Solar		
λ	Intensity	λ	Intensity	Identification	λ	Intensity	λ	Intensity	Identification
4,841.98	0	1.975	−2		3,565.41	5	5.397	12	Fe
4,565.43	3	.427	−1		3,561.11	1	.137	−3	
4,445.88	1	.858	−2 N		3,554.09	7	.123	5	Fe
4,040.24	4	.265	−1		3,539.05	4	.077	−1	Ce^+
4,031.35	2	.345	0	Ce^+	3,514.64	4	.636	2	Fe ?
3,855.43	3	.414	1		3,512.67	3	.647	6	Co
3,800.73	5	.741	−1		3,431.57	6	.587	4	Co
3,782.24	4	.220	0	CN−	3,402.87	7	.901	0	NH
3,767.89	5	.899	−1		3,394.63	3	.612	3	Fe
3,757.80	8	.812	−1 N		3,340.55	15	.571	2	Fe
3,710.47	1	.449	−1 N		3,337.93	2	.924	0	
3,709.27	60	.257	8	Fe	3,313.70	8	.726	0	Fe
3,692.60	1	.571	−3		3,287.31	3	.335	−2	
3,667.40	1	.425	−3 N		3,157.00	10	.032	2	Fe
3,667.06	3	.098	−3*d*?		3,155.68	10	.659	3	Ti^+
3,660.92	3	.922	−3 N		3,060.11	3	.087	−1	
3,655.56	7	.581	−3		3,057.22	5	.277	−1	
3,633.49	10	.513	−1*d*?		3,030.91	10	.943	1	
3,612.34	3	.383	−3 N		2,998.49	2	.505	−1	
3,572.47	30	.479	4		2,991.40	3	.436	−2	
					2,990.10	3	.071	−1	

Another limitation to the method of coincidences, however, is the fact that not all the lines theoretically possible appear in emission spectra obtained by the ordinary methods of excitation. This is true of Zr II, as revealed by the foregoing analysis. Only a few of the multiplets have their full complement of lines; in many only those lines which represent the stronger transition probabilities are present; and in yet others no lines appear at all in the spectrum. But with a well-established set of terms based on accurate wave lengths it is possible to calculate wave lengths for lines which are missing from a spectrum though not forbidden by the selection principles. We have done this for all the multiplets of Zr II which lie in the Rowland region of the solar spectrum. The calculated wave lengths which agree with solar lines and the terms used in deriving them are presented in Table 10. It is of interest to note that the multiplets $b^4P - z^4G°$, $b^4P - z^4F°$, and $b^4F - z^2G°$ which do not appear at all in emission are represented in the solar spectrum by two or more lines.

TABLE 10.—*Identification of Fraunhofer lines with calculated lines of Zr^+*

Calculated λ	Solar			Term combination
	λ	Intensity	Identification	
6,085.98	5.921	−3		$c^2D_{2\frac{1}{2}}-z^2D^\circ_{2\frac{1}{2}}$
5,881.72	.728	−2	Fe	$b^2D_{2\frac{1}{2}}-z^2D^\circ_{2\frac{1}{2}}$
5,549.34	.332	−3		$b^4P_{2\frac{1}{2}}-z^4G^\circ_{3\frac{1}{2}}$
5,278.26	.252	−1N	Cr	$b^4P_{2\frac{1}{2}}-z^4G^\circ_{3\frac{1}{2}}$
4,989.93	.973	−2		$b^4P_{1\frac{1}{2}}-z^4F^\circ_{1\frac{1}{2}}$
4,857.07	.101	−2		$b^4P_{2\frac{1}{2}}-z^4F^\circ_{3\frac{1}{2}}$
4,794.63	.666	−3		$a^4P_{2\frac{1}{2}}-z^4G^\circ_{3\frac{1}{2}}$
4,697.80	.810	−2		$b^4P_{2\frac{1}{2}}-z^4F^\circ_{3\frac{1}{2}}$
4,050.04	.028	−1	Cr ?	$b^4F_{3\frac{1}{2}}-z^4G^\circ_{3\frac{1}{2}}$
3,748.49	.508	1	Fe	$b^4P_{2\frac{1}{2}}-y^4D^\circ_{1\frac{1}{2}}$
3,716.37	.379	−1	Ce^+	$b^4P_{2\frac{1}{2}}-y^4F^\circ_{3\frac{1}{2}}$
3,690.98	.974	−3N		$b^4P_{0\frac{1}{2}}-y^4D^\circ_{1\frac{1}{2}}$
3,675.08	.120	−3N		$b^4P_{2\frac{1}{2}}-y^4D^\circ_{2\frac{1}{2}}$
3,554.25	.278	−2		$c^2D_{2\frac{1}{2}}-x^2F^\circ_{3\frac{1}{2}}$
3,496.99	7.010	1	Zr, CN	$b^4F_{1\frac{1}{2}}-z^2D^\circ_{2\frac{1}{2}}$
3,457.79	.775	−3N		$b^2F_{3\frac{1}{2}}-w^2F^\circ_{3\frac{1}{2}}$
3,354.93	.891	−1N		$a^4F_{3\frac{1}{2}}-z^2F^\circ_{3\frac{1}{2}}$
3,287.28	.335	−2		$b^4F_{2\frac{1}{2}}-y^2D^\circ_{1\frac{1}{2}}$
3,240.85	.874	−3		$b^4F_{1\frac{1}{2}}-y^2D^\circ_{2\frac{1}{2}}$
3,205.67	.654	−2		$b^4F_{3\frac{1}{2}}-z^2G^\circ_{3\frac{1}{2}}$
3,180.96	.992	−2		$b^4F_{4\frac{1}{2}}-z^2G^\circ_{4\frac{1}{2}}$
3,120.72	.733	0	Zr	$a^2F_{2\frac{1}{2}}-y^2F^\circ_{3\frac{1}{2}}$

V. CONCLUSION AND ACKNOWLEDGMENTS

The foregoing analysis of Zr II has shown that it is possible to account for 75 per cent of the lines of this spectrum as combinations of terms which can be predicted as to number and type from modern theoretical concepts of the atom. All the terms theoretically possible for the low, metastable group have been found. All the middle group terms arising from configurations containing p electrons have also been found except the term $^2P^\circ$ coming from $5s^2\,5p$. This term, which is prominent in Yt I through its combinations with the lowest term a^2D and higher terms, would reveal its existence in Zr II only through combination with d^2D, itself uncertain. No terms of the middle group arising from the configuration $4d^2\,4f$ have been found, although in Zr III and Zr IV there are prominent terms arising from the binding of the current electron in a $4f$ orbit. If such terms exist for Zr II they would combine with the low terms coming from $4d^3$. But search through the available wave length data has failed to reveal $\Delta\nu$'s characteristic of these low terms from which the $4f$ terms must be established.

Of the high terms, which combine with those of the middle group, only a few have been established with certainty. As stated above many of the lines originating in these high terms are nebulous. It is reasonable to attribute, therefore, the remaining unclassified lines, many of which are nebulous, to combinations with unidentified high terms which are predictable. All these unclassified lines are relatively faint, and if they are the strongest members of multiplets originating in the unknown high terms, it will be almost impossible to classify them since the still fainter satellites, necessary to reveal the characteristic $\Delta\nu$'s, are missing.

As stated in the introduction the analysis of the first spark spectrum of Zr presented in this paper has been carried forward at various times during the past eight years. A similar analysis of Zr I, which we shall describe in a forthcoming paper in this journal, has been carried on at the same time. In the laborious task of making the necessary observations and calculations we have received assistance from Mrs. F. J. Stimson, and E. Z. Stowell, D. D. Laun, and Bourdon F. Scribner, former and present members of the bureau's staff. For the help they have given us we here wish to record our appreciation. We are also indebted to the late Prof. B. E. Moore, of the Brace Laboratory, University of Nebraska, for placing at our disposal not only his recent observations of the Zeeman effect of Zr, but also a set of plates obtained by him in 1907 in Göttingen; to Dr. A. S. King and Miss Edna Carter, of the Mount Wilson Observatory, who sent us copies of their furnace spectra of Zr and lists of temperature classifications in advance of publication; to Dr. K. Burns, of the Allegheny Observatory, for preliminary values of ultra-violet standard wave lengths of Fe; and finally to Prof. R. J. Lang, of the University of Alberta, who has furnished us with lists of Zr wave lengths observed by him with the vacuum spectrograph.

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