THE STRUCTURE OF THE ARC SPECTRUM OF ZIRCONIUM

By C. C. Kiess and Harriet K. Kiess

ABSTRACT

Nearly 1,600 lines have been measured in the arc spectrum of zirconium between 2,085 A in the ultra-violet and 9,300 A in the infra-red. Approximately 80 per cent of these lines, which includes all but 7 for which temperature classes have been determined, have been classified as combinations between terms of the singlet, triplet, and quintet systems. The terms, without exception, are those required by Hund's theory, and many of them have been confirmed by Zeeman effect observations. Many pairs of terms of nearly the same value, with the same inner quantum number, and arising from the same electron configuration, mutually perturb one another with the result that lines originating in them exhibit abnormal intensities and Zeeman effects. The lowest term of the spectrum, a^3F, and the lowest term of the quintet system, a^5F, both form Rydberg series with higher terms, from which the distance separating the ground states of Zr I and Zr II proves to be 56,077 cm^{-1}, giving an ionization potential of 6.92 volts for the neutral Zr atom. The resonance lines are given by the combination $a^3F-z^5G^\circ$, whereas the raies ultimes are given by $a^3F-z^3G^\circ$. More than 200 Zr lines have been identified with dark lines in the solar spectrum, of which nearly half represent term combinations which do not appear in emission spectra observed in the laboratory.

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I. INTRODUCTION

For more than a decade the spectra of zirconium, as emitted by arcs and condensed spark discharges, have been under investigation at the National Bureau of Standards not only to obtain as accurate a description of them as possible, but also for the purpose of finding the series relationships underlying their structure. Various steps in the completion of this problem have been described in three earlier papers, of which the first,[1] by one of us (C. C. K.), gives tables of wave lengths observed in the arc and spark spectra between 9,300 A and 2,100 A; the second, by Kiess and Lang,[2] describes the structure of Zr III and Zr IV; and the third,[3] by the present writers, presents

[1] B. S. Sci. Papers, No. 548, 22, p. 47; 1927.
[2] B. S. Jour. Research (RP. 202), 5, p. 305; 1930.
[3] B. S. Jour. Research (RP. 255), 5, p. 1205; 1930.

an analysis of the first spark spectrum, Zr II. In this paper we present a similar analysis of the arc spectrum, Zr I.

The work on both Zr I and Zr II was carried on at the same time, and our earliest efforts at disentangling these spectra centered about the groups of strong lines in the ultra-violet and infra-red. From these we detected the wave-number differences which are characteristic of the low ^4F term of Zr II and the low ^5F term of Zr I. However, as stated in our paper on Zr II, we laid aside the Zr problem while we endeavored to work out the structure of the titanium spectrum in which we sought a small scale pattern of the structure to be expected in Zr. That our expectation in this respect was justified has been verified by our subsequent progress with the Zr spectra; for we have, indeed, found that the spectral structures of Zr closely parallel those which our own [4] and the more complete investigation of Russell [5] have revealed in Ti.

When we resumed our work on the Zr spectra we had acquired from Dr. A. S. King, of the Mount Wilson Observatory, a set of plates copied from his furnace spectra of Zr, supplemented later with an advance copy of the temperature classifications of the Zr lines made by him and Miss Carter.[6] And from the late Prof. B. E. Moore, of the Brace Laboratory, University of Nebraska, we had obtained the films on which he had recorded the Zeeman effect of Zr out to 7,000 A in the red. With these aids we were able to identify most of the stronger lines of Zr I as members of the quintet and triplet systems.

II. EXPERIMENTAL

1. WAVE LENGTHS AND INTENSITIES

When the Zr wave-length tables, presented in the first paper referred to above, were published in 1927, it was decided to terminate the list of arc lines at approximately 4,900 A because it seemed unnecessary to duplicate Vahle's [7] excellent description of the spectrum from this point onward to the ultra-violet. However, we found it desirable to have for inspection a map of the spectrum covering the range of the published wave lengths. New observations of the arc spectrum have, therefore, been made at the National Bureau of Standards with both the concave grating and the Hilger E_1 quartz prism spectrographs. The plates secured with the prism spectrograph cover the region from 2,000 to 3,050 A. The first order of the grating, with a dispersion of 3.7 A per mm. was used for the region from 2,200 to 2,900 A. For the region 2,900 to 4,900 A the second order of the grating was employed giving a dispersion of 1.8 A per mm. At least two plates of each region were secured. The material used as electrodes in the arcs was metallic Zr obtained from three different sources. Although these samples are of high purity from the chemical point of view yet they were found to contain traces of other elements, of which the more conspicuous are Fe, Ti, and Si. Each of them contains traces of Hf also; and, in addition, the sample used for the ultra-violet observations with the prism spectrograph contains traces of Ni, Cb, Al, Pb, and Sn.

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[4] J. Opt. Soc. Am. & Rev. Sci. Inst., 8, p. 607; 1924.
[5] Astrophys. J., 66, pp. 283 and 347; 1927.
[6] Astrophys. J., 65, p. 86; 1927.
[7] Zeit. für Wiss. Phot., 18, p. 84; 1918.

Most of these newer spectrograms have been measured for wave-length determinations and intensity estimates, since it was noted that many of Vahle's faintest lines appear on our plates with increased strength. The wave lengths and intensities which appear in Table 3, therefore, are derived entirely from measurements made at the National Bureau of Standards. The compilation of these wave lengths afforded opportunity to revise the earlier tabulation of the spectrum in the range from 4,900 to 9,300 A and, accordingly, in the list as presented in this paper, a few lines have been added, but others have been omitted as not belonging to Zr I. We believe that the wave lengths as given in Table 3 are characteristic of the arc spectrum of zirconium, but the possibility of eliminating other lines from the list, especially in the ultra-violet where most of the unclassified lines of Zr I occur, is recognized. At the present time, however, it is not possible to make thorough comparisons with other elements owing to the inadequate descriptions of their spectra.

2. ZEEMAN EFFECTS

When Landé's quantum theoretical interpretation of the anomalous Zeeman effect [8] was published we found Moore's [9] observations of Zr of great service not only in confirming the classifications of Zr I lines we had already made, but in leading to the classification of additional lines. However, only a few of Moore's observations referred to lines of wave length longer than 4,900 A. When his attention was directed to the fact that the arc spectrum of Zr contains many strong lines in the red and near infra-red he generously offered, as stated above, to secure additional observations for our investigation with the equipment of the Brace Laboratory. These observations and the results obtained from them have been described in our paper on Zr II cited above, and to which the reader is referred for the details. Here also will be found a description of our preliminary observations of the Zeeman effect of Zr obtained with the magnet and spectrographs at the National Bureau of Standards.

III. STRUCTURE OF THE ARC SPECTRUM

1. THE TERM SYSTEMS

The terms on which the arc spectrum of Zr is built belong to the singlet, triplet, and quintet systems. Of these, the quintet system is simplest, having as its lowest term a^5F, with the characteristic $\Delta\nu$'s 348.4, 291.5, 225.7, 152.9. It was these wave-number differences that were found first, separating the strong infra-red lines in the group lying between 7,849 and 8,498 A, and also those in the blue-green group containing the lines which de Gramont [10] has described as specially sensitive for visual spectrochemical analysis. After the stronger lines, which were linked by these $\Delta\nu$'s had been assigned to multiplets, several fragmentary groups remained which were suspected as intersystem combinations with triplet terms. This view proved to be correct, and led to the identification of the low and metastable terms of the triplet system. The triplet system

[8] Zeit. für Physik, **15**, p. 189; 1923.
[9] Astrophys. J., **28**, p. 15; 1908.
[10] Compt. Rend., **166**, p. 367; 1918.

is by far the most complex and contains more observed terms than the singlet and quintet systems combined. Although the singlet system is much less complex than the triplet system, yet it proved to be the most difficult to unravel owing to the lack of term combinations with distinctive wave-number differences and the uniform character of the Zeeman effects.

The terms which have been established for Zr I are presented in Tables 1 and 2. The relative positions of these terms are shown in Figures 1, 2, and 3, the black dots representing the even terms of Table 1 and the open circles the odd terms of Table 2. The combinations between the terms, which are usually shown in diagrams of this kind, are omitted because of the confusion that would result

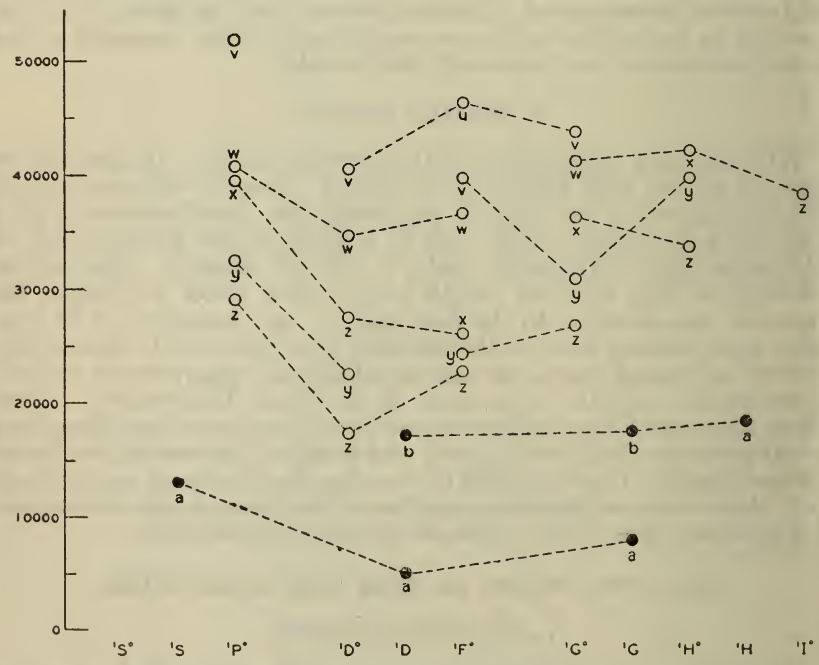

FIGURE 1.—*Term diagram of the singlet system of Zr I*

from drawing in so many lines. The visual representation of the term combinations is supplied to some extent, however, by Table 4, which contains the key numbers of the classified lines of Table 3 and shows at a glance all the combinations which occur. It is of interest to note that there are about 20 combinations between terms of the singlet and quintet systems. An explanation of their appearance in the spectrum is offered in a subsequent paragraph. The symbols used in defining the terms are those proposed in the report of Russell, Shenstone, and Turner. [11]

All the quintet terms and most of those of the triplet system are regular. The triplet terms that depart from regularity show only partial inversion. The most conspicuous of these is a^3P, of which

[11] Phys. Rev., **33**, p. 900; 1929.

the component a^3P_2 lies 10.7 cm^{-1} below a^3P_0. It exhibits a close affinity with the lowest term of the singlet system, a^1D_2, the mean of their term values being very nearly that which a^3P_2 would have if it occupied its normal position as determined by the interval rule. These two terms are almost identical in their behavior, with the result that many combinations into which they enter show abnormal intensities and Zeeman effects. The properties of these terms in the magnetic field will be discussed in a subsequent paragraph. Other terms which are partially inverted are c^3P, $z^3I°$, $x^3H°$, $y^3F°$, $t^3D°$, $z^3P°$, and $y^3P°$. With these may be included such terms as a^3G, $x^3G°$, $v^3G°$, $u^3F°$, $v^3D°$, etc., which show marked deviations from the interval

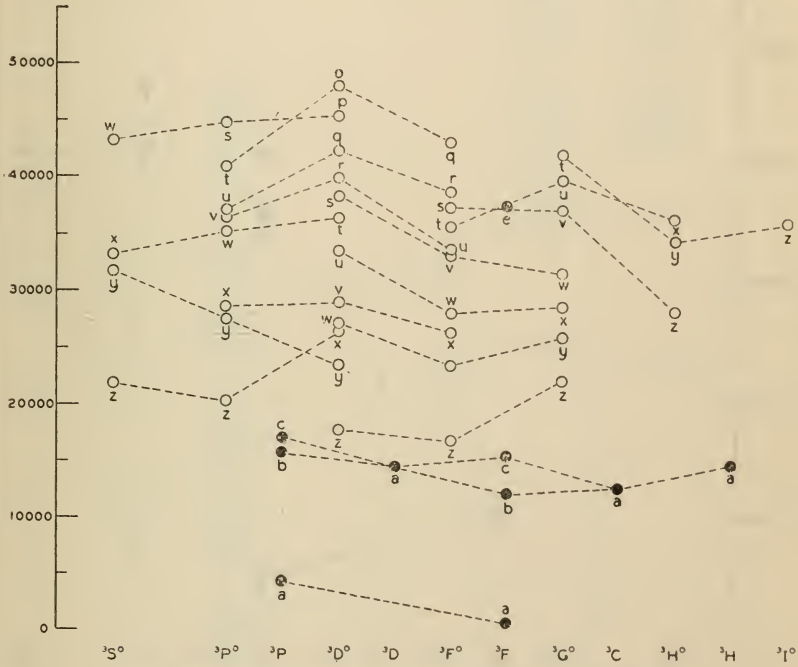

FIGURE 2.—*Term diagram of the triplet system of Zr I*

rule. In fact, very few of the complex terms of Zr I have separations which follow the interval rule closely.

Of the nearly 1,600 lines recorded in Table 3 approximately 80 per cent have been classified as combinations between the terms of Tables 1 and 2. Each classified line is provided with a key number giving the number of the multiplet of which it is a member. For comparison with our intensity estimates we give those of King and Miss Carter, and also their temperature classifications. Inspection of the table shows that all but seven of the lines observed in the furnace spectra have been classified. The lowest term, a^3F, and the two related terms, a^3P and a^1D, each enter into combination with about 60 of the 80 odd terms comprising the middle group, while a^5F combines with 40 of them. These combinations account for nearly all of the strong arc lines of Temperature Classes I and II.

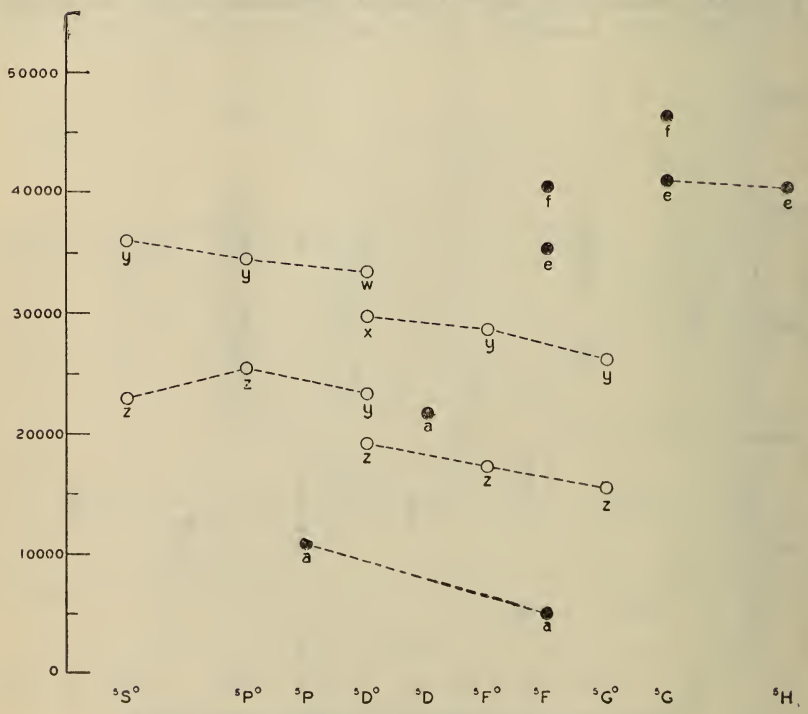

FIGURE 3.—*Term diagram of the quintet system of Zr I*

TABLE 1.—*Even terms of Zr I*

Term	a	b	c	e	f
$^5H_7$				42,086.82	
				643.29	
$^5H_6$				41,443.53	
				806.48	
$^5H_5$				40,637.05	
				700.35	
$^5H_4$				39,936.70	
$^5H_3$				?	
$^5G_6$				41,940.86	47,698.29
				402.63	*563.79*
$^5G_5$				41,538.23	47,134.50
				358.93	*493.08*
$^5G_4$				41,179.30	46,641.42
				291.69	*446.27*
$^5G_3$				40,887.61	46,195.15
				226.96	*396.67*
$^5G_2$				40,660.65	45,798.48
$^5F_5$	5,888.93			36,360.20	41,068.00
	348.39			*499.37*	*218.30*
$^5F_4$	5,540.54			35,860.83	40,849.70
	291.47			*384.76*	*196.29*
$^5F_3$	5,249.07			35,476.07	40,653.41
	225.66			*265.77*	
$^5F_2$	5,023.41			35,210.30	?
	152.88			*163.35*	
$^5F_1$	4,870.53			35,046.95	?
$^5D_4$	22,398.00				
	252.69				
$^5D_3$	22,145.31				
	201.57				
$^5D_2$	21,943.74				
	142.53				
$^5D_1$	21,801.21				
	74.93				
$^5D_0$	21,726.28				
$^5P_3$	11,258.38				
	241.73				
$^5P_2$	11,016.65				
	131.29				
$^5P_1$	10,885.36				
$^3H_6$	15,119.66				
	131.15				
$^3H_5$	14,988.51				
	197.23				
$^3H_4$	14,791.28				
$^3G_5$	12,772.78				
	12.12				
$^3G_4$	12,760.66				
	257.22				
$^3G_3$	12,503.44				
$^3F_4$	1,240.84	12,342.37	15,699.86	38,101.09	
	670.43	*386.04*	*242.46*	*400.01*	
$^3F_3$	570.41	11,956.33	15,457.40	37,701.08	
	570.41	*315.61*	*310.92*	*241.48*	
$^3F_2$	0.00	11,640.72	15,146.48	37,459.60	
$^3D_3$	14,697.03				
	348.25				
$^3D_2$	14,348.78				
	225.77				
$^3D_1$	14,123.01				
$^3P_2$	4,186.11	15,932.10	17,142.72		
	−190.17		*82.90*		
$^3P_1$	4,376.28	?	17,059.82		
	179.43		*−261.70*		
$^3P_0$	4,196.85	?	17,321.52		
$^1H_5$	18,738.94				
$^1G_4$	8,057.30	17,752.73			
$^1F_3$	?				
$^1D_2$	5,101.68	17,228.42			
$^1P_1$	?				
$^1S_0$	13,141.76				

TABLE 2.—*Odd terms of Zr I*

Term	z	y	x	w	v	u	t	s	r	q	p	o
$^5G^\circ_6$	16,978.29	27,214.89										
	661.33	*449.23*										
$^5G^\circ_5$	16,316.96	26,765.66										
	596.60	*423.13*										
$^5G^\circ_4$	15,720.36	26,342.53										
	519.10	*370.82*										
$^5G^\circ_3$	15,201.26	25,971.71										
	417.72	*341.23*										
$^5G^\circ_2$	14,783.54	25,630.48										
$^5F^\circ_5$	18,276.92	29,535.48										
	444.19	*412.77*										
$^5F^\circ_4$	17,832.73	29,122.71										
	410.56	*304.69*										
$^5F^\circ_3$	17,422.17	28,818.02										
	362.56	*222.99*										
$^5F^\circ_2$	17,059.61	28,595.03										
	272.68	*148.11*										
$^5F^\circ_1$	16,786.93	28,446.92										
$^5D^\circ_4$	19,833.78	24,376.37	30,384.50	34,287.49								
	208.20	*487.34*	*297.17*	*375.40*								
$^5D^\circ_3$	19,625.58	23,889.03	30,087.33	33,912.09								
	301.74	*399.60*	*239.84*	*279.61*								
$^5D^\circ_2$	19,323.84	23,489.43	29,847.49	33,632.48								
	227.31	*243.10*	*170.35*	*187.61*								
$^5D^\circ_1$	19,096.53	23,246.33	29,677.14	33,444.87								
	120.17	*124.04*	*89.07*	*95.31*								
$^5D^\circ_0$	18,976.36	23,122.29	29,588.07	33,349.56								
$^5P^\circ_3$	25,898.16	35,090.90										
	252.19	*329.38*										
$^5P^\circ_2$	25,645.97	34,761.52										
	156.10	*144.52*										
$^5P^\circ_1$	25,489.87	34,617.00										
$^3S^\circ_1$	23,085.06	35,990.21										
$^3I^\circ_7$	36,152.85											
	−20.18											
$^3I^\circ_6$	36,173.03											
	391.36											
$^3I^\circ_5$	35,781.67											

$^{2}H_{6}^{6}$	28,608.62	35,135.07	36,840.59									
	396.80	*429.17*	*243.11*									
$^{3}H_{5}^{5}$	28,211.82	34,705.90	36,597.48									
	303.54	*255.30*	*−10.93*									
$^{3}H_{4}^{4}$	27,908.28	34,450.60	36,608.41									
$^{3}G_{5}^{5}$	22,563.89	26,433.72	29,001.65	32,152.16	37,422.36	40,178.44	42,834.96					
	419.81	*422.17*	*251.85*	*457.64*	*192.82*	*244.30*	*562.55*					
$^{3}G_{4}^{4}$	22,144.08	26,011.55	28,749.80	31,694.52	37,229.54	39,934.14	42,272.41					
	294.75	*281.59*	*345.54*	*367.71*	*287.89*	*544.85*	*169.85*					
$^{3}G_{3}^{3}$	21,849.33	25,729.96	28,404.26	31,326.81	36,941.65	39,389.29	42,102.56					
$^{3}F_{4}^{4}$	17,556.26	24,006.30	26,938.42	28,528.36	33,688.23	33,559.34	36,001.35	37,920.96	39,174.44	43,276.00		
	712.83	*439.18*	*494.54*	*370.94*	*496.37*	*138.87*	*195.72*	*452.09*	*292.64*	*7.76*		
$^{3}F_{3}^{3}$	16,843.93	23,567.12	26,443.88	28,157.42	33,191.86	33,420.47	35,805.63	37,468.87	38,881.80	43,268.24		
	547.42	*−30.35*	*382.18*	*281.26*	*219.56*	*256.49*	*291.10*	*345.45*	*315.80*	*562.24*		
$^{3}F_{2}^{2}$	16,296.51	23,597.47	26,061.70	27,876.16	32,972.30	33,163.98	35,514.53	37,123.42	38,566.00	42,706.00		
$^{3}D_{3}^{3}$	18,243.56	23,660.97	27,111.16	27,482.26	29,274.82	34,239.82	36,220.45	38,435.88	40,346.35	42,799.20	45,710.29	48,713.44
	429.92	*341.11*	*553.95*	*360.30*	*216.98*	*475.70*	*−74.42*	*109.16*	*579.88*	*365.55*	*122.67*	*579.80*
$^{3}D_{2}^{2}$	17,813.64	23,319.86	26,557.21	27,121.96	29,057.84	33,764.12	36,294.87	38,326.72	39,766.47	42,433.65	45,587.62	48,133.64
	383.78	*300.94*	*403.08*	*219.51*	*257.33*	*277.30*	*169.71*	*55.91*		*136.85*	*182.32*	*368.08*
$^{3}D_{1}^{1}$	17,429.86	23,018.92	26,154.13	26,902.45	28,800.51	33,486.82	36,125.16	38,270.81	?	42,296.80	45,405.30	47,765.56
$^{3}P_{2}^{2}$	20,466.83	27,673.35	28,909.57	35,456.25	37,008.40	37,450.23	41,787.62	45,017.13				
	−52.37	*100.83*	*199.69*	*250.73*	*519.30*	*479.58*	*813.68*	*134.83*				
$^{3}P_{1}^{1}$	20,519.20	27,572.52	28,709.88	35,205.52	36,489.10	36,970.65	40,973.94	44,882.30				
	285.23	*−27.72*	*77.13*		*454.56*	*432.58*	*437.56*					
$^{3}P_{0}^{0}$	20,233.97	27,600.24	28,632.75	?	36,034.54	36,538.27	40,536.38	?				
$^{3}S_{1}^{1}$	21,974.18	31,850.77	33,113.80	43,182.96								
$^{1}I_{6}^{6}$	38,475.82											
$^{1}H_{5}^{5}$	33,839.20	39,855.22	42,309.29									
$^{1}G_{4}^{4}$	26,931.35	31,050.48	36,336.48	41,319.96								
$^{1}F_{3}^{3}$	22,862.02	24,387.52	26,226.97	36,759.90	39,803.73	46,328.16						
$^{1}D_{2}^{2}$	17,511.78	22,750.53	27,515.38	34,850.96	40,557.65							
$^{1}P_{1}^{1}$	28,999.46	32,722.80	39,704.10	40,931.60	51,899.40							
$^{1}S_{0}^{0}$	?											

TABLE 3.—*Wave lengths in the arc spectrum of Zr*

Key No.	λ I. A.	Intensities, temperature class, and notes		Wave No.	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
		B. S.	King				
1	9, 276. 94	1		10, 776. 46	$a^5F_4-z^5G^\circ_5$		
2	9, 139. 33	1		10, 938. 72	$a^3H_4-y^3G^\circ_3$		
3	9, 099. 90	0		10, 986. 12	$a^3G_3-y^5D^\circ_2$		
2	9, 069. 40	2		11, 023. 06	$a^3H_5-y^3G^\circ_4$		
1	9, 015. 13	5		11, 089. 43	$a^5F_5-z^5G^\circ_6$		
4	9, 011. 31	1		11, 094. 12	$a^3G_3-y^3F^\circ_2$		
5	8, 941. 74	1		11, 180. 45	$a^3H_4-y^5G^\circ_3$		
6	8, 930. 10	1		11, 195. 01	$a^1D_2-z^3F^\circ_2$		
7	8, 925. 04	1		11, 201. 36	$a^3D_3-z^5P^\circ_3$		
2	8, 910. 05	1		11, 220. 20	$a^3H_4-y^3G^\circ_4$		
8	8, 906. 33	1		11, 224. 89	$b^3F_4-y^3F^\circ_3$		
4	8, 899. 52	6		11, 233. 48	$a^3G_5-y^3F^\circ_4$		
	8, 894. 01	0		11, 240. 44			
9	8, 844. 50	0		11, 303. 36	$a^5F_4-z^3F^\circ_3$		
2	8, 836. 09	8		11, 314. 12	$a^3H_6-y^3G^\circ_5$		
5	8, 804. 98	3		11, 354. 06	$a^3H_5-y^5G^\circ_4$		
10	8, 786. 23	2		11, 378. 32	$b^3F_2-y^3D^\circ_1$		
11	8, 778. 48	0		11, 388. 37	$c^3P_0-x^3P^\circ_1$		
	8, 771. 02	0		11, 398. 05			
	8, 762. 93	1		11, 408. 58			
9	8, 749. 48	5		11, 426. 12	$a^5F_1-z^3F^\circ_2$		
12	8, 742. 11	1		11, 435. 75	$a^3H_4-x^1F^\circ_3$		
2	8, 734. 86	4		11, 445. 24	$a^3H_5-y^3G^\circ_5$		
13	8, 709. 24	1		11, 478. 91	$c^3P_0-v^3D^\circ_1$		
7	8, 656. 04	0		11, 549. 35	$a^3D_2-z^5P^\circ_3$		
18					$y^3D^\circ_3-e^5F_2$		
5	8, 654. 59	0		11, 551. 39	$a^3H_4-y^5G^\circ_4$		
11	8, 642. 76	2		11, 567. 20	$c^3P_2-x^3P^\circ_1$		
	8, 641. 01	3		11, 569. 55			
11	8, 638. 51	1		11, 572. 90	$c^3P_1-x^3P^\circ_0$		
14	8, 627. 71	1		11, 587. 38	$y^5D^\circ_3-e^5F_3$		
3	8, 615. 66	1		11, 603. 58	$a^3G_5-y^5D^\circ_2$		
15	8, 614. 16	0		11, 605. 61	$b^3F_2-y^5D^\circ_1$		
8	8, 610. 24	2		11, 610. 89	$b^3F_3-y^3F^\circ_3$		
8	8, 587. 84	4		11, 641. 17	$b^3F_3-y^3F^\circ_2$		
17	8, 585. 90	0		11, 643. 81	$a^5D_1-w^5D^\circ_1$		
5	8, 584. 21	6		11, 646. 10	$a^3H_6-y^5G^\circ_5$		
11	8, 581. 22	1		11, 650. 16	$c^3P_1-x^3P^\circ_1$		
16	8, 579. 47	1		11, 652. 53	$a^3H_4-x^3F^\circ_3$		
13	8, 575. 69	1		11, 657. 67	$c^3P_2-v^3D^\circ_1$		
8	8, 571. 05	4		11, 663. 98	$b^3F_4-y^3F^\circ_4$		
9	8, 568. 54	4		11, 667. 40	$a^5F_5-z^3F^\circ_4$		
19	8, 558. 64	2		11, 680. 90	$b^1D_2-x^3P^\circ_2$		
	8, 554. 42	2		11, 686. 66			
	8, 536. 22	1		11, 711. 57			
20	8, 535. 13	1		11, 713. 07	$a^3D_2-x^3F^\circ_2$		
18	8, 524. 99	1		11, 727. 00	$y^3D^\circ_2-e^5F_1$		
13	8, 515. 06	3		11, 740. 68	$c^3P_1-v^3D^\circ_1$		
6	8, 513. 78	3		11, 742. 44	$a^1D_2-z^3F^\circ_3$		
20	8, 510. 38	1		11, 747. 13	$a^3D_3-x^3F^\circ_3$		
	8, 502. 77	2		11, 757. 65			
21	8, 498. 44	10		11, 763. 64	$a^5F_2-z^5F^\circ_1$		
11	8, 495. 98	4		11, 767. 04	$c^3P_2-x^3P^\circ_2$		
21	8, 464. 65	10		11, 810. 59	$a^5F_3-z^5F^\circ_2$		
9	8, 457. 50	4		11, 820. 58	$a^5F_2-z^3F^\circ_3$		
22	8, 453. 17	10		11, 826. 63	$a^5P_3-z^5S^\circ_2$		
23	8, 429. 14	0		11, 860. 35	$a^3D_3-x^3D^\circ_2$		
24	8, 416. 91	1		11, 877. 59	$a^3D_2-x^1F^\circ_3$		
21	8, 414. 00	7		11, 881. 69	$a^5F_4-z^5F^\circ_5$		
17	8, 408. 50	1		11, 889. 47	$a^5D_4-w^5D^\circ_4$		
13	8, 390. 18	2		11, 915. 43	$c^3P_2-v^3D^\circ_2$		
21	8, 389. 42	8		11, 916. 50	$a^5F_1-z^5F^\circ_1$		
25	8, 386. 70	3		11, 920. 37	$a^3P_1-z^3F^\circ_2$		
8	8, 382. 79	1		11, 925. 93	$b^3F_2-y^3F^\circ_3$		
21	8, 370. 21	10		11, 943. 85	$a^5F_5-z^5F^\circ_4$		
16	8, 365. 98	2		11, 949. 86	$a^3H_5-x^3F^\circ_4$		

TABLE 3.—*Wave lengths in the arc spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities, temperature class, and notes		Wave No.	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
		B. S.	King				
8	8,361.17	2		11,956.77	$b^3F_2-y^3F_3^\circ$		
26	8,360.17	0		11,958.20	$a^1D_2-z^5F_2^\circ$		
14	8,350.45	0		11,972.12	$y^5D_3^\circ-e^5F_4$		
	8,345.99	0		11,978.52			
14	8,342.10	0		11,984.10	$y^5D_4^\circ-e^5F_5$		
13	8,332.44	6		11,997.99	$c^3P_1-v^3D_2^\circ$		
	8,328.54	1		12,003.61			
9	8,320.12	5		12,015.76	$a^5F_4-z^3F_4^\circ$		
10	8,316.97	1		12,020.31	$b^3F_2-y^3D_3^\circ$		
23	8,309.50	4		12,031.11	$a^3D_1-x^3D_1^\circ$		
21	8,305.94	15	8, III	12,036.27	$a^5F_2-z^5F_2^\circ$		
27	8,299.79	4		12,045.19	$b^3F_4-y^1F_3^\circ$		
8	8,296.54	2		12,049.91	$b^3F_3-y^3F_4^\circ$		
22	8,283.84	10		12,068.38	$a^5P_2-z^5S_2^\circ$		
13	8,240.36	8		12,132.06	$c^2P_2-v^3D_3^\circ$		
21	8,212.59	18	10, III	12,173.07	$a^5F_3-z^5F_3^\circ$		
21	8,201.73	10		12,189.20	$a^5F_1-z^5F_2^\circ$		
18	8,194.64	6	20, V	12,199.75	$y^3D_3^\circ-e^5F_4$		
22					$a^5P_1-z^5S_2^\circ$		
23	8,188.76	3		12,208.51	$a^3D_2-x^3D_2^\circ$		
28	8,174.63	1		12,229.61	$a^5P_2-y^5D_1^\circ$		
28	8,169.72	2		12,236.96	$a^5P_1-y^5D_0^\circ$		
29	8,152.59	4		12,262.67	$a^5F_3-z^1D_2^\circ$		
21	8,133.00	20	15, III	12,292.21	$a^5F_4-z^5F_4^\circ$		
30	8,125.84	1		12,303.04	$a^5P_2-y^3D_2^\circ$		
31	8,120.15	6		12,311.66	$a^1H_5-y^1G_4^\circ$		
26	8,114.29	4		12,320.55	$a^1D_2-z^3F_3^\circ$		
32	8,109.23	2		12,328.24	$a^1D_2-z^3D_1^\circ$		
	8,107.5*u*	1		12,330.87			
28	8,087.79	2		12,360.92	$a^5P_1-y^5D_1^\circ$		
21	8,070.12	25	20, III	12,387.99	$a^5F_5-z^5F_5^\circ$		
21	8,063.10	10	3, V	12,398.77	$a^5F_2-z^5F_3^\circ$		
33	8,058.14	7		12,406.41	$a^5F_2-z^3D_1^\circ$		
34	8,055.73	5		12,410.12	$a^1D_2-z^1D_2^\circ$		
35	8,055.32	4		12,410.75	$a^3P_1-z^5F_1^\circ$		
23	8,053.08	4		12,414.20	$a^3D_3-x^3D_3^\circ$		
36	8,046.08	1		12,425.00	$a^3D_3-w^3D_2^\circ$		
23	8,040.12	2		12,434.21	$a^3D_1-x^3D_2^\circ$		
28	8,015.22	3		12,472.84	$a^5P_2-y^5D_3^\circ$		
29	8,005.28	5		12,488.33	$a^5F_2-z^1D_2^\circ$		
36	7,963.69	5		12,553.54	$a^3D_2-w^3D_1^\circ$		
33	7,960.01	7	2, V	12,559.35	$a^5F_1-z^3D_1^\circ$		
33	7,956.69	7	2, IV	12,564.59	$a^5F_3-z^3D_2^\circ$		
21	7,944.65	15	6, V	12,583.63	$a^5F_3-z^5F_4^\circ$		
35	7,940.46	5		12,590.27	$a^3P_0-z^5F_1^\circ$		
28	7,931.76	3		12,604.08	$a^5P_1-y^5D_2^\circ$		
37	7,924.17	3		12,616.15	$a^5D_3-y^5P_2^\circ$		
28	7,915.17	3		12,630.50	$a^5P_3-y^5D_3^\circ$		
29	7,908.46	6		12,641.21	$a^5F_1-z^1D_2^\circ$		
30	7,906.55	2		12,644.27	$a^5P_2-y^3D_3^\circ$		
25	7,897.98	5		12,657.99	$a^3P_2-z^3F_3^\circ$		
37	7,888.52	3		12,673.17	$a^5D_2-y^5P_1^\circ$		
35	7,882.15	6		12,683.41	$a^3P_1-z^5F_2^\circ$		
37	7,876.24	6		12,692.93	$a^5D_4-y^5P_3^\circ$		
33	7,870.00	12	4, III	12,702.99	$a^5F_4-z^3D_3^\circ$		
38	7,868.34	3		12,705.67	$a^5D_3-w^1D_2^\circ$		
39	7,864.37	3		12,712.08	$a^5P_1-y^3F_2^\circ$		
32					$a^1D_2-z^3D_2^\circ$		
21	7,849.38	15	5, III	12,736.35	$a^5F_4-z^5F_5^\circ$		
27	7,842.93	2		12,746.84	$b^3F_2-y^1F_3^\circ$		
23	7,833.36	2		12,762.41	$a^3D_2-x^3D_3^\circ$		
36	7,826.75	9	2, V	12,773.19	$a^3D_2-w^3D_2^\circ$		
36	7,822.96	8	2, V	12,779.37	$a^3D_1-w^3D_1^\circ$		
36	7,819.36	15	5, V	12,785.26	$a^3D_3-w^3D_3^\circ$		
33	7,816.31	5		12,790.25	$a^5F_2-z^3D_2^\circ$		

TABLE 3.—*Wave lengths in the arc spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities, temperature class, and notes		Wave No.	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
		B. S.	King				
37	7,800.73	4		12,815.79	$a^5D_1-y^5P^\circ_1$		
37	7,799.51	2		12,817.80	$a^5D_2-y^5P^\circ_2$		
28	7,766.54	5		12,872.21	$a^5P_2-y^5D^\circ_3$		
35	7,765.67	4		12,873.65	$a^3P_2-z^5F^\circ_2$		
37	7,755.39	2		12,890.72	$a^5D_0-y^5P^\circ_1$		
38	7,745.43	2		12,907.29	$a^5D_2-w^1D^\circ_2$		
	7,744.05	2		12,909.59			
33	7,723.70	5		12,943.60	$a^5F_1-z^3D^\circ_2$		
37	7,722.48	4		12,945.65	$a^5D_3-y^5P^\circ_3$		
40	7,721.72	1		12,946.92	$c^3F_3-x^3G^\circ_3$		
41	7,708.38	6		12,969.33	$a^3G_4-y^3G^\circ_3$		
42	7,704.24	7		12,976.30	$a^3D_3-y^3P^\circ_2$		
33	7,693.45	2		12,994.50	$a^5F_3-z^3D^\circ_3$		
36	7,690.81	7	1, V	12,998.96	$a^3D_1-w^3D^\circ_2$		
40	7,660.75	1		13,049.97	$c^3F_4-x^3G^\circ_4$		
43	7,658.62	8	3, IV	13,053.60	$a^3P_1-z^3D^\circ_1$		
	7,654.40	2		13,060.79			
	7,650.50	1		13,067.45			
	7,646.71	2		13,073.93			
44	7,621.60	3		13,117.00	$a^3H_4-z^3H^\circ_4$		
28	7,621.16	7	1, V	13,117.76	$a^5P_3-y^5D^\circ_4$		
45	7,615.74	4		13,127.09	$a^3G_3-y^5G^\circ_2$		
46	7,614.48	2		13,129.27	$a^5P_3-y^1F^\circ_3$		
36	7,612.08	7		13,133.40	$a^3D_2-w^3D^\circ_3$		
47	7,610.89	5		13,135.45	$a^3P_1-z^1D^\circ_2$		
48	7,609.69	3		13,137.53	$a^3G_4-z^5P^\circ_3$		
32	7,607.19	15	8, III	13,141.85	$a^1D_2-z^3D^\circ_3$		
33	7,562.17	6		13,219.91	$a^5F_2-z^3D^\circ_3$		
44	7,560.31	4		13,223.33	$a^3H_5-z^3H^\circ_5$		
42	7,560.04	5		13,223.80	$a^3D_2-y^3P^\circ_1$		
41	7,558.47	9	2, V	13,226.55	$a^3G_3-y^3G^\circ_3$		
43	7,554.73	10	5, III	13,233.10	$a^3P_0-z^3D^\circ_1$		
49, 35	7,552.99	5		13,236.15	$z^3S^\circ_1-e^5F_2$; $a^3P_2-z^5F^\circ_3$		
41	7,551.50	10	2, V	13,238.76	$a^3G_5-y^3G^\circ_4$		
41	7,544.62	8	1, V	13,250.83	$a^3G_4-y^3G^\circ_4$		
40	7,540.65	8	1, V	13,257.82	$c^3F_2-x^3G^\circ_3$		
40	7,521.03	6		13,292.40	$c^3F_3-x^3G^\circ_4$		
	7,519.34	2		13,295.38			
50	7,517.97	6		13,297.81	$b^1G_4-y^1G^\circ_4$		
40	7,515.74	8	1, V	13,301.75	$c^3F_4-x^3G^\circ_5$		
	7,506.56	6		13,318.02			
42	7,502.91	6	1, V	13,324.49	$a^3D_2-y^3P^\circ_2$		
47	7,502.25	1		13,325.68	$a^3P_2-z^1D^\circ_2$		
51	7,479.61	8		13,366.00	$a^3H_4-w^3F^\circ_3$		
52	7,467.57	8	1, V?	13,387.56	$b^3F_4-y^3G^\circ_3$		
43	7,439.89	20	10, III	13,437.36	$a^3P_1-z^3D^\circ_2$		
42	7,433.12	6		13,449.60	$a^3D_1-y^3P^\circ_1$		
53	7,423.83	2		13,466.44	$a^3G_4-x^1F^\circ_3$		
45	7,422.77	6		13,468.35	$a^3G_3-y^3G^\circ_3$		
42	7,417.91	5		13,477.18	$a^3D_1-y^3P^\circ_0$		
	7,414.24	1		13,483.85			
44	7,411.42	4		13,488.98	$a^3H_6-z^3H^\circ_6$		
41	7,400.89	6	tr, V	13,508.17	$a^3G_3-y^3G^\circ_4$		
	7,399.33	4		13,511.02			
51	7,383.64	7	1, V	13,539.73	$a^3H_5-w^3F^\circ_4$		
	7,379.19	1		13,547.90			
42	7,377.85	1		13,550.35	$a^3D_1-y^3P^\circ_2$		
54	7,374.80	3		13,555.96	$b^3F_4-z^5P^\circ_3$		
55	7,373.51	6	1, V	13,558.33	$a^3G_3-x^3F^\circ_4$		
45	7,367.22	3		13,569.91	$a^3G_5-y^5G^\circ_4$		
45	7,360.66	2		13,582.01	$a^3G_4-y^5G^\circ_4$		
	7,358.60	1		13,585.80			
	7,353.34	1		13,595.52			
56	7,343.98	8	4, III	13,612.85	$a^3H_4-x^3G^\circ_3$		

TABLE 3.—*Wave lengths in the arc spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities, temperature class, and notes		Wave No.	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
		B. S.	King				
44	7,340.03	1		13,620.18	$a^3H_5-z^3H^\circ_6$		
43	7,336.03	8	*4, II	13,627.60	$a^3P_2-z^3D^\circ_2$		
	7,332.73	1		13,633.74			
	7,327.84	4		13,642.83			
	7,323.75	2		13,650.45			
41	7,318.15	9	8, III	13,660.90	$a^3G_5-y^3G^\circ_5$		
	7,317.32	2		13,662.45			
52	7,313.73	7	2, V	13,669.15	$b^3F_4-y^3G^\circ_4$		
41	7,311.68	7	2, V	13,672.99	$a^3G_4-y^3G^\circ_5$		
	7,307.38	3		13,681.03			
55	7,306.24	5	1, V	13,683.17	$a^3G_4-x^3F^\circ_3$		
53	7,284.76	3		13,723.51	$a^3G_3-x^1F^\circ_3$		
	7,284.02	2		13,724.91			
56	7,264.79	8	4, V	13,761.24	$a^3H_5-x^3G^\circ_4$		
52	7,258.23	5		13,773.67	$b^3F_3-y^3G^\circ_3$		
57	7,248.50	3		13,792.16	$a^1G_4-z^3G^\circ_3$		
45	7,223.87	2		13,839.19	$a^3G_3-y^5G^\circ_4$		
56	7,201.67	8	4, V	13,881.85	$a^3H_6-x^3G^\circ_5$		
58	7,193.37	3		13,897.87	$a^3D_3-y^5F^\circ_2$		
	7,179.59	3		13,924.54			
	7,177.26	2		13,929.05			
59	7,169.14	40	150, II	13,944.84	$a^5F_5-z^5D^\circ_4$	(0.60) 1.16	(**0.00**, 0.10, 0.20, ---) **1.00**, 1.10, 1.20, ---
56	7,162.12	2		13,958.51	$a^3H_4-x^3G^\circ_4$		
60	7,161.02	2		13,960.65	$a^3F_4-z^5G^\circ_5$		
	7,157.88	3		13,966.77			
61	7,146.11	2		13,989.78	$b^3F_2-y^5G^\circ_2$		
45	7,144.48	5		13,992.97	$a^3G_3-y^5G^\circ_5$		
	7,143.87	3		13,994.16			
62	7,143.43	3		13,995.03	$a^1D_2-z^5D^\circ_1$		
61	7,140.74	4		14,000.29	$b^3F_4-y^5G^\circ_4$		
54- 45-	7,138.30	5		14,005.08	-$b^3F_2-z^5P^\circ_2$ -$a^3G_4-y^5G^\circ_5$		
61	7,132.98	5		14,015.53	$b^3F_3-y^5G^\circ_3$		
63	7,113.54	5	1, V	14,053.83	$a^3G_3-x^3D^\circ_2$		
52	7,112.83	8	4, IV?	14,055.23	$b^3F_3-y^3G^\circ_4$		
43	7,111.71	12	20, II	14,057.45	$a^3P_2-z^3D^\circ_3$		
59	7,103.77	18	40, II	14,073.16	$a^3F_2-z^5D^\circ_1$	(0.00) 0.00 *w*	(**0.00**, 0.50) **0.50**, 1.00, 1.50
59	7,102.95	20	80, II	14,074.78	$a^5F^3-z^5D^\circ_2$		
59	7,097.78	25	150, II	14,085.04	$a^5F_4-z^5D^\circ_3$	(0.00 *w*) 1.10	(**0.00**, 0.15, 0.30, 0.45) **0.90**, 1.05, 1.20, ---
52	7,095.66	8	5, V	14,089.24	$b^3F_2-y^3G^\circ_3$		
52	7,094.61	7	3, IV	14,091.33	$b^3F_4-y^3G^\circ_5$		
64	7,092.82	3		14,094.88	$y^3F^\circ_4-e^3F_4$		
	7,091.27	2		14,097.96			
65	7,089.50	5	1, V	14,101.49	$b^3F_4-x^3F^\circ_3$		
59	7,087.35	20	20, III	14,105.76	$a^5F_1-z^5D^\circ_0$	(0.00) 0.00	(0.00) 0.00
66	7,060.84	3		14,158.72	$a^3G_5-z^1G^\circ_4$		
	7,057.99	4	1, V	14,164.44			
55	7,057.38	7	3, V	14,165.66	$a^3G_5-x^3F^\circ_4$		
59	7,027.40	15	30, III	14,226.10	$a^5F_1-z^5D^\circ_1$	(1.48) 0.00, 1.55	(1.50) 0.00, 1.50
67	7,005.46	4		14,270.65	$b^3F_3-x^1F^\circ_3$		
59	6,994.38	12	15, IV?	14,293.25	$a^5F_4-z^5D^\circ_4$	(0.51) 1.51	(--- 0.45, **0.60**) --- 1.20, **1.35**, **1.50**, 1.65, ---
59	6,990.86	18	50, III	14,300.45	$a^5F_2-z^5D^\circ_2$	(0.93) 0.80, 1.77	(0.50, **1.00**) 0.50, **1.00**, **1.50**, 2.00
61	6,975.94	4		14,331.04	$b^3F_2-y^3G^\circ_1$		
63	6,966.49	12	15, III	14,350.48	$a^3G_4-x^3D^\circ_3$	(0.00) 0.64	(**0.00**, 0.28, ---) **0.20**, 0.48, 0.77, ---
59	6,953.87	20	60, III	14,376.52	$a^5F_3-z^5D^\circ_3$	(0.68) 1.53	(0.25, 0.50, **0.75**) ---, 1.00, **1.25**, **1.50**, 1.75, ---
68	6,948.51	8	4, V	14,387.61	$a^3P_3-z^5P^\circ_2$		
65	6,932.41	6	2, V	14,421.03	$b^3F_2-x^3F^\circ_2$		
66	6,929.09	3		14,427.93	$a^3G_3-z^1G^\circ_4$		
55	6,925.71	2		14,434.98	$a^3G_3-x^3F^\circ_4$		
45	6,922.23	3		14,442.23	$a^3G_3-y^5G^\circ_5$		
59	6,916.90	7	2, III	14,453.36	$a^5F_1-z^5D^\circ_2$		
68	6,907.40	8	3, IV	14,473.24	$a^5P_2-z^5P^\circ_1$		

TABLE 3.—*Wave lengths in the arc spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities, temperature class, and notes		Wave No.	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
		B. S.	King				
60	6,904.40	7	2, III	14,479.53	$a^3F_4-z^5G^\circ_4$		
65	6,900.59	8	2, IV	14,487.52	$b^3F_3-x^3F^\circ_3$		
69	6,888.30	15	20, IV	14,513.37	$b^3F_2-x^3D^\circ_1$	(0.00) 0.66	(0.00, 0.17) 0.50, 0.67, 0.83
	6,885.20	3		14,519.91			
62	6,883.27	4		14,523.98	$a^1D_2-z^5D^\circ_3$		
70	6,857.93	3		14,577.64	$a^3D_3-v^3D^\circ_3$		
59	6,854.63	3		14,584.66	$a^5F_3-z^5D^\circ_4$		
67	6,853.85	3		14,586.32	$b^3F_2-x^1F^\circ_3$		
71	6,852.59	4		14,589.00	$b^3F_4-z^1G^\circ_4$		
65	6,849.29	8	4, V	14,596.03	$b^3F_4-x^3F^\circ_4$		
72	6,847.34	2		14,600.19	$a^3P_1-z^5D^\circ_0$		
69	6,847.03	18	25, V	14,600.85	$b^3F_3-x^3D^\circ_2$	(0.00) 0.85	(0.00, 0.08, 0.17) 0.92, 1.00, 1.08, ---
59	6,846.42	5		14,602.15	$a^5F_2-z^5D^\circ_3$		
68	6,845.30	5		14,604.54	$a^5P_1-z^5P^\circ_1$		
63	6,843.76	2		14,607.83	$a^3G_3-x^3D^\circ_3$		
73	6,838.69	3		14,618.65	$a^3G_3-w^3D^\circ_2$		
68	6,833.69	4		14,629.35	$a^5P_2-z^5P^\circ_2$		
60	6,832.93	12	12, III	14,630.98	$a^3F_3-z^5G^\circ_3$		
68	6,828.82	10	10, V	14,639.80	$a^5P_3-z^5P^\circ_3$	(0.00) 1.66	(0.00) 1.67
	6,812.66	3		14,674.51			
70	6,811.32	2		14,677.40	$a^3D_1-v^3D^\circ_1$		
70	6,796.71	4		14,708.95	$a^3D_2-v^3D^\circ_2$		
74, 75	6,794.66	2		14,713.38	$a^5P_2-y^3G^\circ_3$, $a^5P_3-y^5G^\circ_3$		
73	6,790.89	10	4, V	14,721.55	$a^3G_4-w^3D^\circ_3$		
68	6,772.92	8	3, V	14,760.61	$a^5P_1-z^5P^\circ_2$		
69	6,769.16	20	40, V	14,768.81	$b^3F_4-x^3D^\circ_3$	(0.00*w*) 0.72	0.00, 0.08, ---) 1.00, 1.08, 1.17, ---
60	6,762.38	20	30, III	14,783.62	$a^3F_2-z^5G^\circ_2$	(0.55) 0.58	(0.33, 0.67) 0.00, 0.33, 0.67, 1.00
76	6,752.73	10	4, V	14,804.74	$a^1G_4-z^1F^\circ_3$	(0.00) 0.90	(0.00) 1.00
68	6,717.89	8	3, III	14,881.53	$a^5P_2-z^5P^\circ_3$	(0.00*w*) 1.25	(0.00, 0.17, 0.33) 1.33, 1.50, 1.67, ---
72	6,709.61	7	2, IV	14,899.89	$a^3P_0-z^5D^\circ_1$		
69	6,702.13	6	1, V	14,916.52	$b^3F_2-x^3D^\circ_2$		
	6,698.50	2		14,924.60			
70	6,697.94	3		14,925.85	$a^3D_2-v^3D^\circ_3$		
70	6,693.95	3		14,934.75	$a^3D_1-v^3D^\circ_2$		
72	6,688.19	7	2, V	14,947.61	$a^3P_1-z^5D^\circ_2$	(0.00) 1.44	(0.00) 1.50
77	6,678.81	3		14,968.60	$a^5P_3-x^1F^\circ_3$		
78	6,645.16	3		15,044.40	$a^5P_2-x^3F^\circ_2$		
81	6,620.62	5	1, V	15,100.16	$a^1H_5-z^1H^\circ_5$	(0.00) 1.08	(0.00) 1.00
	6,617.28	2		15,107.78			
	6,616.40	2		15,109.79			
80	6,603.27	8	4, V	15,139.84	$b^3F_4-w^3D^\circ_3$	(0.00*w*) 0.78	(0.00, 0.08, 0.17, 0.25) 1.00, 1.08, 1.17, ---
82	6,599.89	2		15,147.59	$a^3G_4-z^3H^\circ_4$		
60	6,598.86	3		15,149.95	$a^3F_3-z^5G^\circ_4$		
69	6,596.75	3		15,154.80	$b^3F_3-x^3D^\circ_3$		
80	6,592.02	8	4, V	15,165.68	$b^3F_3-w^3D^\circ_2$	(0.00) 0.82	(0.00, 0.08, 0.17) 0.92, 1.00, 1.08, ---
78	6,583.61	2		15,185.05	$a^5P_3-x^3F^\circ_3$		
60	6,576.57	3	1, V	15,201.30	$a^3F_2-z^5G^\circ_3$		
79	6,569.43	4	1, V	15,217.82	$a^5F_3-z^3D^\circ_2$		
80	6,550.57	5	3, V	15,261.64	$b^3F_2-w^3D^\circ_1$	(0.00) 0.72	(0.00, 0.17) 0.50, 0.67, 0.83
83	6,506.39	4	6, IV?	15,365.27	$a^1D_2-z^3P^\circ_2$	(0.46) 1.46	(0.50, 1.00) 0.50, 1.00, 1.50, 2.00
84	6,503.31	5	5, IV?	15,372.55	$a^3G_3-w^3F^\circ_2$	(0.00) 0.92	(0.00, 0.08, 0.17) --- 0.75, 0.83, 0.92
85, 84	6,493.12	4	1, V?	15,396.67	$a^3H_5-z^5D^\circ_4$, $a^3G_4-w^3F^\circ_3$		
82	6,489.68	10	25, IV	15,404.83	$a^3G_3-z^3P^\circ_4$	(0.00) 0.84	(0.00, 0.05, 0.10, 0.15) --- 0.85, 0.90, 0.95
83	6,484.35	2		15,417.49	$a^1D_2-z^3P^\circ_1$		

TABLE 3.—*Wave lengths in the arc spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities, temperature class, and notes		Wave No.	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
		B. S.	King				
82	6,470.25	10	15, IV	15,451.09	$a^3G_4-z^3H^\circ_5$	(0.00) 0.79	(**0.00**, 0.02, 0.03, ---) **0.97**, 0.98, 1.00, ---
80	6,457.60	3	1, V	15,481.36	$b^3F_2-w^3D^\circ_2$		
79	6,451.62	3		15,495.71	$a^5F_2-z^3P^\circ_1$		
86	6,445.76	8	10, IV	15,509.80	$a^1G_4-y^3F^\circ_3$	(0.00) 0.90	(**0.00**, 0.08, ---) **0.75**, 0.83, 0.92, ---
80	6,439.01	4		15,526.05	$b^3F_3-w^3D^\circ_3$		
87	6,434.40	4	1, V	15,537.18	$z^3G^\circ_5-e^3F_4$	(0.00) 1.14	
87	6,426.20	2		15,557.00	$z^3G^\circ_4-e^3F_3$	(0.00) 1.04	
88	6,407.03	5	4, V	15,603.55	$a^1G_4-y^3D^\circ_3$		
89					$a^3F_4-z^3F^\circ_3$		
87	6,404.27	2		15,610.28	$z^3G^\circ_3-e^3F_2$		
90	6,390.61	2		15,643.64	$a^3G_4-x^3G^\circ_3$		
84	6,386.40	2		15,653.96	$a^3G_3-w^3F^\circ_3$		
84	6,345.23	15	8, IV	15,755.52	$a^3G_3-w^3F^\circ_4$		
84	6,340.39	4	1, V	15,767.55	$a^3G_4-w^3F^\circ_4$	(0.00 *w*) 1.18	(---, 0.60, **0.80**) --- 0.85, **1.05**, **1.25**, 1.45, ---
	6,324.55	2		15,807.04			
91	6,321.37	6	2, V	15,814.99	$b^3F_4-w^3F^\circ_3$	(0.00 *w*) 1.54	(**0.00**, 0.17, ---) --- 1.42, 1.58, **1.75**
92	6,314.71	2		15,831.67	$a^1G_4-y^5D^\circ_3$		
82	6,313.05	12	50, V	15,835.83	$a^3G_5-z^3H^\circ_6$	(0.00) 1.12	(**0.00**, 0.03, 0.07, ---) **1.00**, 1.03, 1.07, ---
93	6,304.35	3		15,857.69	$a^1S_0-z^1P^\circ_1$	(0.00) 1.44	(0.00) 1.50
94					$a^3P_1-z^3P^\circ_0$		
95	6,299.72	7	12, V	15,869.34	$b^3F_4-z^3H^\circ_5$	(0.00) 0.78	(**0.00**, 0.22, 0.43, ---) **0.17**, 0.38, 0.60, ---
96	6,282.66	2		15,912.43	$c^3P_1-v^3F^\circ_2$		
91	6,279.77	1		15,919.76	$b^3F_3-w^3F^\circ_2$		
95	6,267.09	4		15,951.97	$b^3F_3-z^3H^\circ_4$		
90	6,257.28	5	8, V	15,976.98	$a^3G_5-z^3G^\circ_4$	(0.00) 1.27	(**0.00**, 0.15, 0.30 ---) --- 1.50, 1.65, **1.80**
97	6,224.22	2		16,061.83	$b^3F_4-x^3G^\circ_3$		
98	6,220.86	2		16,070.51	$z^5D^\circ_0-e^5F_1$		
99	6,214.72	8	6, V	16,086.39	$b^1G_4-z^1H^\circ_5$	(0.00) 1.00	(0.00) 1.00
94	6,213.06	8	8, IV?	16,090.68	$a^3P_1-z^3P^\circ_2$	(0.00) 1.49	(0.00) 1.50
98	6,204.13	3		16,113.85	$z^5D^\circ_1-e^5F_2$		
94	6,192.96	7	5, III	16,142.91	$a^3P_1-z^3P^\circ_1$	(0.00) 1.51	(0.00) 1.50
98	6,189.38	3		16,152.25	$z^5D^\circ_2-e^5F_3$		
100	6,178.26	3		16,181.32	$a^3F_4-z^5F^\circ_5$	(0.00) 1.26	(0.00) 1.25
90	6,160.27	2		16,228.57	$a^3G_5-z^3G^\circ_5$	(0.00) 1.22	(0.00) 1.20
98	6,157.75	6	20, IV	16,235.22	$z^5D^\circ_3-e^5F_4$	(0.00) 0.80	(0.00) 0.67
91					$b^3F_2-w^3F^\circ_2$		
90	6,155.56	2		16,240.99	$a^3G_4-x^3G^\circ_5$	(0.00) 1.36	(**0.00**, 0.15, 0.30, ---) --- 1.50, 1.65, **1.80**
101	6,149.94	1		16,255.83	$a^5F_5-z^3G^\circ_4$		
89	6,143.23	30	150, II	16,273.59	$a^3F_3-z^3F^\circ_3$	(0.00) 1.10	(0.00) 1.08
94	6,140.50	10	15, II	16,280.82	$a^3P_2-z^3P^\circ_2$	(0.48) 1.44	(0.00) 1.50
89	6,134.58	25	125, II	16,296.53	$a^3F_2-z^3F^\circ_2$	(0.00) 0.69	(0.00) 0.67
89	6,127.49	35	200, II	16,315.39	$a^3F_4-z^3F^\circ_4$	(0.00) 1.26	(0.00) 1.25
94	6,124.86	10	5, III	16,322.39	$a^3P_0-z^3P^\circ_1$	(0.00) 1.50	(0.00) 1.50
102	6,121.95	12	20, II	16,330.16	$a^1G_4-y^1F^\circ_3$	(0.00) 0.74 A[1]	(0.00) 1.00
94	6,120.86	5	3, IV	16,333.06	$a^3P_2-z^3P^\circ_1$	(0.00) 1.15	(0.00) 1.50
100	6,062.88	7	12, II	16,489.26	$a^3F_3-z^5F^\circ_2$	(0.00) 1.17	(**0.00**, 0.08, 0.17), --- 1.08, 1.17, **1.25**
91	6,052.84	4		16,516.61	$b^3F_2-w^3F^\circ_3$		
98	6,049.29	6	3, IV	16,526.30	$z^5D^\circ_4-e^5F_5$	(0.00) 1.14	(**0.00**, 0.10, 0.20, ---) **1.00**, 1.10, 1.20, ---
103	6,045.89	7	4, IV	16,535.59	$a^3H_4-w^3G^\circ_3$	(0.00) 0.88	(**0.00**, 0.05, ---) --- 0.85, 0.90, **0.95**
91	6,032.62	7	5, IV	16,571.96	$b^3F_3-w^3F^\circ_4$	(0.00) 1.45	(**0.00**, 0.17, ---) --- 1.42, 1.58, **1.75**
100	6,025.41	3		16,591.80	$a^3F_4-z^5F^\circ_4$		
104	6,014.69	1		16,621.37	$c^3P_2-u^3D^\circ_2$		
	6,002.66	2		16,654.68			
97	6,001.03	4		16,659.20	$b^3F_4-x^3G^\circ_5$	(0.00) 1.36	(**0.00**, 0.05, ---) **1.00**, 1.05, 110, ---
101	5,995.41	2		16,674.82	$a^5F_5-z^3G^\circ_5$		
104	5,984.82	2		16,704.32	$c^3P_1-u^3D^\circ_2$		

TABLE 3.—*Wave lengths in the arc spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities, temperature class, and notes		Wave No.	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
		B. S.	King				
103	5,984.24	6	5, V	16,705.94	$a^3H_5-w^3G^\circ_4$	(0.00) 1.02	(**0.00**, 0.02, 0.03, ---) **0.97**, 0.98, 1.00, ---
105	5,969.29	2		16,747.78	$a^1D_2-z^3G^\circ_3$		
100	5,955.37	12	12, II	16,786.93	$a^3F_2-z^5F^\circ_1$	(**0.00**, 0.52) 0.68, **1.14**	(**0.00**, 0.67) 0.00, 0.67, **1.33**
89	5,935.23	10	10, II	16,843.89	$a^3F_2-z^3F^\circ_3$	(**0.00**, 0.42, 0.87) 1.52, **1.96**	(**0.00**, 0.42, 0.83) --- 1.08, 1.50, **1.92**
106	5,925.17	7	12, III	16,872.49	$a^1D_2-z^3S^\circ_1$	(**0.00**, 0.71) **0.49**, 1.30	(**0.00**, 1.00) **0.00**, 1.00, 2.00
107	5,901.09	4	2, III	16,941.34	$a^3F_3-z^1D^\circ_2$	(0.00) 1.25	(**0.00**, 0.08, 0.17) --- 1.08, 1.17, **1.25**
89	5,885.61	10	8, II	16,985.90	$a^3F_3-z^3F^\circ_4$	(0.00 *w*) 1.29, **1.74**	(**0.00**, 0.17, ---) --- 1.42, 1.58, **1.75**
108	5,879.79	25	40, II	17,002.71	$a^3F_4-z^3D^\circ_3$	(0.00) 1.12	(**0.00**, 0.08, ---) **1.00**, 1.08, 1.17, ---
101	5,872.62	1		17,023.47	$a^5F_4-z^3G^\circ_3$		
103	5,869.51	8	4, IV	17,032.49	$a^3H_6-w^3G^\circ_5$	(0.00) 1.10	(**0.00**, 0.03, 0.07, ---) **1.00**, 1.03, 1.07, ---
100	5,868.28	4		17,036.07	$a^3F_4-z^5F^\circ_5$		
104	5,847.33	5		17,097.09	$c^3P_2-u^3D^\circ_3$	(0.00) 1.20	(**0.00**, 0.17, 0.33) **1.00**, 1.17, 1.33, ---
109	5,818.48	2		17,181.87	$b^3P_2-x^3S^\circ_1$		
	5,809.15	2		17,209.46			
110	5,801.31	2		17,232.72	$z^3D^\circ_3-e^5F_3$		
108	5,797.76	12	25 II	17,243.27	$a^3F_3-z^3D^\circ_2$	(0.00) 1.03	(**0.00**, 0.08, 0.17) **0.92**, 1.00, 1.08, ---
111	5,791.30	2		17,262.50	$a^1H_5-t^3F^\circ_4$		
100					$a^3F_3-z^5F^\circ_4$		
110	5,746.59	2		17,396.81	$z^3D^\circ_2-e^5F_2$		
103	5,735.70	12	20, II	17,429.84	$a^3F_2-z^3D^\circ_1$	(0.00) 0.90 A[3]	(**0.00**, 0.17) 0.50, 0.67, **0.83**
107	5,708.88	4	2, III	17,511.73	$a^3F_2-z^1D^\circ_2$	(0.66) 0.77	(0.33, **0.67**) 0.33, **0.67**, **1.00**, 1.33
112	5,685.47	3		17,583.83	$z^5F^\circ_5-e^5F_4$		
113					$a^3G_3-x^5D^\circ_3$		
114	5,680.93	12	15, II	17,597.88	$a^1H_5-x^1G^\circ_4$	(0.50) 1.47, 2.01	(0.50) 1.50, 2.00
115					$a^3P_1-z^3S^\circ_1$		
110	5,674.76	2		17,617.02	$z^3D^\circ_1-e^5F_1$		
110					$z^3D^\circ_2-e^5F_4$		
112	5,666.28	2		17,643.38	$z^5F^\circ_4-e^5F_3$		
116	5,664.55	12	25, II	17,648.77	$a^1D_2-y^1D^\circ_2$	(0.51) 1.09	(0.00) 1.00
117	5,659.83	3		17,663.49	$a^3P_2-z^5G^\circ_3$		
118	5,629.02	4		17,760.16	$a^1D_2-z^1F^\circ_3$		
115	5,623.56	5	3, V	17,777.41	$a^3P_0-z^3S^\circ_1$	(0.00) 1.97	(0.00) 2.00
112	5,620.16	10	15, IV	17,788.16	$z^5F^\circ_5-e^5F_2$	(**0.00**, 0.75) **0.44**, 1.27, 2.00	(**0.00**, 0.50) **1.00**, 1.50, 2.00
115					$a^3P_2-z^3S^\circ_1$		
108	5,612.11	3		17,813.68	$a^3F_2-z^3D^\circ_2$		
112	5,557.91	2		17,987.39	$z^5F^\circ_2-e^5F_1$		
119	5,555.38	2		17,995.58	$a^5F_2-y^3D^\circ_1$		
120	5,550.34	2		18,011.88	$y^5F^\circ_3-f^3G_5$		
112	5,545.42	8	3, V	18,027.90	$z^5F^\circ_4-e^5F_4$	(0.00) 1.35	(0.00) 1.35
112	5,537.45	5	2, V	18,053.85	$z^5F^\circ_3-e^5F_3$	(0.00) 1.23	(0.00) 1.25
	5,536.67	3		18,056.39			
119	5,532.30	4		18,070.66	$a^5F_3-y^3D^\circ_2$		
112	5,528.44	10	8, V	18,083.28	$z^5F^\circ_5-e^5F_5$	(0.00) 1.40	(0.00) 1.40
	5,523.88	3		18,098.20			
121	5,522.78	2		18,101.81	$a^1H_5-x^3H^\circ_6$		
122	5,518.06	2		18,117.29	$a^5F_5-y^3F^\circ_4$		
119	5,517.12	4	2, V	18,120.38	$a^5F_4-y^3D^\circ_3$		
112	5,507.96	3		18,150.51	$z^5F^\circ_2-e^5F_2$		
120	5,504.22	1		18,162.84	$y^5F^\circ_5-f^3G_6$		
123	5,502.16	12	15, V	18,169.65	$a^1G_4-x^1F^\circ_3$	(0.00) 0.90	(0.00) 1.00
124	5,487.52	2		18,218.12	$a^1D_2-y^3D^\circ_2$		
125	5,486.09	4	2, IV	18,222.87	$a^5F_2-y^5D^\circ_1$		
	5,481.17	3		18,239.23			
125	5,480.82	5	2, IV	18,240.39	$a^5F_3-y^5D^\circ_2$		
126	5,478.34	5	3, III	18,248.65	$b^1G_4-z^3F^\circ_3$		

TABLE 3.—*Wave lengths in the arc spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities, temperature class, and notes		Wave No.	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
		B. S.	King				
125	5,477.40	3		18,251.78	$a^5F_1-y^5D^\circ_0$		
127	5,475.55	2		18,257.95	$a^5P_2-v^3D^\circ_3$		
112	5,474.94	2		18,259.98	$z^5F^\circ_1-e^5F_1$		
	5,474.39	2		18,261.81			
119	5,464.02	1		18,296.47	$a^5F_2-y^3D^\circ_2$		
128	5,460.71	3		18,307.56	$b^3P_2-u^3D^\circ_3$		
122	5,457.58	1		18,318.06	$a^5F_3-y^3F^\circ_3$		
125, 122	5,448.55	5	3, III	18,348.42	$a^5F_4-y^5D^\circ_3$; $a^5F_3-y^3F^\circ_2$		
	5,447.94	2		18,350.48			
129	5,443.16	2		18,366.59	$z^3F^\circ_3-e^5F_2$		
125	5,440.41	4		18,375.87	$a^5F_1-y^5D^\circ_1$		
130	5,437.74	5	2, IV	18,384.89	$a^3F_4-z^5D^\circ_3$		
131	5,437.26	3		18,386.52	$a^1G_4-x^3F^\circ_3$		
132	5,436.91	3		18,387.70	$a^1D_2-y^3D^\circ_2$		
112	5,428.42	4		18,416.46	$z^5F^\circ_2-e^5F_3$		
112	5,426.36	3		18,423.45	$z^5F^\circ_1-e^5F_2$		
	5,423.50	2		18,433.17			
112	5,421.86	3		18,438.74	$z^5F^\circ_3-e^5F_4$		
119	5,418.73	2		18,449.39	$a^5F_1-y^3D^\circ_2$		
132, 122	5,413.92	3		18,465.79	$a^1D_2-y^3F^\circ_2$; $a^5F_4-y^3F^\circ_4$		
125	5,407.63	10	7, II	18,487.26	$a^5F_5-y^5D^\circ_4$	(0.00) 1.22	(0.00, 0.10, 0.20, ---)1.00, 1.10, 1.20, ---
133	5,405.13	4	2, III	18,495.82	$a^1D_2-y^3F^\circ_2$		
112	5,395.88	3		18,527.52	$z^5F^\circ_4-e^5F_5$		
122	5,391.18	3		18,543.67	$a^5F_2-y^3F^\circ_3$		
124	5,386.65	3		18,559.27	$a^1D_2-y^3D^\circ_3$	(0.00) 1.32	(0.00, 0.33, 0.67)---1.33, 1.67, 2.00
134	5,385.14	15	40, II	18,564.47	$a^3P_2-y^1D^\circ_2$	(0.45) 1.10	(0.50, 1.00) 0.50, 1.00, 1.50, 2.00
122	5,382.36	3		18,574.06	$a^5F_2-y^3F^\circ_2$		
135	5,379.54	3		18,583.80	$b^1G_4-x^1G^\circ_4$		
	5,372.43	2		18,608.39			
125	5,369.39	4		18,618.92	$a^5F_1-y^5D^\circ_2$		
125	5,363.35	3		18,639.89	$a^5F_3-y^5D^\circ_3$		
136	5,362.56	8	6, III	18,642.64	$a^3P_1-y^3D^\circ_1$	(0.97) 0.50, 1.53	(1.00) 0.50, 1.50
	5,351.92	5		18,679.70			
137	5,350.89	4		18,683.30	$a^1H_5-v^3G^\circ_5$		
138, 139	5,343.59	2		18,708.82	$a^3P_1-z^5S^\circ_2$; $a^1G_4-y^5G^\circ_5$		
122	5,338.41	4		18,726.97	$a^5F_1-y^3F^\circ_2$		
129	5,331.74	3		18,750.40	$z^3F^\circ_2-e^5F_1$		
130	5,330.83	5		18,753.60	$a^3F_3-z^5D^\circ_2$		
122	5,329.83	3		18,757.12	$a^5F_5-y^3F^\circ_4$		
	5,321.81	2		18,735.39			
132	5,321.27	4		18,787.30	$a^1D_2-y^5D^\circ_3$		
140	5,319.98	2		18,791.85	$a^5P_1-x^5D^\circ_1$		
141	5,316.75	1		18,803.27	$c^3P_0-t^3D^\circ_1$		
136	5,311.42	8	6, III	18,822.13	$a^3P_0-y^3D^\circ_1$	(0.00) 0.54	(0.00) 0.50
142	5,310.97	2		18,823.73	$a^3G_3-w^3G^\circ_3$		
140	5,309.64	2		18,828.45	$a^5P_3-x^5D^\circ_3$		
140	5,308.94	2		18,830.93	$a^5P_2-x^5D^\circ_2$		
136	5,308.38	2		18,832.91	$a^3P_2-y^3D^\circ_1$		
125	5,307.62	2		18,835.61	$a^5F_4-y^5D^\circ_4$		
143	5,305.50	2		18,843.14	$a^3D_2-v^3F^\circ_3$		
143	5,303.80	2		18,849.18	$a^3D_1-v^3F^\circ_2$		
144	5,303.36	1		18,850.74	$a^3H_5-z^1H^\circ_5$		
145	5,301.98	7		18,855.65	$b^1G_4-x^3H^\circ_4$	(0.00*w*) 0.98	(---, 0.60, 0.80) --- 0.60, 0.80, 1.00, 1.20, ---
146	5,300.11	3		18,862.30	$a^3D_3-w^3F^\circ_4$		
	5,299.53	3		18,864.36			
125	5,299.20	3		18,865.54	$a^5F_3-y^5D^\circ_3$		
147	5,296.78	10	5, III	18,874.21	$a^1G_4-z^1G^\circ_4$	(0.19) 1.04	(0.00) 1.00
131	5,294.82	7	2, V	18,881.14	$a^1G_4-x^3F^\circ_4$		
	5,292.52	3		18,839.35			
142	5,280.06	10	2, V	18,933.92	$a^3G_4-w^3G^\circ_4$	(0.00) 1.54	(0.00) 1.05

TABLE 3.—*Wave lengths in the arc spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities, temperature class, and notes		Wave No.	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
		B. S.	King				
136	5,277.40	12	8, III	18,943.47	$a^3P_1-y^3D^\circ_2$	(**0.00**, 0.34) **0.70**, 1.13	(**0.00**, 0.33) **0.83**, 1.17, 1.50
140	5,272.15	2		18,962.33	$a^5P_1-x^5D^\circ_2$		
143	5,264.04	4		18,991.55	$a^3D_3-v^3F^\circ_4$		
	5,263.74	1		18,992.63			
146	5,250.33	2		19,041.14	$a^3D_1-u^3F^\circ_2$		
144	5,248.51	3		19,047.74	$a^3H_4-z^1H^\circ_5$		
148	5,248.03	3		19,049.48	$a^3P_0-y^5D^\circ_1$		
141	5,243.46	5		19,066.09	$c^3P_1-t^3D^\circ_1$		
140	5,242.19	2		19,070.71	$a^5P_2-x^5D^\circ_3$		
146	5,241.93	1		19,071.65	$a^3D_2-u^3F^\circ_3$		
130	5,235.07	3		19,096.64	$a^3F_2-z^5D^\circ_1$		
148	5,230.55	4		19,113.14	$a^3P_1-y^5D^\circ_2$		
140	5,227.00	3		19,126.12	$a^5P_3-x^5D^\circ_3$		
136	5,224.94	9	6, III	19,133.66	$a^3P_2-y^3D^\circ_2$	(0.00*w*) 1.18	(0.33, **0.67**) 0.83, **1.17**, **1.50**, 1.83
149	5,223.62	2		19,138.50	$a^5F_3-y^1F^\circ_3$		
150	5,215.58	2		19,168.00	$c^3P_0-v^3P^\circ_1$		
142	5,209.31	8	4, V	19,191.07	$a^3G_3-w^3G^\circ_4$	(**0.00** *w*, 0.55) 1.29, **1.70**	(**0.00**, 0.30, ---) --- 1.35, 1.65, **1.95**
151	5,201.17	8	4, III	19,221.11	$a^3P_1-y^3F^\circ_2$	(**0.00**, 0.59) 0.00, 0.98	(**0.00**, 0.83) **0.17**, 0.67, 1.50
152	5,187.04	4		19,273.46	$b^3P_2-w^3P^\circ_1$		
153	5,184.55	2		19,282.72	$a^3D_2-w^5D^\circ_2$		
154	5,183.71	8	6, III	19,285.85	$a^1D_2-y^1F^\circ_3$	(0.00) 1.02	(0.00) 1.00
148	5,178.99	3		19,303.42	$a^5P_2-y^5D^\circ_2$		
153	5,174.31	2		19,320.88	$a^3D_1-w^5D^\circ_1$		
155	5,165.97	8	4, V	19,352.07	$b^3F_4-w^3G^\circ_4$		
	5,164.71	3		19,356.80			
155	5,161.01	7	3, V	19,370.67	$b^3F_3-w^3G^\circ_3$		
142	5,158.68	6		19,379.42	$a^3G_5-w^3G^\circ_3$		
156	5,158.02	12	7, V	19,381.90	$z^5G^\circ_6-e^5F_5$	(0.00) 1.10	(**0.00**, 0.07, 0.13, ---) **1.00**, 1.07, 1.13, ---
142	5,155.46	15	12, V	19,391.53	$a^3G_4-w^3G^\circ_5$	(0.00) 1.30	(**0.00**, 0.15, 0.30, ---) --- 1.50, 1.65, **1.80**
151	5,150.22	1		19,411.25	$a^3P_2-y^3F^\circ_2$		
150	5,145.46	1		19,429.21	$c^3P_1-v^3P^\circ_1$		
157	5,140.42	1		19,448.26	$a^3H_4-u^3D^\circ_3$		
158	5,136.78	3		19,462.04	$a^3H_5-y^3H^\circ_4$		
	5,136.16	4		19,464.39			
	5,135.16	2		19,468.18			
	5,134.43	1		19,470.95			
136	5,133.42	10	6, V	19,474.78	$a^3P_2-y^3D^\circ_3$	(0.00) 1.23	(**0.00**, 0.17, 0.33) **1.00**, 1.17, 1.33, ---
159	5,132.88	3		19,476.83	$b^1G_4-v^3G^\circ_4$		
	5,128.16	2		19,494.76			
	5,126.06	3		19,502.74			
152	5,120.44	7		19,524.15	$b^3P_2-w^3P^\circ_2$	(0.00) 1.46	(0.00) 1.50
	5,119.44	2		19,527.96			
156	5,115.27	15	5, V	19,543.88	$z^5G^\circ_5-e^5F_4$	(0.00) 1.13	(**0.00**, 0.08, 0.17, ---) **0.93** 1.02, 1.10, ---
	5,113.69	1		19,549.92			
	5,112.82	1		19,553.24			
153	5,110.17	2		19,563.39	$a^3D_2-w^5D^\circ_3$		
160	5,105.56	5		19,581.05	$a^1S_0-y^1P^\circ_1$		
158	5,104.23	2		19,586.15	$a^3H_6-y^3H^\circ_5$		
	5,102.54	1		19,592.64			
	5,098.56	2		19,607.93			
	5,089.62	2		19,642.37			
158	5,085.26	10	3, V	19,659.21	$a^3H_4-y^3H^\circ_4$	(0.00) 0.80	(0.00) 0.80
	5,082.02	2		19,671.75			
	5,080.00	4		19,679.57			
	5,079.01	2		19,683.40			

TABLE 3.—*Wave lengths in the arc spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities, temperature class, and notes		Wave No.	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
		B. S.	King				
155	5,078.28	20	20, V	19,686.23	$b^3F_2-w^3G^\circ_3$	(0.00) 0.82	(**0.00**, 0.08, 0.17) --- 0.75, 0.83, **0.92**
	5,075.23	3		19,698.06			
148	5,074.00	10	2, V	19,702.84	$a^3P_2-y^5D^\circ_3$		
	5,073.14	2		19,706.18			
	5,072.29	2		19,709.48			
	5,071.82	1		19,711.31			
158	5,070.27	12	3, V	19,717.33	$a^3H_5-y^3H^\circ_5$	(0.00) 1.02	(0.00) 1.03
161	5,065.25	12	4, V	19,736.87	$a^1H_5-z^1H^\circ_6$	(0.00) 1.00	(0.00) 1.00
155	5,064.92	35	15, V	19,738.16	$b^3F_3-w^3G^\circ_4$	(0.00) 1.06	(**0.00**, 0.03, 0.07, 0.10) **0.95**, 0.98, 1.02, ---
156	5,060.42	12	3, V	19,755.71	$z^5G^\circ_4-e^5F_5$	(0.00*w*) 1.08	(**0.00**, 0.10, 0.20, 0.30) **0.85**, 0.95, 1.05, ---
	5,059.89	1		19,757.78			
	5,056.10	3		19,772.59			
155	5,046.61	25	10, V	19,809.77	$b^3F_4-w^3G^\circ_5$	(0.00) 1.25	(**0.00**, 0.05, 0.10 ---) **1.00**, 1.05, 1.10, ---
	5,037.43	1		19,845.87			
162	5,034.45	4		19,857.62	$z^3D^\circ_3-e^3F_4$		
150	5,032.42	2		19,865.63	$c^3P_2-v^3P^\circ_2$		
162	5,026.91	2		19,887.41	$z^3D^\circ_2-e^3F_3$		
150	5,011.47	4		19,948.67	$c^3P_1-v^3P^\circ_2$		
	5,002.16	2		19,985.80			
156	4,996.35	10	2, V	20,009.05	$z^5G^\circ_3-e^5F_2$	(0.00) 0.92 A[1]	(**0.00**, 0.08, 0.17), **0.75**, 0.83, 0.92, ---
158	4,994.77	12	5, IV	20,015.38	$a^3H_6-y^3H^\circ_6$	(0.00) 1.16	(0.00) 1.17
	4,992.45	1		20,024.68			
162	4,991.19	2 +Ti		20,029.74	$z^3D^\circ_1-e^3F_2$		
156	4,987.83	4		20,043.22	$z^5G^\circ_5-e^5F_5$		
	4,980.59	2		20,072.36			
163	4,968.17	2		20,122.54	$a^5F_5-y^5G^\circ_4$		
156	4,963.74	5		20,140.50	$z^5G^\circ_4-e^5F_4$		
158	4,962.30	5		20,146.34	$a^3H_5-y^3H^\circ_6$	(0.00*w*) 1.25	(**0.00**, 0.13, 0.27, ---) --- 1.57, 1.70, **1.83**
164	4,960.31	2		20,154.42	$a^1G_4-z^3H^\circ_5$		
	4,960.10	2		20,155.28			
	4,959.12	2		20,159.26			
165	4,956.90	2		20,168.29	$y^5G^\circ_2-f^5G_2$		
166					$b^1G_4-s^3F^\circ_4$		
163	4,951.73	3		20,189.34	$a^5F_4-y^5G^\circ_3$		
	4,950.83	2		20,193.01			
	4,949.94	2		20,196.66			
167	4,948.77	6	2, V	20,201.42	$a^3P_2-y^1F^\circ_3$	(0.00) 1.06	(**0.00**, 0.50, 1.00) **0.00**, 0.50, 1.00, ---
165	4,943.48	1		20,223.04	$y^5G^\circ_3-f^5G_3$		
	4,939.93	3		20,237.57			
156	4,933.66	7	3, V	20,263.29	$z^5G^\circ_2-e^5F_1$		
168	4,932.45	1		20,268.26	$a^3D_2-y^5P^\circ_1$		
156	4,930.88	5		20,274.71	$z^5G^\circ_3-e^5F_3$		
165	4,925.03	1		20,298.80	$y^5G^\circ_4-f^5G_4$		
169	4,922.92	2		20,307.50	$c^3P_2-u^3P^\circ_2$		
170	4,922.23	4		20,310.34	$a^5P_2-w^5G^\circ_3$		
171	4,913.07	1		20,348.21	$c^3F_3-t^3F^\circ_3$		
	4,911.60	2		20,354.30			
172	4,910.78	3		20,357.70	$a^5F_4-z^5P^\circ_3$		
171	4,908.29	1		20,368.02	$c^3F_2-t^3F^\circ_2$		
	4,908.10	2		20,368.81			
173	4,905.09	4		20,381.31	$a^5F_3-y^5G^\circ_2$	(**0.00**, **0.86**, 1.74)?	(**0.00**, 0.92, 1.83) --- 1.25, 2.17, **3.08**
169	4,902.89	1		20,390.46	$c^3P_1-u^3P^\circ_2$		
156	4,894.18	4		20,426.74	$z^5G^\circ_2-e^5F_2$		
174	4,893.12	6	2, IV	20,431.18	$a^3G_4-v^3F^\circ_3$		
173					$a^5F_4-y^5G^\circ_3$		
173	4,887.72	2		20,453.74	$a^5F_5-y^5G^\circ_4$		

TABLE 3.—*Wave lengths in the arc spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities, temperature class, and notes		Wave No.	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
		B. S.	King				
165 174	4,884.12	3		20,468.82	$y^5G^0_3-f^5G_5$ $a^3G_3-p^3F^0_2$		
163	4,833.61	8	5, II	20,470.96	$a^5F_4-y^3G^0_4$	(0.96) 1.10	(--- 0.90, **1.20**) --- 0.75, **1.05**, **1.35**, 1.65, ---
163	4,881.25	8	4, III	20,480.85	$a^5F_3-y^3G^0_3$	(0.78, **1.24**) 1.14	(0.50, 1.00, **1.50**) --- 0.25, **0.75**, **1.25**, **1.75**, ---
165	4,880.66	1		20,483.33	$y^5G^0_6-f^5G_6$		
163 175	4,866.07	10	5, II	20,544.74	$a^5F_5-y^3G^0_5$ $z^3F^0_4-e^3F_4$	(0.87) 1.25	(--- 0.80, **1.00**) --- 1.00, **1.20**, **1.40**, 1.60, ---
173	4,851.36	12	12, II	20,607.04	$a^5F_2-y^5G^0_2$	(0.61, **1.24**) **0.31**, 0.95, 1.59	(0.67, **1.33**) **0.33**, **1.00**, 1.67
	4,850.10	1		20,612.39			
172	4,847.67	1		20,622.72	$a^5F_2-z^5P^0_2$		
176	4,846.35	2		20,628.34	$a^1D_2-y^3G^0_3$		
156	4,843.84	1		20,639.02	$z^5G^0_3-e^5F_5$		
172	4,841.45	1		20,649.21	$a^5F_3-z^5P^0_3$		
177 156	4,838.99	4	2, V	20,659.71	$a^3G_4-u^3F^0_3$ $z^5G^0_3-e^5F_4$	(0.00) 1.20	(0.00, 0.03, ---) **0.95**, 0.98, 1.02, ---
177	4,838.77	5	4, IV	20,660.64	$a^3G_3-u^3F^0_2$	(0.00) 0.80	(0.00, 0.08, 0.17) --- 0.75, **0.83**, **0.92**
178	4,832.75	2		20,686.37	$a^5F_4-x^1F^0_3$		
163	4,828.05	10	10, II	20,706.53	$a^5F_2-y^3G^0_3$	(0.00) 0.61	(**0.00**, 0.25, 0.50) **0.25**, 0.50, 0.75, ---
173	4,824.29	12	12, II	20,722.67	$a^5F_3-y^5G^0_3$	(0.90) 1.11	(0.33, 0.67, **1.00**) --- 0.58, **0.92**, **1.25**, 1.58, ---
179	4,815.77	2		20,759.34	$a^3D_3-w^3P^0_2$		
173	4,815.62	25	60, I	20,759.98	$a^5F_1-y^5G^0_2$	(0.00, 0.37) 0.00, 0.37, **0.75***	(**0.00**, 0.33) 0.00, 0.33, **0.67**
163	4,815.05	12	12, II	20,762.43	$a^5F_3-y^3G^0_4$	(0.00) 0.85	(**0.00**, 0.20, ---) **0.45**, 0.65, 0.85, ---
172	4,811.99	1		20,775.63	$a^5F_1-z^5P^0_2$		
177	4,809.48	10	8, IV	20,786.47	$a^3G_5-u^3F^0_4$	(0.00) 1.07	(**0.00**, 0.05, ---) **1.00**, 1.05, 1.10, ---
180	4,807.10	1		20,796.77	$a^1D_2-z^5P^0_3$		
177	4,806.68	3		20,798.58	$a^3G_4-u^3F^0_4$		
173	4,805.88	12	15, II	20,802.05	$a^5F_4-y^5G^0_4$	(**0.70**) **1.20**	(--- 0.60, **0.80**) --- 0.95, **1.15**, **1.35**, 1.55, ---
181	4,803.45	3		20,812.56	$a^5F_3-x^3F^0_2$		
	4,802.20	1		20,817.98			
152	4,794.95	4		20,849.44	$b^3F_4-v^3F^0_3$	(0.00) **1.35**	(**0.00**, 0.17, ---) --- 1.42, 1.58, **1.75**
179	4,793.27	4		20,856.76	$a^3D_2-w^3P^0_1$		
175	4,793.18	2		20,857.14	$z^3F^0_3-e^3F_3$		
172	4,789.12	5	2, III	20,874.86	$a^5F_2-z^5P^0_3$		
173	4,788.69	10	8, II	20,876.70	$a^5F_5-y^5G^0_5$	(0.61) 1.25	(--- 0.53, **0.67**) --- 1.13, **1.27**, **1.40**, 1.53, ---
163	4,784.94	12	12, II	20,893.10	$a^5F_4-y^3G^0_5$	(0.00*w*) 0.79	(**0.00**, 0.15, ---) **0.60**, 0.75, 0.90, ---
	4,783.43	1		20,899.70			
181 183	4,782.59	3		20,903.35	$a^5F_4-x^3F^0_3$ $a^3F_4-z^3G^0_4$		
	4,775.66	1		20,933.68			
184	4,773.23	0		20,944.34	$a^1G_4-x^3G^0_3$		
173	4,772.32	30	80, I	20,948.33	$a^5F_2-y^5G^0_3$	(0.00) 0.76*	(**0.00**, 0.08, 0.17) **0.75**, 0.83, 0.92, ---
185	4,769.65	2		20,960.06	$a^1D_2-x^3F^0_2$		
186	4,762.78	10	8, IV	20,990.29	$a^3H_4-z^3I^0_5$	(0.00) 1.01*	(**0.00**, 0.03, ---) --- 0.90, 0.93, **0.97**
182	4,756.94	1		21,016.04	$b^3F_2-v^3F^0_2$		
186	4,753.06	4	3, V	21,033.19	$a^3H_6-z^3I^0_7$	(0.00) 1.07	(**0.00**, 0.02, ---) **1.00**, 1.02, 1.05, ---
181	4,751.90	3	2, IV	21,038.35	$a^5F_2-x^3F^0_3$	(0.59) ?	(0.33, **0.67**) 0.33, **0.67**, **1.00**, 1.33
187	4,750.98	1		21,042.44	$a^5F_5-z^1G^0_4$		
181	4,749.39	2		21,049.49	$a^5F_5-x^3F^0_4$		
188	4,748.70	1		21,052.54	$a^1D_2-x^3D^0_1$		
189	4,742.95	3		21,078.06	$b^3F_4-u^3F^0_3$		
173	4,739.48	45	100, I	21,093.48	$a^5F_3-y^5G^0_4$	(0.00) 0.84 A1*	(**0.00**, 0.10, ---) **0.85**, 0.95, 1.05, ---
	4,736.96	2		21,104.71			
	4,735.10	1		21,112.99			

TABLE 3.—*Wave lengths in the arc spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities, temperature class, and notes		Wave No.	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
		B. S.	King				
190	4,734.93	1		21,113.75	$a^3P_1-z^5P_1^\circ$		
191	4,734.37	3		21,116.24	$a^1H_5-y^1H_5^\circ$		
192	4,732.34	15	15, III	21,125.30	$a^1D_2-x^1F_3^\circ$	(00.0w) 0.61, 1.07*	(0.00) 1.00
193	4,731.14	3		21,130.66	$a^5F_2-x^3D_1^\circ$		
175	4,723.89	3		21,163.09	$z^3F_2^\circ-e^3F_2$		
	4,720.30	1		21,179.17			
186	4,719.12	10	10, V	21,184.48	$a^3H_5-z^3I_6^\circ$	(0.00) 1.05	(0.00, 0.01, 0.02, ---) 0.98, 0.99, 1.00, ---
181	4,717.62	8	6, IV	21,191.22	$a^5F_1-x^3F_2^\circ$	(0.00, 0.70) 0.00, 0.70, 1.37	(0.00, 0.67) 0.00, 0.67, 1.33
181	4,716.79	2		21,194.97	$a^5F_3-x^3F_3^\circ$		
178	4,714.86	1		21,203.65	$a^5F_2-x^1F_3^\circ$		
189	4,713.91	1		21,207.92	$b^3F_3-u^3F_2^\circ$		
194	4,713.43	5	2, IV	21,210.08	$a^3H_4-t^3F_4^\circ$		
189	4,711.91	7	8, V	21,216.90	$b^3F_4-u^3F_4^\circ$	(0.30) 1.20	(0.00) 1.25
173	4,710.03	45	100, I	21,225.16	$a^5F_4-y^5G_5^\circ$	(0.00) 1.06	(0, 00, 0.08, 0.17, ---) 0.93, 1.02, 1.10, ---
182	4,707.78	5	4, V	21,235.52	$b^5F_3-v^3F_3^\circ$	(0.00) 1.05*	(0.00) 1.08
	4,704.73	2		21,249.29			
195	4,703.59	2		21,254.44	$a^3P_1-y^5G_2^\circ$		
196	4,702.20	2		21,260.72	$a^3G_3-u^3D_2^\circ$		
197	4,700.83	1		21,266.91	$c^3P_1-s^3D_2^\circ$		
190	4,700.18	3		21,269.86	$a^3P_1-z^5P_2^\circ$		
	4,700.09	3		21,270.25			
183	4,698.14	1		21,279.08	$a^3F_2-z^3G_3^\circ$		
193	4,697.14	2		21,283.62	$a^5F_1-x^3D_1^\circ$		
197, 190	4,695.04	3		21,293.14	$c^3P_2-s^3D_3^\circ$; $a^3P_0-z^5P_1^\circ$		
193	4,691.73	3		21,308.15	$a^5F_3-x^3D_2^\circ$		
183	4,688.45	25	40, I	21,323.05	$a^3F_4-z^3G_5^\circ$	(0.00) 1.03	(0.00, 0.05, 0.10, ---) 1.00, 1.05, 1.10, ---
173	4,687.80	50	150, I	21,326.02	$a^5F_5-y^5G_6^\circ$	(0.00) 1.06*	(0.00, 0.07, 0.13, ---) 1.00, 1.07, 1.13, ---
182	4,686.57	2		21,331.60	$b^3F_2-v^3F_2^\circ$		
185	4,684.25	4	2, V	21,342.18	$a^1D_2-x^3F_3^\circ$		
182	4,683.43	10	15, V	21,345.91	$b^3F_4-v^3F_4^\circ$	(0.00) 1.08*	(0.00) 1.25
181	4,667.14	5	4, II	21,420.42	$a^5F_2-x^3F_3^\circ$	(0.00) 1.12	(0.00, 0.08, 0.17) --- 1.08, 1.17, 1.25
198	4,662.97	2		21,439.58	$a^1H_5-u^3G_5^\circ$		
188	4,659.49	4		21,455.59	$a^1D_2-x^3D_2^\circ$		
199	4,659.20	2		21,456.93	$a^3D_2-t^3F_3^\circ$		
189	4,657.64	6	7, V	21,464.11	$b^3F_3-u^3F_3^\circ$	(0.00) 1.07*	(0.00) 1.08
196	4,654.37	3		21,479.19	$a^3G_4-u^3D_3^\circ$		
200, 189	4,644.82	6	8, V	21,523.35	$a^3D_3-t^3D_3^\circ$; $b^3F_2-u^3F_2^\circ$	(0.00) 0.70*	(0.00) 0.67
201	4,640.38	2		21,543.92	$a^3P_2-y^3G_3^\circ$		
202	4,640.12	3	2, V	21,545.15	$a^3H_4-x^1G_4^\circ$		
193	4,634.63	3		21,570.67	$a^5F_4-x^3D_3^\circ$		
183	4,633.99	30	50, I	21,573.67	$a^3F_3-z^3G_4^\circ$	(0.00) 0.98*	(0.00, 0.03, ---) 0.95, 0.98, 1.02, ---
189	4,627.70	2		21,602.99	$b^3F_3-u^3F_4^\circ$		
203	4,626.42	10	12, IV	21,608.92	$a^3H_5-x^3H_5^\circ$	(0.00) 1.04*	(0.00) 1.03
203	4,624.07	1		21,619.94	$a^3H_5-x^3H_4^\circ$		
204	4,619.56	0		21,641.04	$a^3D_2-y^5S_2^\circ$		
	4,613.35	3	1, IV	21,670.17			
187	4,610.77	2		21,682.29	$a^5F_3-z^1G_4^\circ$		
205	4,610.10	4	2, IV	21,685.44	$a^5P_1-x^3F_2^\circ$		
193	4,609.83	3		21,686.71	$a^5F_1-x^3D_2^\circ$		
181	4,609.28	3		21,689.29	$a^5F_3-x^3F_4^\circ$		
206	4,609.15	3		21,689.92	$a^3G_4-y^1H_4^\circ$		
190	4,604.42	10	8, III	21,712.18	$a^3P_2-z^5P_3$	(0.00 w) 2.11 A²	(0.00, 0.17, 0.33) --- 1.67, 1.83, 2.00
203	4,602.57	12	15, IV	21,720.93	$a^3H_6-x^1H_6^\circ$	(0.00) 1.13*	(0.00) 1.17
	4,601.43	2		21,726.33			

TABLE 3.—*Wave lengths in the arc spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities, temperature class, and notes		Wave No.	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
		B. S.	King				
182	4, 600. 27	3		21, 731. 79	$b^3F_3-v^3F_4^\circ$		
207	4, 590. 55	10	6, II	21, 777. 80	$a^3P_1-x^3D_1^\circ$	(1. 00) 0. 49, 1. 47	(1. 00) 0. 50, 1. 50
189	4, 590. 15	3		21, 779. 71	$b^3F_2-u^3F_3^\circ$		
208	4, 585. 72	2		21, 800. 74	$a^1D_2-w^3D_1^\circ$		
209	4, 584. 95	2		21, 804. 40	$b^3F_2-w^5D_1^\circ$		
203	4, 584. 57	1		21, 806. 21	$a^3H_4-x^3H_5^\circ$		
210	4, 584. 23	4	2, IV?	21, 807. 82	$b^3F_3-u^3D_2^\circ$		
203	4, 582. 29	5	3, V	21, 817. 05	$a^3H_4-x^3H_4^\circ$	(0. 00 *w*) 0. 73*	(0. 00) 0. 80
210	4, 576. 20	4	2, V	21, 846. 09	$b^3F_2-u^3D_1^\circ$	(0. 00) 0. 64	(**0. 00**, 0. 17) 0. 50, 0. 67, **0. 83**
183	4, 575. 52	25	40, I	21, 849. 33	$a^3F_2-z^3G_3^\circ$	(0. 00) 0. 83*	(**0. 00**, 0. 08, 0. 17) --- 0. 75, 0. 83, **0. 92**
203	4, 574. 94	2		21, 852. 09	$a^3H_5-x^3H_6^\circ$		
193	4, 572. 85	2		21, 862. 09	$a^5F_3-x^3D_3^\circ$		
211	4, 570. 59	1		21, 872. 92	$a^5F_3-w^3D_2^\circ$		
210	4, 565. 45	5	2, V	21, 897. 55	$b^3F_4-u^3D_3^\circ$	(0. 00) 0. 85	(**0. 00**, 0. 08, ---) **1. 00**, 1. 08, 1. 17, ---
212	4, 562. 54	1		21, 911. 51	$a^3D_1-v^3P_0^\circ$		
	4, 562. 12	3		21, 913. 51			
	4, 558. 69	3		21, 930. 01			
213 / 206	4, 558. 03	3	2, V	21, 933. 04	$a^5P_3-v^3F_3^\circ$ / $a^3G_5-y^3H_5^\circ$		
211	4, 556. 25	1		21, 941. 74	$a^5F_4-w^3D_3^\circ$		
209 / 206	4, 555. 52	10	8, V	21, 945. 27	$b^3F_4-w^5D_4^\circ$ / $a^3G_4-y^3H_4^\circ$		
206	4, 555. 12	10	10, V	21, 947. 20	$a^3G_3-y^3H_4^\circ$	(0. 00) 0. 80*	(**0. 00**, 0. 05, ---) ------ 0. 85, 0. 90, **0. 95**
207	4, 553. 01	10	12, II	21, 957. 36	$a^3P_0-x^3D_1^\circ$	(0. 00) 0. 51*	(0. 00) 0. 50
207	4, 550. 70	2		21, 968. 42	$a^3P_2-x^3D_2^\circ$		
214	4, 549. 62	1		21, 973. 73	$a^3F_2-z^3S_1^\circ$		
188	4, 542. 22	20	20, II	22, 009. 51	$a^1D_2-x^3D_3^\circ$	(0. 00) 1. 39*	(**0. 00**, 0. 33, 0. 67) --- 1. 33, 167, **2. 00**
208	4, 539. 98	8	4, II	22, 020. 37	$a^1D_2-w^3D_2^\circ$	(0. 00) 1. 22	(0. 17, **0. 33**) 0. 83, **1. 00**, **1. 17**, 1. 33
211	4, 537. 60	1		22, 031. 92	$a^5F_1-w^3D_1^\circ$		
215	4, 535. 75	25	30, II	22, 040. 90	$a^3P_2-x^1F_3^\circ$	(0. 00*w*) 0. 67 A1*	(**0. 00**, 0. 50, 1. 00) **0. 00**, 0. 50, 1. 00, ---
216	4, 533. 67	2		22, 051. 02	$b^1G_4-v^1F_3^\circ$		
213	4, 526. 40	1		22, 086. 47	$a^5P_1-v^3F_2^\circ$		
193	4, 526. 12	3		22, 087. 83	$a^5F_2-x^3D_3^\circ$		
217	4, 524. 20	1		22, 097. 21	$a^5P_2-x^3S_1^\circ$		
211	4, 523. 91	3		22, 098. 60	$a^5F_2-w^3D_2^\circ$		
218	4, 523. 12	3		22, 102. 48	$b^1G_4-y^1H_5^\circ$		
219	4, 521. 93	2		22, 108. 29	$b^3F_4-y^3H_4^\circ$		
212	4, 515. 41	2		22, 140. 20	$a^3D_2-v^3P_1^\circ$		
220	4, 513. 34	2		22, 150. 36	$a^3H_4-v^3G_3^\circ$		
221	4, 511. 15	1		22, 161. 11	$b^1D_2-u^3G_3^\circ$		
222	4, 507. 26	2		22, 180. 23	$a^3F_3-y^1D_2^\circ$		
207	4, 507. 11	20	30, II	22, 180. 97	$a^3P_1-x^3D_2^\circ$	(0. 00, 0. 32) **0. 79**, 1. 13*	(**0. 00**, 0. 33) **0. 83**, 1. 17, 150
211	4, 496. 53	2		22, 233. 15	$a^5F_3-w^3D_3^\circ$		
220	4, 494. 93	3	2, IV	22, 241. 05	$a^3H_5-v^3G_4^\circ$		
211	4, 492. 80	1		22, 251. 60	$a^5F_1-w^3D_2^\circ$		
205	4, 491. 55	3	2, IV	22, 257. 78	$a^3P_2-x^3F_3^\circ$		
	4, 490. 38	3		22, 264. 08			
210	4, 486. 36	2		22, 283. 58	$b^3F_3-u^3D_3^\circ$		
223	4, 484. 71	1		22, 291. 77	$a^3F_3-z^1F_3^\circ$		
220	4, 482. 49	3	2, V	22, 302. 81	$a^3H_6-v^3G_5^\circ$	(0. 00) 1. 12	(**0. 00**, 0. 03, 0. 07, ---) **1. 00**, 1. 03, 1. 07, ---
212	4, 480. 77	3	2, V	22, 311. 37	$a^3D_3-v^3P_2^\circ$	(0. 00) 1. 15	(**0. 00**, 0. 17, 0. 33) **1. 00**, 1. 17, 1. 33, ---
224	4, 478. 45	2		22, 322. 92	$a^5F_5-z^3H_5^\circ$		
206	4, 470. 55	10	15, III	22, 362. 36	$a^3G_5-y^3H_6^\circ$	(0. 00) 0. 98 A1*	(**0. 00**, 0. 03, 0. 07, ---) **1. 00**, 1. 03, 1. 07, ---
219	4, 470. 31	6	5, IV	22, 363. 56	$b^3F_4-y^3H_5^\circ$		
224	4, 469. 50	2		22, 367. 61	$a^5F_4-z^3H_4^\circ$		

TABLE 3.—*Wave lengths in the arc spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities, temperature class, and notes: B. S.	King	Wave No.	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
207	4,468.78	5	3, II	22,370.71	$a^3P_2-x^3D_3^\circ$	(0.00) 1.16	(0.33, **0.67**) 0.83, **1.17**, **1.50**, 183
225	4,468.22	3		22,374.02	$a^5P_3-w^5D_2^\circ$		
208	4,466.90	7	10, II	22,380.63	$a^1D_2-w^3D_3^\circ$	(0.00) 1.44*	(**0.00**, 0.33, 0.67) --- 1.33, 1.67, **2.00**
226	4,462.27	1		22,403.84	$a^5P_2-u^3F_3^\circ$		
227	4,460.33	1		22,413.60	$a^1D_2-x^1D_2^\circ$		
228	4,460.00	1		22,415.24	$a^3D_1-u^3P_0^\circ$		
229	4,459.02	4	2, II	22,420.17	$a^3F_4-y^3D_3^\circ$		
230	4,457.92	2		22,425.70	$b^1G_4-u^3G_5^\circ$		
231					$a^3D_3-s^3F_2^\circ$		
225	4,457.42	10 Zr II		22,428.23	$a^5P_2-w^5D_1^\circ$	(0.00, **1.31**) **1.36**, 2.10	(**0.00**, 0.33) 1.50, 1.83, **2.17**
220	4,456.29	6	3, IV	22,433.90	$a^3H_5-v^3G_6^\circ$	(0.50) 0.75	(--- 0.67, **0.83**) --- 0.87, **1.03**, **1.20**, 1.37, ---
220	4,455.43	5	2, IV	22,438.23	$a^3H_4-v^3G_4^\circ$	(0.75) 1.08	(--- 0.75, **1.00**) --- 0.55, **0.80**, **1.05**, 1.30, ---
211	4,451.34	1		22,458.84	$a^5F_2-w^3D_3^\circ$		
225	4,450.27	7	5, IV	22,464.24	$a^5P_1-w^5D_0^\circ$	(0.00) 2.49*	(0.00) 2.50
232	4,448.94	3	2, IV	22,471.00	$a^1D_2-y^3P_1^\circ$		
233					$a^5P_2-u^3D_1^\circ$		
234	4,448.00	3		22,475.75	$b^1D_2-x^1P_1^\circ$		
219	4,444.33	4	2, V	22,494.30	$b^3F_3-y^3H_4^\circ$		
235	4,438.04	8	8, II	22,526.17	$a^3P_1-w^3D_1^\circ$	(0.96) 0.50, 1.43	(1.00) 0.50, 1.50
236	4,436.76	3		22,532.67	$a^3D_3-v^3G_4^\circ$		
	4,436.08	1		22,536.17			
	4,435.84	2		22,537.34			
	4,435.48	1		22,539.17			
225	4,431.48	8	10, III	22,559.51	$a^5P_1-w^5D_1^\circ$	(1.01) 1.49, 2.49*	(1.00) 1.50, 2.50
237	4,431.11	3		22,561.40	$c^3P_2-x^1P_1^\circ$		
232	4,429.09	4	3, III	22,571.68	$a^1D_2-y^3P_2^\circ$	(0.44) 1.42	(0.50, **1.00**) 0.50, **1.00**, **1.50**, 2.00
238	4,428.86	1		22,572.85	$z^5F_5^\circ-f^5F_4$		
239	4,428.38	1		22,575.30	$b^1D_2-v^1F_3^\circ$		
240	4,427.24	6		22,581.12	$a^1H_5-u^1G_4^\circ$	(0.00) 0.99*	(0.00) 1.00
236	4,424.98	2		22,592.64	$a^3D_2-v^3G_3^\circ$		
233	4,423.27	1		22,601.37	$a^5P_1-u^3D_1^\circ$		
225	4,420.45	10	12, III	22,615.79	$a^5P_2-w^5D_2^\circ$	(0.35, **0.65**) 1.64B*	(0.33, **0.67**) 1.17, **1.50**, **1.83**, 2.17
241	4,420.25	1		22,616.81	$a^5F_4-w^3F_3^\circ$		
228	4,419.31	1		22,621.62	$a^3D_2-u^3P_1^\circ$		
241	4,418,25	3		22,627.04	$a^5F_3-w^3F_2^\circ$		
220	4,417.46	1		22,631.09	$a^3H_4-v^3G_5^\circ$		
241	4,415.85	5		22,639.34	$a^5F_5-w^3F_4^\circ$		
237	4,414.89	2		22,644.26	$c^3P_1-x^1P_1^\circ$		
242	4,414.14	4	2, II	22,648.20	$a^3F_4-y^5D_3^\circ$		
225	4,413.04	10	12, II	22,653.75	$a^5P_3-w^5D_3^\circ$	(0.47) 1.57*	(0.17, 0.33, **0.50**) --1.33, **1.50** **1.67**, 1.83, ---
212	4,411.92	2		22,659.55	$a^3D_2-v^3P_2^\circ$		
224					$a^5F_5-z^3H_4^\circ$		
243	4,411.62	2		22,661.10	$c^3P_2-v^1F_3^\circ$		
224	4,409.63	3		22,671.31	$a^5F_4-z^3H_5^\circ$		
244	4,408.32	1		22,678.05	$a^3H_4-s^3F_3^\circ$		
235	4,402.96	6	4, II	22,705.65	$a^3P_0-w^3D_1^\circ$		
235	4,400.89	1		22,716.33	$a^3P_2-w^3D_1^\circ$		
224	4,400.23	7	5, II	22,719.69	$a^5F_5-z^3H_6^\circ$	(0.00) 0.00*w*	(**0.00**, 0.23, 0.47, ---) **0.00**, 0.23, 0.47, ---
235	4,395.20	7	6, ?	22,745.72	$a^3P_1-w^3D_2^\circ$		
225	4,394.94	10	8, IV	22,747.08	$a^5P_1-w^5D_2^\circ$	(**0.00**, 0.97) **0.43**, 1.60	(**0.00**, 1.00) **0.50**, 1.50, 2.50
229	4,394.49	4	2, II	22,749.41	$a^3F_3-y^3D_2^\circ$		
222	4,394.29	2		22,750.44	$a^3F_2-y^1D_2^\circ$		
	4,392.73	2 Cb?		22,758.52			
231	4,390.15	2		22,771.88	$a^3D_3-s^3F_3^\circ$		
231	4,389.61	2		22,774.69	$a^3D_2-s^3F_2^\circ$		
245					$a^1D_2-w^3F_2^\circ$		
238	4,386.47	2		22,790.98	$z^5F_5^\circ-f^5F_5$		
	4,382.73	1		22,810.43			

TABLE 3.—*Wave lengths in the arc spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities, temperature class, and notes		Wave No.	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
		B. S.	King				
238	4,380.75	1		22,820.73	$z^5F_4^\circ-f^5F_3$		
228	4,375.65	1		22,847.32	$a^3D_1-u^3P_1^\circ$		
246	4,373.07	5	2, V	22,860.83	$a^5F_5-x^3G_4^\circ$	(0.00) 2.10	(0.00, 0.35, 0.70, ---) ---2.10 2.45, 2.80
246	4,372.52	2		22,863.73	$a^5F_4-x^3G_3^\circ$		
	4,371.63	1		22,868.43			
212	4,368.41	2 Cb?		22,885.23	$a^3D_1-v^3P_2^\circ$		
225	4,366.45	10	15, II	22,895.51	$a^5P_2-w^5D_3^\circ$	(0.00, 0.38, 0.69) 0.80, 1.15*	(0.00, 0.33, 0.67) 0.83, 1.17, 1.17, 1.50, ---
	4,366.18	1		22,896.92			
	4,364.67	1		22,904.83			
242	4,361.94	2		22,919.16	$a^3F_3-y^5D_2^\circ$		
207	4,360.80	10	15, II	22,925.15	$a^3P_2-x^3D_3^\circ$	(0.00) 1.47*	(0.00, 0.17, 0.33) 1.00, 1.17, 1.33, ---
244	4,359.25	1		22,933.31	$a^3H_5-s^3F_4^\circ$		
235	4,358.74	6	4, II	22,935.98	$a^3P_2-w^3D_2^\circ$	(0.00) 1.24*	(0.33, 0.67) 0.83, 1.17, 1.50 1.83
	4,353.91	4		22,961.43			
	4,350.56	1		22,979.11			
233	4,350.07	4		22,981.69	$a^5P_3-u^3D_3^\circ$		
	4,349.39	1		22,985.29			
241	4,348.93	4	2, IV	22,987.72	$a^5F_4-w^3F_4^\circ$	(0.69) 1.11	(--- 0.30, 0.40) --- 1.15, 1.25, 1.35, 1.45, ---
	4,348.10	2		22,992.11			
247	4,347.89	25	30, II	22,993.21	$a^1G_4-y^1G_4^\circ$	(0.00) 1.01*	(0.00) 1.00
	4,347.37	2		22,995.96			
248	4,347.23	3	2, IV	22,996.70	$a^3F_3-y^3F_3^\circ$		
231	4,346.53	5	4, IV	23,000.41	$a^3D_1-s^3F_2^\circ$	(0.00) 0.76	(0.00, 0.17) 0.50, 0.67, 0.83
241	4,345.58	2		23,005.43	$a^5F_1-u^3F_2^\circ$		
249	4,345.05	1		23,008.24	$a^3G_5-z^3I_6^\circ$		
	4,344.92	1		23,008.92			
238	4,343.40	2		23,016.99	$z^5F_5^\circ-f^5F_4$		
229	4,343.04	4	4, II	23,018.90	$a^3F_2-y^3D_1^\circ$	(0.00) 0.95	(0.00, 0.17) 0.50, 0.67, 0.83
249	4,342.65	1		23,020.95	$a^3G_4-z^3I_5^\circ$		
248	4,341.49	1		23,027.10	$a^3F_3-y^3F_2^\circ$		
225	4,341.13	20	20, II	23,029.00	$a^5P_3-w^5D_4^\circ$	(0.00 *w*) 1.06A1*	(0.00, 0.17, ---) 1.00, 1.17, 1.33, ---
250	4,338.11	1		23,045.03	$a^3G_4-t^3F_3^\circ$		
245	4,336.11	2		23,055.71	$a^1D_2-w^3F_3^\circ$		
229	4,329.56	3	3, II	23,090.58	$a^3F_3-y^3D_3^\circ$		
246	4,325.44	10	15, II	23,112.56	$a^5F_5-x^3G_5^\circ$		
231	4,324.03	5	4, IV	23,120.10	$a^3D_2-s^3F_3^\circ$	(0.00) 0.95	(0.00, 0.08, 0.17) 0.92, 1.00, 1.08, ---
251	4,323.90	2		23,120.80	$b^3F_2-y^5P_3^\circ$		
244	4,322.23	0		23,129.73	$a^3H_4-s^3F_4^\circ$		
241	4,321.44	2		23,133.96	$a^5F_2-w^3F_3^\circ$		
242	4,321.17	6	4, II	23,135.41	$a^3F_4-y^5D_4^\circ$		
252	4,319.05	5	3, IV	23,146.76	$a^3F_4-y^1F_3^\circ$	(0.00) 1.12	(0.00, 0.25, ---)---1.50, 1.75, 2.00
	4,313.98	1		23,173.95			
253	4,310.48	1		23,192.76	$a^5P_3-y^3H_4^\circ$		
254	4,309.82	4	3, IV	23,196.31	$a^3P_1-y^5P_1^\circ$	(0.00) 1.44	(0.00) 1.50
	4,309.10	3		23,200.19			
246	4,307.42	0		23,209.24	$a^5F_4-x^3G_4^\circ$		
255	4,307.22	1		23,210.31	$b^3F_2-w^1D_2^\circ$		
	4,305.03	2		23,222.11			
231	4,304.68	8	8, III	23,224.00	$a^3D_2-s^3F_3^\circ$	(0.00) 1.01*	(0.00, 0.08, ---) 1.00, 1.08,
233					$a^5P_2-u^3D_3^\circ$		1.17, ---
254					$a^3P_1-y^3F_0^\circ$	(0.00) 1.46*	(0.00) 1.50
250	4,303.75	0		23,229.02	$a^3G_5-t^3F_4^\circ$		
238	4,303.38	1		23,231.07	$z^5F_5^\circ-f^5F_3$		
256	4,302.88	15	15, II	23,233.71	$a^5F_5-y^5F_4^\circ$	(0.00) 1.53*	(0.00, 0.05, 0.10, ---)---1.50. 1.55, 1.60
238	4,302.57	3		23,235.39	$z^5F_4^\circ-f^5F_5$		
250	4,301.58	3		23,240.79	$a^3G_4-t^3F_4^\circ$		
	4,298.92	2		23,255.16			
	4,295.17	2		23,275.46			

TABLE 3.—*Wave lengths in the arc spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities, temperature class, and notes		Wave No.	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
		B. S.	King				
256	4,294.78	18	20, II	23,277.58	$a^5F_4-y^5F_3^\circ$	(0.00) 1.51 A²*	(**0.00**, 0.10, 0.20, 0.30) --- 1.45, 1.55, **1.65**
241	4,294.47	3	2, IV	23,279.23	$a^5F_3-w^3F_4^\circ$		
235	4,291.34	6	8, III	23,296.21	$a^3P_2-w^3D_3^\circ$	(0.00) 1.47*	(**0.00**, 0.17, 0.33) **1.00**, 1.17, 1.33, ---
254	4,291.18	5	5, II	23,297.10	$a^3P_1-y^3P_2^\circ$	(0.00) 1.45*	(0.00) 1.50
	4,290.44	2		23,301.11			
257	4,290.20	4		23,302.42	$a^1D_2-x^3G_3^\circ$		
250					$a^3G_3-t^3F_3^\circ$		
242	4,287.20	1		23,318.72	$a^3F_3-y^5D_3^\circ$		
229	4,286.96	2		23,320.03	$a^3F_2-y^3D_2^\circ$		
258	4,285.24	2		23,329.37	$b^1D_2-v^1D_2^\circ$		
259					$a^3P_2-x^1D_2^\circ$		
	4,284.73	3		23,332.16			
256	4,282.20	15	20, II	23,345.94	$a^5F_3-y^5F_2^\circ$	(0.00) 1.54, **1.77***	(**0.00**, 0.25, 0.50) ---1.25, 1.50, **1.75**
260	4,282.03	3		23,346.87	$z^5F_4^\circ-e^5G_4$		
261	4,280.31	4		23,356.24	$a^3H_6-z^1I_6^\circ$		
254	4,276.71	5	5, III	23,375.90	$a^3P_0-y^3P_1^\circ$	(0.00) 1.50	(0.00) 1.50
254	4,274.76	7	5, III	23,386.56	$a^3P_2-y^3P_1^\circ$	(0.00) 1.08	(0.00) 1.50
249	4,272.25	3		23,400.30	$a^3G_5-z^3I_6^\circ$		
262	4,269.62	3		23,414.71	$c^3P_2-v^1D_2^\circ$		
256	4,268.01	15	20, II	23,423.54	$a^5F_2-y^5F_1^\circ$	(**0.00**, 0.98) 0.00, 0.99, **1.98***	(**0.00**, 1.00) 0.00, 1.00, **2.00**
238	4,267.30	1		23,427.43	$z^5F_2^\circ-f^5F_4$		
248	4,265.75	3		23,435.94	$a^3F_3-y^3F_4^\circ$		
263	4,265.13	1		23,439.34	$b^3F_4-z^3I_5^\circ$		
	4,264.02	2		23,445.45			
	4,261.92	1		23,457.00			
264	4,261.42	4	3, V	23,459.78	$a^3G_4-t^3D_3^\circ$		
246	4,261.20	4	4, III	23,460.96	$a^5F_4-x^3G_5^\circ$		
265	4,260.77	2		23,463.32	$b^3F_4-t^3F_4^\circ$		
260	4,260.38	1		23,465.48	$z^5F_3^\circ-e^5G_3$		
272	4,258.32	1		23,476.88	$c^3P_1-t^3P_0^\circ$		
261	4,256.44	5	4, III	23,487.24	$a^3H_5-z^1I_6^\circ$	(0.24) **1.35**	(0.00) 1.50
254					$a^3P_2-y^3P_2^\circ$		
242	4,256.04	2	1, IV	23,489.46	$a^3F_2-y^5D_2^\circ$		
	4,255.86	1		23,490.42			
271	4,255.32	1		23,493.42	$a^1D_2-y^5F_2^\circ$		
270	4,253.56	5	4, IV	23,503.13	$a^5F_3-y^5F_2^\circ$	(0.00) 1.96 A²	(**0.00**, 0.17, 0.33) **1.33**, 1.50, 1.67, ---
265	4,243.56	3		23,558.51	$b^3F_3-t^3F_2^\circ$	(0.00) 1.30	(**0.00**, 0.42, 0.83) ---1.08, 1.50, **1.92**
266	4,242.61	2		23,563.79	$a^3G_5-x^1G_4^\circ$		
267	4,242.01	3	2, IV	23,567.12	$b^1G_4-w^1G_4^\circ$		
248					$a^3F_2-y^3F_3^\circ$		
256	4,241.68	18	80, II	23,568.96	$a^5F_3-y^5F_3^\circ$	(0.00) 1.26*	(0.00) 1.25
268	4,241.43	3 Cb?		23,570.34	$a^1H_5-x^1H_5^\circ$		
256	4,241.20	15	50, II	23,571.62	$a^5F_2-y^5F_2^\circ$	(0.00) 1.01*	(0.00) 1.00
256	4,240.35	18	50, II	23,576.34	$a^5F_1-y^5F_1^\circ$	(0.00) 0.00*	(0.00) 0.00
256	4,239.31	25	150, II	23,582.13	$a^5F_4-y^5F_4^\circ$	(0.00) 1.32*	(0.00) 1.35
	4,238.34	3		23,587.52			
269	4,237.42	6	4, IV	23,592.64	$a^5P_3-w^1D_2^\circ$	(0.00) 1.96	(**0.00**, 0.17, 0.33) **1.33**, 1.50, 1.67, ---
238	4,237.19	4		23,593.92	$z^5F_2^\circ-f^5F_3$		
248	4,236.56	5		23,597.43	$a^3F_2-y^3F_2^\circ$		
270	4,236.04	7	6, III	23,600.32	$a^5P_2-y^5P_1^\circ$	(**0.00**, 0.62) **1.24**, 1.84*	(**0.00**, 0.67) **1.17**, 1.83, 2.50
	4,235.04	1		23,605.89			
273	4,234.63	8	7, II	23,608.18	$a^1D_2-x^3P_1^\circ$	(0.00*w*) 1.13*	(**0.00**, 0.50) **0.50**, 1.00, 1.50
	4,232.08	2		23,622.40			
256	4,227.76	30	200, II	23,646.56	$a^5F_5-y^5F_5^\circ$	(0.00) 1.37*	(0.00) 1.40
265	4,225.49	4		23,659.25	$b^3F_4-t^3F_4^\circ$	(0.00) 1.41	(0.00) 1.25
229	4,225.25	3		23,660.58	$a^3F_2-y^3D_3^\circ$		
274					$a^5F_1-x^3P_2^\circ$		
260	4,224.65	4	2*n*, V	23,663.94	$z^5F_5^\circ-e^5G_6$		

TABLE 3.—*Wave lengths in the arc spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities, temperature class, and notes		Wave No.	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
		B. S.	King				
274	4, 220. 65	3	2, III	23, 686. 41	$a^5F_2-x^3P_1^0$		
275	4, 219. 94	0		23, 690. 40	$a^3P_2-w^3F_2^0$		
276	4, 218. 44	6	6, III	23, 698. 79	$a^1D_2-v^3D_1^0$	(0. 00) 1. 68	(**0. 00**, 0. 50) 0. 50, 1. 00, **1. 50**
260	4, 217. 25	3		23, 705. 50	$z^5F_4^0-e^5G_5^0$		
264 271	4, 215. 31	1		23, 716. 41	$a^3G_3-t^3D_3^0$ $a^1D_2-y^5F_3^0$		
256	4, 213. 86	10	15, III	23, 724. 55	$a^5F_1-y^5F_2^0$	(**0. 00**, 0. 98) 0. 00, 0. 99, **2. 00***	(**0. 00**, **1. 00**) 0. 00, 1. 00, **2. 00**
270	4, 212. 63	4		23, 731. 49	$a^5P_1-y^5P_1^0$		
277	4, 212. 16	1		23, 734. 14	$a^5F_4-v^3D_3^0$		
278	4, 211. 34	4		23, 738. 76	$a^3D_3-s^3D_3^0$	(0. 00) 1. 41	(0. 00) 1. 33
260	4, 208. 09	3		23, 757. 09	$z^5F_3^0-e^5G_4^0$		
256	4, 201. 45	18	20, III	23, 794. 63	$a^5F_2-y^5F_3^0$	(0. 00*w*) 1. 69 A²*	(**0. 00**, 0. 25, 0. 50) 1. 25, 1. 50, **1. 75**
273	4, 199. 08	15	20, III	23, 808. 05	$a^1D_2-x^3P_2^0$	(0. 42) 1. 39 B*	(0. 50, **1. 00**) 0. 50, **1. 00**, **1. 50**, 2. 00
279	4, 197. 76	2		23, 815. 53	$b^3F_2-w^3P_2^0$		
280	4, 196. 14	4		23, 824. 73	$a^3G_5-x^3H_5^0$		
270	4, 194. 76	8	10, V	23, 832. 57	$a^5P_3-y^5P_3^0$	(0. 00) 1. 66*	(0. 00) 1. 67
269	4, 194. 46	2		23, 834. 27	$a^5P_2-w^1D_2^0$		
280	4, 194. 01	3		23, 836. 83	$a^3G_4-x^3H_5^0$		
280	4, 192. 10	4		23, 847. 68	$a^3G_4-x^3H_4^0$		
265	4, 191. 80	5		23, 849. 38	$b^3F_3-t^3F_3^0$	(0. 00) 1. 03	(0. 00) 1. 08
265 256	4, 187. 56	15	20, III	23, 873. 59	$b^3F_2-t^3F_2^0$ $a^5F_3-y^5F_4^0$	(0. 00) 1. 64*	(**0. 00**, 0. 10, ---) 1. 45, 1. 55, **1. 65**
270	4, 187. 12	3		23, 876. 06	$a^5P_1-y^5P_2^0$	(0. 00) 0. 32*	(**0. 00**, 0. 67) **1. 17**, 1. 83, 2. 50
281	4, 186. 79	3		23, 877. 98	$b^3F_4-t^3D_3^0$		
	4, 186. 05	1		23, 882. 20			
282	4, 183. 31	6	10, III	23, 897. 80	$a^1D_2-z^1P_1^0$	(**0. 00**, 0. 47) 1. 26, **1. 76***	(0. 00) 1. 00
278	4, 179. 07	1		23, 922. 07	$a^3D_2-s^3D_1^0$		
276	4, 173. 13	2		23, 956. 11	$a^1D_2-v^3D_2^0$		
269	4, 171. 47	6		23, 965. 64	$a^5P_1-w^1D_2^0$	(0. 00, 1. 07) 0. 29*	(**0. 00**, 1. 50) **0. 50**, 1. 00, 2. 50
275	4, 170. 48	1		23, 971. 33	$a^3P_2-w^3F_3^0$		
283	4, 169. 67	1		23, 975. 99	$a^5F_2-z^1P_1^0$		
278	4, 169. 36	4		23, 977. 77	$a^3D_2-s^3D_2^0$		
	4, 168. 45	3		23, 983. 00			
284	4, 166. 51	4		23, 994. 17	$b^3F_4-x^1G_4^0$	(0. 00) 1. 35	(---0. 75, **1. 00**) ---0. 75, **1. 00**, **1. 25**, 1. 50, ---
256	4, 166. 37	8	10, II	23, 994. 97	$a^5F_4-y^5F_5^0$	(0. 00) 1. 47*	(**0. 00**, 0. 05, 0. 10, ---) --- 1. 50, 1. 55, **1. 60**
285	4, 165. 63	1		23, 999. 23	$a^3G_4-w^1F_3^0$		
277	4, 159. 54	3		24, 034. 36	$a^5F_2-v^3D_2^0$		
265	4, 157. 70	1		24, 044. 99	$b^3F_3-t^3F_4^0$		
280	4, 153. 75	3		24, 067. 85	$a^3G_5-x^3H_6^0$		
270	4, 152. 64	7+Cb	10, IV	24, 074. 28	$a^5P_2-y^5P_3^0$	(0. 00) 1. 43	(**0. 00**, 0. 17, 0. 33) **1. 33**, 1. 50, 1. 67, ---
278	4, 150. 47	1		24, 086. 87	$a^3D_2-s^3D_3^0$		
280	4, 147. 36	3		24, 104. 98	$a^3G_3-x^3H_4^0$	(0. 00) 1. 08	(**0. 00**, 0. 05, ---) ---0. 85, 0. 90, **0. 95**
278	4, 140. 01	3		24, 147. 76	$a^3D_1-s^3D_1^0$	(0. 00) 0. 00*w*	(0. 00) 0. 50
276	4, 135. 68	6	10, II	24, 173. 02	$a^1D_2-v^3D_3^0$	(0. 00) 1. 41*	(**0. 00**, 0. 33, 0. 67) ---1. 33, 1. 67, **2. 00**
286	4, 134. 32	4		24, 180. 99	$a^3G_4-v^3G_3^0$	(0. 00) 1. 49	(**0. 00**, 0. 30, ---) ---1. 35, **1. 65**, **1. 95**
287	4, 133. 70	2		24, 184. 62	$a^3D_3-r^3F_3^0$		
288	4, 133. 52	1		24, 185. 67	$a^3H_5-r^3F_4^0$		
278	4, 130. 46	2		24, 203. 58	$a^3D_1-s^3D_2^0$		
289	4, 128. 30	2		24, 216. 24	$z^5G_4^0-e^5H_5^0$		
290 291	4, 127. 97	4		24, 218. 18	$a^3P_2-x^3G_3^0$ $a^3P_1-y^5F_2^0$		
292	4, 121. 67	3		24, 255. 18	$b^3F_4-x^3H_5^0$		
285 293	4, 121. 45	10	30, III	24, 256. 48	$a^3G_3-w^1F_3^0$ $a^3P_1-x^3P_0^0$	(0. 00)‖1. 51*	(0. 00) 1. 50
281	4, 120. 16	2		24, 264. 07	$b^3F_3-t^3D_3^0$		
292	4, 119. 83	4		24, 266. 01	$b^3F_4-x^3H_4^0$		
289 294	4, 110. 66	2		24, 320. 13	$z^5G_5^0-e^5H_5^0$ $a^5P_1-w^3P_1^0$		
293	4, 108. 39	8	15, III	24, 333. 62	$a^3P_1-x^3P_1^0$	(0. 00) 1. 48*	(0. 00) 1. 50

TABLE 3.—*Wave lengths in the arc spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities, temperature class, and notes		Wave No.	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
		B. S.	King				
281	4, 107. 50	7	8, V	24, 338. 89	$b^3F_3-t^3D_2^\circ$	(0. 00) 0. 86*	(**0. 00**, 0. 08, 0. 17) **0. 92**, 1. 00, 1. 08, ---
252	4, 099. 31	4	4, III	24, 387. 51	$a^3F_2-y^1F_3^\circ$	(0. 00) 1. 70	(**0. 00**, 0. 33, 0. 67) ---1. 00, 1. 33, **1. 67**
295	4, 094. 26	5	3, II?	24, 417. 57	$b^3F_4-w^1F_3^\circ$	(0.00) 1. 31	(**0.00**, 0. 25, ---) ---, 1. 50, 1.75, **2.00**
296	4, 093. 16	3		24, 424. 14	$a^3P_1-v^3D_1^\circ$	(0. 00, **0.81**) **0.60**, 1. 50	(1. 00) 0. 50, 1. 50
286	4, 090. 78	6	5, V	24, 438. 34	$a^3G_3-z^3G_3^\circ$	(0. 00) 0. 50	(0. 00) 0. 75
	4, 088. 20	2		24, 453. 76			
286	4, 087. 68	4	3, II	24, 456. 87	$a^3G_5-v^3G_4^\circ$	(0. 00) 1. 57	(**0.00**, 0. 15, ---) ---, 1. 50, 1. 65, **1.80**
286	4, 085. 68	6		24, 468. 84	$a^3G_4-v^3G_3^\circ$		
287	4, 084. 29	5	4, IV	24, 477. 17	$a^3D_3-r^3F_4^\circ$	(0. 00) 1. 06*	(**0.00**, 0. 08, ---) **1.00**, 1. 08, 1. 17, ---
281	4, 083. 08	4	4, II	24, 484. 43	$b^3F_2-t^3D_1^\circ$	(0. 00) 0. 68*	(**0.00**, 0. 17) 0. 50, 0. 67, **0. 83**
297	4, 082. 29	4	3, II	24, 489. 16	$a^3F_4-y^3G_3^\circ$		
298	4, 081. 22	40	100, II	24, 495. 59	$a^5F_5-x^5D_4^\circ$	(0. 00*w*) 1. 08A1*	(**0. 00**, 0. 10, ---) **1. 00**, 1. 10, 1. 20, ---
293	4, 078. 31	7	12, II	24, 513. 06	$a^3P_0-x^3P_1^\circ$	(0. 00) 1. 42*	(0. 00) 1. 50
293	4, 076. 53	5	10, III	24, 523. 75	$a^3P_2-x^3P_1^\circ$	(0. 00) 1. 13	(0. 00) 1. 50
287	4, 075. 05	4		24, 532. 65	$a^3D_2-r^3F_3^\circ$		
293	4, 074. 93	6	15, II	24, 533. 40	$a^3P_1-x^3P_2^\circ$	(0. 00) 1. 50	(0. 00) 1. 50
303	4, 074. 35	1		24, 536. 87	$a^1H_5-q^3F_4^\circ$		
298	4, 072. 71	30	100, II	24, 546. 75	$a^5F_4-x^5D_3^\circ$	(0. 00) 1. 14	(**0. 00**, 0. 15, ---) **0. 90**, 1. 05, 1. 20, ---
	4, 069. 53	1		24, 565. 98			
294	4, 068. 71	5	4, II	24, 570. 93	$a^5P_1-w^3P_2^\circ$	(**0. 00**, 1. 01) 0. 44, 1. 40	(**0. 00**, 1. 00) **0. 50**, 1. 50, 2. 50
298	4, 064. 16	30	100, II	24, 598. 41	$a^5F_3-x^5D_2^\circ$	(0. 00) 0. 95	(**0. 00**, 0. 25, 0. 50) **0. 75**, 1. 00, 1. 25, ---
296	4, 063. 32	2		24, 603. 51	$a^3P_0-v^3D_1^\circ$		
	4, 062. 65	4		24, 607. 55			
296	4, 061. 53	10	15, II	24, 614. 33	$a^3P_2-v^3D_2^\circ$	(**0. 00**, 0. 46) 1. 60	(**0. 00**, 1. 00) 0. 50, 1. 50, **2. 50**
299	4, 060. 58	4	4, IV	24, 620. 09	$a^3G_3-s^3F_2^\circ$	(0. 00) 0. 93	(**0. 00**, 0. 08, 0. 17) ---, 0. 75, 0. 83, **0. 92**
300	4, 060. 08	3	2, IV	24, 623. 14	$a^3P_1-z^1P_1^\circ$		
	4, 059. 23	1		24, 628. 29			
301	4, 058. 98	5		24, 629. 82	$a^5P_1-t^3F_2^\circ$		
291	4, 058. 63	3	3, IV	24, 631. 93	$a^3P_2-y^5F_3^\circ$	(0. 00) 0. 80	(**0. 00**, 0. 25, 0. 50) **0. 75**, 1. 00, 1. 25, ---
	4, 057. 06	3		24, 641. 47			
272	4, 056. 50	3		24, 644. 87	$c^3P_2-t^3P_2^\circ$		
286	4, 055. 71	10	20, V	24, 649. 66	$a^3G_5-v^3G_5^\circ$	(0. 00) 1. 19	(0. 00) 1. 20
292	4, 055. 30	2		24, 652. 16	$b^3F_3-x^3H_4^\circ$		
298	4, 055. 03	20	60, II	24, 653. 79	$a^5F_2-x^5D_1^\circ$	(**0. 00**, 0. 48) **0. 48**, 1. 00	(**0. 00**, 0. 50) **0. 50**, 1. 00, 1. 50
302	4, 054. 43	6	10, II	24, 657. 44	$a^3F_4-z^5P_3^\circ$	(0. 00) 0. 50	(**0. 00**, 0. 42, ---) **0. 00**, 0. 42, 0. 83, ---
286	4, 053. 67	2		24, 662. 07	$a^3G_4-v^3G_5^\circ$		
	4, 052. 99	3		24, 666. 21			
296	4, 050. 48	5	10, II	24, 681. 48	$a^3P_1-v^3D_2^\circ$		
299	4, 046. 08	3		24, 708. 32	$a^3G_4-s^3F_3^\circ$		
298	4, 044. 57	12	25, II	24, 717. 54	$a^5F_1-x^5D_0^\circ$	(0. 00) 0. 00	(0. 00) 0. 00
293	4, 043. 57	15	30, II	24, 723. 65	$a^3P_2-x^3P_3^\circ$	(0. 49) 1. 33	(0. 00) 1. 50
304	4, 042. 23	7	10, IV	24, 731. 84	$a^5P_3-y^5S_2^\circ$	(0. 00) 1. 24	(**0. 00**, 0. 33, 0. 67) **1. 00**, 1. 33, 1. 67, ---
289	4, 041. 63	4	5, IV	24, 735. 53	$z^5G_5^\circ-e^5H_4$	(0. 00) 1. 48	(**0. 00**, 0. 17, ---) ---, 1, 67,
305					$a^3H_6-y^1H_5^\circ$		1. 83, **2. 00**
297	4, 035. 89	15	40, II	24, 770. 69	$a^3F_4-y^3G_4^\circ$	(0. 60) 1. 17	(---, 0. 60, **0. 80**) ---, 0. 85, **1. 05**, **1. 25**, 1. 45, ---
	4, 033. 56	2		24, 784. 99			
301	4, 032. 78	3		24, 789. 79	$a^5P_2-t^3F_3^\circ$		
	4, 032. 47	2		24, 791. 69			
300	4, 030. 75	3	3, IV	24, 802. 62	$a^3P_0-z^1P_1^\circ$	(0. 00) 0. 86	(0. 00) 1. 00
298	4, 030. 03	15	5, II	24, 806. 63	$a^5F_1-x^5D_1^\circ$		
300	4, 028. 95	7	15, III	24, 813. 37	$a^3P_2-z^1P_1^\circ$	(0. 00) 1. 57	(**0. 00**, 0. 50) 1. 00, 1. 50, **2. 00**
	4, 027. 31	2		24, 823. 51			
298	4, 027. 20	20	15, II	24, 824. 03	$a^5F_2-x^5D_2^\circ$	(0. 98) 0. 73, **1. 23**, 1. 75	(0. 50, **1. 00**) 0. 50, **1. 00**, **1. 50**, 2. 00

TABLE 3.—*Wave lengths in the arc spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities, temperature class, and notes		Wave No.	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
		B. S.	King				
298	4,024.92	18	15, II	24,838.22	$a^5F_3-x^5D^\circ_3$	(0.66) 1.25	(0.25, 0.50, **0.75**) ---, 1.00, **1.25**, **1.50**, 1.75, ---
298	4,023.99	15	30, II	24,843.96	$a^5F_4-x^5D^\circ_4$	(0.50) 1.39	(---, 0.45, **0.60**) ---, 1.20, **1.35**, **1.50**, 1.65, ---
306	4,023.29	2		24,848.30	$b^3F_2-v^3P^\circ_1$		
	4,023.04	3		24,849.85			
307	4,021.01	1		24,862.39	$z^5G^\circ_5-e^5G_4$		
	4,018.13	2		24,880.20			
308	4,017.00	5	8, IV	24,887.19	$b^3F_4-v^3G^\circ_4$	(0.39) 1.01	(---, 0.60, **0.80**) ---, 0.85, **1.05**, **1.25**, 1.45, ---
289	4,012.25	6	12, IV	24,916.65	$z^5G^\circ_4-e^5H_5$	(0.00) 0.85	(**0.00**, 0.05, ---) **0.90**, 0.95, 1.00, ---
	4,009.39	2		24,934.43			
309	4,007.59	8	15, IV	24,945.62	$a^3H_5-u^3G^\circ_4$	(0.00) 0.97	(**0.00**, 0.02, ---) **0.97**, 0.98, 1.00 ---
307 310	4,004.87	4	4*n*, IV	24,962.57	$z^5G^\circ_5-e^5G_6$ $a^5P_3-l^3D^\circ_3$	(0.00) 1.41	(0.00) 1.33
299	4,004.39	4	4, IV	24,965.56	$a^2G_3-s^3F^\circ_3$	(0.71) 0.90	(0.33, 0.67, **1.00**) ---, 0.42, **0.75**, **1.08**, 1.42, ---
304	4,003.09	6	12, IV	24,973.66	$a^5P_2-y^5S^\circ_2$	(0.26) 1.85	(0.17, **0.33**) 1.67, **1.83**, **2.00**, 2.17
298	4,002.55	5	8, IV	24,977.04	$a^5F_1-x^5D^\circ_2$		
308	4,001.22	2	2, V	24,985.32	$b^3F_3-r^3G^\circ_3$		
311	4,001.09	3	4, IV	24,986.13	$a^3F_4-x^1F^\circ_3$		
312	3,992.46	1		25,040.12	$a^3D_2-u^3G^\circ_3$		
	3,992.05	1		25,042.70			
309	3,989.50	6	12, V	25,058.74	$a^3H_6-u^3G^\circ_5$	(0.00) 1.20	(**0.00**, 0.03, ---) **1.00**, **1.03**, 1.07, ---
313	3,989.29	4	7, III	25,060.05	$a^3F_3-y^5G^\circ_2$		
305 298	3,988.68	5	10, IV	25,063.88	$a^3H_4-y^1H^\circ_5$ $a^5F_2-x^5D^\circ_3$		
302	3,986.80	4	5, V	25,075.71	$a^3F_3-z^5P^\circ_2$		
303	3,986.14	2		25,079.86	$b^3F_4-v^3G^\circ_5$		
296	3,984.75	8	20, III	25,088.57	$a^3P_2-v^3D^\circ_3$	(0.00) 1.41	(**0.00**, 0.17, 0.33) **1.00**, **1.17**, 1.33, ---
304	3,982.16	4	5, V	25,104.92	$a^5P_1-y^5S^\circ_2$		
310 289	3,981.59	10	20*n*, IV	25,108.53	$a^5P_2-l^3D^\circ_1$ $z^5G^\circ_6-e^5H_7$	(0.00) 1.21	(**0.00**, 0.05, ---) **1.00**, **1.05**, 1.10, ---
314 289	3,978.73	6	30*n*, III	25,126.57	$b^3F_4-s^3F^\circ_3$ $z^5G^\circ_5-e^5H_5$	(0.00) 1.32	(**0.00**, 0.17, ---) ---, **1.42**, 1.58, **1.75**
	3,978.26	3	2, V	25,129.53		(0.00) 0.94	
315	3,977.47	7	15, III	25,134.53	$a^1G_4-v^3F^\circ_3$	(0.00) 0.95	(**0.00**, 0.08, ---) **0.75**, 0.83, 0.92, ---
298	3,977.32	3	3, V	25,135.47	$a^5F_3-x^5D^\circ_4$		
309	3,976.17	2		25,142.74	$a^3H_4-u^3G^\circ_4$		
299	3,975.29	7	15, IV	25,148.31	$a^3G_5-s^3F^\circ_4$	(0.00) 1.10	(**0.00**, 0.05, ---) **1.00**, **1.05**, 1.10, ---
	3,974.20	2		25,155.20			
297	3,973.51	15	60, II	25,159.58	$a^3F_3-y^3G^\circ_3$	(0.51) 1.03	(0.33, 0.67, **1.00**) --- 0.42, **0.75**, **1.08**, 1.42, ---
299	3,973.39	3		25,160.33	$a^3G_4-s^3F^\circ_4$		
307 314	3,972.30	3	3, V	25,167.24	$z^5G^\circ_4-e^5G_3$ $b^3F_3-s^3F^\circ_2$		
	3,970.45	3		25,178.96			
297	3,968.25	18	80, II	25,192.91	$a^3F_4-y^3G^\circ_5$	(0.00) 1.05	(**0.00**, 0.05, ---) **1.00**, 1.05, 1.10, ---
316	3,966.65	8	6, II	25,203.07	$a^3F_4-x^3F^\circ_3$	(0.00) 1.52	(**0.00**, 0.17, ---) --- 1.42, 1.58, **1.75**
307	3,963.79	5	2*n*, V	25,221.27	$z^5G^\circ_5-e^5G_5$		
	3,957.41	3		25,261.90			
	3,956.52	3		25,267.58			
	3,955.81	2		25,272.15			
308	3,955.64	2		25,273.23	$b^3F_3-p^3G^\circ_4$		
317	3,952.87	2		25,290.94	$c^3P_2-q^3D^\circ_2$		
308	3,951.33	2		25,300.82	$b^3F_2-p^3G^\circ_3$		
318	3,941.62	5	5, IV	25,363.13	$a^1G_4-u^3F^\circ_3$	(0.00) 0.91	(**0.00**, 0.08, ---) **0.75**, 0.83, 0.92, ---
321 299	3,933.18	3	2, V	25,417.54	$a^3D_2-r^3D^\circ_2$ $a^3G_3-s^3F^\circ_4$		
297	3,929.53	30	150, II	25,441.15	$a^3F_3-y^3G^\circ_4$	(0.00) 1.03	(**0.00**, 0.03, ---) **0.95**, 0.98, 1.02, ---

TABLE 3.—*Wave lengths in the arc spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities, temperature class, and notes		Wave No.	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
		B. S.	King				
319	3, 927.41	3		25, 454.88	$a^3D_2-v^1F_3^0$		
307	3, 926.78	5	3*n*, V	25, 458.96	$z^5G_3^0-e^5G_2$	(0.00) 1.07	(0.00) 1.15
307					$z^5G_4^0-e^5G_4$		
320	3, 924.87	3		25, 471.35	$a^3P_1-x^5D_2^0$		
320	3, 923.46	3		25, 480.50	$a^3P_0-x^5D_1^0$		
316	3, 921.80	20	100, II	25, 491.30	$a^3F_3-x^3F_2^0$	(0.00) 1.81	(**0.00**, 0.42, 0.83) --- 1.08, 1.50, **1.92**
313	3, 916.64	6		25, 524.89	$a^3F_4-y^5G_5^0$	(0.00) 1.28	(**0.00**, 0.02, ---) --- 1.30, 1.32, **1.33**
	3, 906.14	1		25, 593.52			
307	3, 901.49	3		25, 624.01	$z^5G_5^0-e^5G_6$		
313	3, 900.51	10		25, 630.44	$a^3F_2-y^5G_2^0$	(0.00) 0.00 *w* A[2]	(0.33, **0.67**) 0.00, **0.33**, **0.67**, 1.00
321	3, 898.54	1		25, 643.40	$a^3D_1-r^3D_2^0$		
321	3, 897.65	4	3, V	25, 649.25	$a^3D_3-r^3D_3^0$	(0.00) 1.29	
311	3, 896.53	6	10, II	25, 656.62	$a^3F_3-x^1F_3^0$	(0.00) 1.06	(0.08, 0.17, **0.25**) 0.83, 0.92, **1.00**, **1.08**, 1.17, 1.25
317					$c^3P_2-q^3D_3^0$		
322	3, 893.84	3		25, 674.34	$a^3G_4-s^3D_3^0$		
307	3, 892.02	5	4*n*, IV	25, 686.35	$z^5G_3^0-e^5G_3$	(0.00) 1.09	(0.00) 0.92
323	3, 891.39	20	100, II	25, 690.50	$a^3F_4-z^1G_4^0$	(0.63) 1.15	(--- 0.75, **1.00**) --- 0.75, **1.00**, **1.25**, 1.50, ---
316	3, 890.32	25	125, II	25, 697.56	$a^3F_4-x^3F_4^0$	(0.26) 1.16	(0.00) 1.25
	3, 889.00	3		25, 706.28			
297	3, 885.41	20	100, II	25, 730.02	$a^3F_2-y^3G_3^0$	(0.00) 1.00	(**0.00**, 0.08, **0.17**) --- 0.75, 0.83, **0.92**
324	3, 882.39	2		25, 750.04	$a^5P_3-v^3P_2^0$		
313	3, 879.04	5	10, LA	25, 772.30	$a^3F_3-y^5G_4^0$	(0.00) 1.21	(**0.00**, 0.07, ---) --- 1.22, 1.28, **1.35**
325	3, 877.60	12	40, IV	25, 781.90	$a^1G_4-z^1H_5^0$	(0.00) 1.00	(0.00) 1.00
307	3, 872.18	3		25, 817.98	$z^5G_4^0-e^5G_5$		
322	3, 871.38	2		25, 823.31	$a^3G_3-s^3D_2^0$		
326	3, 864.33	10	40, ?	25, 870.41	$a^3F_4-x^3D_3^0$	(0.00) 1.19	(**0.00**, 0.08, ---) **1.00**, 1.08, 1.17, ---
316	3, 863.88	20	100, II	25, 873.41	$a^3F_3-x^3F_3^0$	(0.00) 1.08	(0.00) 1.08
307	3, 863.33	4		25, 877.11	$z^5G_2^0-e^5G_2$		
	3, 860.65	3		25, 895.06			
313	3, 849.26	10	30, II	25, 971.66	$a^3F_2-y^5G_3^0$	(0.00) 1.21	(**0.00**, 0.25, 0.50) --- 0.92, 1.17, **1.42**
326	3, 847.01	10	30, ?	25, 986.85	$a^3F_3-x^3D_2^0$	(0.00) 1.15	(**0.00**, 0.08, 0.17) **0.92**, 1.00, 1.08, ---
321	3, 845.45	2		25, 997.39	$a^3D_2-r^3D_3^0$		
327	3, 839.12	5		26, 040.31	$c^3P_2-w^3S_1^0$		
316	3, 835.96	20	100, II	26, 061.76	$a^3F_2-x^3F_2^0$	(0.00) 0.68	(0.00) 0.67
	3, 831.51	4		26, 092.02			
328	3, 831.30	3		26, 093.45	$b^3F_4-s^3D_3^0$		
	3, 825.27	6		26, 134.57			
329	3, 822.41	12	40, II	26, 154.11	$a^5F_4-w^3G_4^0$	(0.00) 0.76	(**0.00**, 0.17) 0.50, 0.67, **0.83**
326					$a^3F_2-x^3D_1^0$		
330	3, 809.70	2		26, 241.35	$a^3F_4-w^3D_3^0$		
329	3, 806.52	2		26, 263.26	$a^5F_5-w^3G_5^0$		
323	3, 792.40	4		26, 361.07	$a^3F_3-z^1G_4^0$	(0.00) 1.24	(**0.00**, 0.08, ---) **0.75**, 0.83, 0.92, ---
316	3, 791.39	12	80, II	26, 368.09	$a^3F_3-x^3F_4^0$	(0.00) 1.37	(**0.00**, 0.17, ---) --- 1.42, 1.58, **1.75**
328	3, 791.07	2		26, 370.33	$b^3F_3-s^3D_2^0$		
331	3, 784.86	1		26, 413.59	$a^3D_1-f^3P_0^0$		
332					$a^3G_4-r^3F_4^0$		
316	3, 780.53	18	100, II	26, 443.83	$a^3F_2-x^3F_3^0$	(0.00) 1.72	(**0.00**, 0.42, 0.83) --- 1.08, 1.50, **1.92**
328	3, 775.46	1		26, 479.33	$b^3F_3-s^3D_3^0$		
333	3, 766.95	1		26, 539.14	$b^3F_4-r^3F_3^0$		
326	3, 766.71	8	60, II	26, 540.85	$a^3F_3-x^3D_3^0$		
330	3, 765.18	2		26, 551.61	$a^3F_2-w^3D_2^0$		
326	3, 764.38	15	80, II	26, 557.25	$a^3F_2-x^3D_2^0$	(0.97) **0.78**, **1.21**, 1.67	(0.50, **1.00**) 0.17, **0.67**, **1.17**, 1.67
331	3, 754.79	2		26, 625.11	$a^3D_2-f^3P_1^0$		
328	3, 754.08	3		26, 630.17	$b^3F_2-s^3D_1^0$		

TABLE 3.—*Wave lengths in the arc spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities, temperature class, and notes		Wave No.	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
		B. S.	King				
334	3,737.40	3	5, IV	26,748.99	$a^1D_2-y^3S_1^\circ$	(0.00) 0.93	(0.00, 1.00)0.00, 1.00, 2.00
	3,736.50	1		26,755.42			
	3,731.44	1		26,791.69			
333	3,725.75	1		26,832.60	$b^3F_4-r^3F_4^\circ$		
331	3,723.20	1		26,851.04	$a^3D_1-t^3P_1^\circ$		
335	3,714.13	10	30, III	26,916.60	$a^3F_4-w^3F_3^\circ$	(0.00) 1.85	(0.00, 0.17, ---)---1.42, 1.58, 1.75
333 333	3,712.94	1		26,925.22	$b^3F_3-r^3F_3^\circ$ $b^3F_2-r^3F_2^\circ$		
336	3,706.63	7	10, III	26,971.05	$a^3F_4-z^3H_5^\circ$	(0.00) 0.00*w*	(0.00, 0.22, ---) 0.17, 0.38, 0.60, ---
	3,695.60	1		27,051.52			
331	3,690.33	1		27,090.14	$a^3D_3-t^3P_2^\circ$		
337	3,688.47	0		27,103.79	$a^3F_3-y^3P_2^\circ$		
	3,685.62	5		27,124.82			
338	3,683.47	6		27,140.61	$a^3P_2-w^3G_3^\circ$		
	3,681.64	1		27,154.14			
339	3,680.37	4	5, III	27,163.47	$a^3F_4-x^3G_5^\circ$		
	3,677.05	2 Cb?		27,188.02			
335	3,663.64	40	300, II	27,287.51	$a^3F_4-w^3F_4^\circ$	(0.38) 1.14	(0.00) 1.25
335	3,661.20	10	30, III	27,305.62	$a^3F_3-w^3F_2^\circ$		
	3,658.30	2		27,327.34			
336	3,656.88	5	6, III	27,337.96	$a^3F_3-z^3H_4^\circ$		
	3,650.98	4		27,382.11			
	3,650.47	4		27,386.68			
	3,648.39	3		27,401.54			
	3,646.89	6		27,412.84			
340	3,644.50	2		27,430.86	$a^3G_3-u^3G_4^\circ$		
	3,639.56	4 Pb?		27,468.05			
341	3,638.70	5	3, IV	27,474.54	$a^3P_1-y^3S_1^\circ$		
335	3,634.14	15	50, III	27,509.03	$a^3F_4-x^3G_4^\circ$	(0.31) 1.22	(---0.60, 0.80)---0.85, 1.05, 1.25, 1.45, ---
342	3,625.39	4		27,575.40	$a^3D_3-t^3G_4^\circ$		
335	3,623.87	45	300, II	27,586.97	$a^3F_3-w^3F_3^\circ$	(0.30) 1.04	(0.00) 1.08
343	3,619.38	4		27,621.18	$a^1D_2-y^1P_1^\circ$		
	3,616.30	3		27,644.70			
341	3,615.09	3		27,653.95	$a^3P_0-y^3S_1^\circ$		
341 331	3,613.70	7	15, III	27,664.58	$a^3P_2-y^3S_1^\circ$ $a^3D_1-t^3P_2^\circ$		
337	3,612.55	2		27,673.38	$a^3F_2-y^3P_1^\circ$		
	3,609.64	3		27,695.69			
344	3,605.90	3		27,724.45	$a^1G_4-z^3I_5^\circ$		
345 346	3,602.78	3		27,748.57	$a^1G_4-t^3F_3^\circ$ $b^3F_2-u^3G_3^\circ$		
339	3,601.18	50	400, II	27,760.81	$a^3F_4-x^3G_5^\circ$	(0.00) 1.12*	(0.00, 0.05, ---) 1.00, 1.05, 1.10, ---
347	3,597.42	2		27,789.82	$a^1S_0-w^1P_1^\circ$		
348	3,596.29	2		27,798.55	$a^5F_5-v^3F_4^\circ$		
349	3,594.70	4		27,810.85	$c^3F_3-q^3F_3^\circ$		
	3,593.87	2		27,817.27			
350	3,593.12	2		27,823.06	$c^3P_1-s^3P_1^\circ$		
339	3,591.72	5	2, III	27,833.91	$a^3F_3-x^3G_3^\circ$		
335	3,586.28	25	100, II	27,876.12	$a^3F_2-w^3F_2^\circ$	(0.00) 0.68	(0.00) 0.67
351	3,585.52	2		27,882.03	$a^3F_4-y^5F_4^\circ$		
345	3,577.55	6	15, IV	27,944.12	$a^1G_4-t^3F_4^\circ$	(0.00) 1.04	(---0.75, 1.00)---0.75, 1.00, 1.25, 1.50, ---
335	3,575.79	25	100, II	27,957.89	$a^3F_3-w^3F_4^\circ$	(0.00) 1.21	(0.00, 0.17, ---)---1.42, 1.58, 1.75
352	3,569.46	2		28,007.51	$a^3H_4-q^3D_3^\circ$		
353	3,568.87	5	15, IV	28,012.15	$a^1D_2-x^3S_1^\circ$	(0.42) ?	(0.00, 1.00) 0.00, 1.00, 2.00
354	3,566.10	25	100, II	28,033.86	$a^3F_4-v^3D_3^\circ$	(0.00) 1.11	(0.00, 0.08, ---) 1.00, 1.08, 1.17, ---
355	3,562.48	2		28,062.38	$a^1D_2-u^3F_2^\circ$		
356	3,558.95	4	12, IV	28,090.21	$a^1D_2-v^3F_3^\circ$	(0.00) 0.72	(0.00, 0.08, 0.17)--1.08, 1.17, 1.25
357	3,552.64	2		28,140.09	$a^5F_2-u^3F_2^\circ$		
355	3,550.46	7	30, III	28,157.35	$a^3F_2-w^3F_3^\circ$	(0.00) 1.26	(0.00, 0.42, 0.83)---1.08, 1.50, 1.92

TABLE 3.—*Wave lengths in the arc spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities, temperature class, and notes		Wave No.	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
		B. S.	King				
358	3,549.73	5	15, III	28,163.14	$a^1G_4-t^3D^\circ_3$	(0.00) 0.00	(**0.00**, 0.33, ---) **0.00**, 0.33, 0.67, ---
357	3,548.68	2		28,171.47	$a^5F_5-u^3F^\circ_3$		
359	3,548.39	2		28,173.78	$a^3D_1-q^3D^\circ_1$		
339	3,547.69	25	100, II	28,179.33	$a^3F_3-x^3G^\circ_4$	(0.00) 1.25	(**0.00**, 0.03, ---) **0.95**, 0.98, 1.02, ---
360	3,535.16	8	20, IV	28,279.18	$a^1G_4-x^1G^\circ_3$	(0.00) 1.15	(0.00) 1.00
351	3,533.22	12	60, III	28,294.74	$a^3F_4-y^5F^\circ_5$	(0.00) 1.65	(**0.00**, 0.15, ---)---**1.70**, 1.85, **2.00**
	3,532.46	2		28,300.79			
355	3,530.22	6	15, III	28,318.83	$a^1D_2-u^3F^\circ_3$		
	3,529.44	2		28,325.08			
361	3,524.52	2		28,364.58	$z^5F^\circ_5-f^5G_3$		
	3,524.26	2		28,366.70			
362	3,523.63	3		28,371.77	$a^5F_4-w^5D^\circ_3$		
362	3,522.18	3		28,383.45	$a^5F_3-w^5D^\circ_2$		
362	3,520.30	3		28,398.58	$a^5F_5-w^5D^\circ_4$		
339	3,519.60	35	125, II	28,404.25	$a^3F_2-x^3G^\circ_3$	(0.00) 1.07	(**0.00**, 0.08, **0.17**) --- 0.75, 0.83, **0.92**
	3,518.87	1		28,410.14			
362	3,517.47	3		28,421.43	$a^5F_2-w^5D^\circ_1$		
348	3,515.25	1		28,439.39	$a^5F_3-v^3F^\circ_4$		
363	3,514.49	2		28,445.54	$c^3P_2-p^3D^\circ_2$		
351	3,514.32	3		28,446.90	$a^3F_2-y^5F^\circ_1$		
364	3,512.35	1		28,462.86	$a^5F_2-u^3D^\circ_1$		
362	3,510.36	2		28,478.99	$a^5F_1-w^5D^\circ_0$		
354	3,509.32	25	100, II	28,487.43	$a^3F_3-v^3D^\circ_2$	(0.00) 1.10	(**0.00**, 0.08, 0.17) **0.92**, 1.00, 1.08, ---
365	3,503.27	2		28,536.61	$a^3P_2-y^1P^\circ_1$		
366	3,501.50	7	8, IV	28,551.03	$a^1G_4-x^3H^\circ_4$		
351	3,501.33	8	15, III	28,552.44	$a^3F_3-y^5F^\circ_4$		
367	3,495.37	4		28,601.09	$b^3F_3-v^1D^\circ_2$		
362	3,494.44	4		28,608.70	$a^5F_2-w^5D^\circ_2$		
364	3,493.66	3		28,615.17	$a^5F_1-u^3D^\circ_1$		
368	3,487.91	3		28,662.29	$a^1D_2-u^3D^\circ_2$		
362	3,487.81	3		28,663.11	$a^5F_3-w^5D^\circ_3$		
369	3,483.01	7	15, IV	28,702.61	$a^1G_4-w^1F^\circ_3$	(0.00) 1.24	(0.00) 1.00
354	3,482.80	8	20, III	28,704.34	$a^3F_3-v^3D^\circ_3$		
370	3,482.13	3		28,709.90	$a^3F_2-x^3P^\circ_1$		
371	3,478.78	8	20, III	28,737.53	$a^3P_1-x^3S^\circ_1$	(0.45) 0.79	(0.50) 1.50, 2.00
362	3,477.64	2		28,746.95	$a^5F_4-w^5D^\circ_4$		
	3,476.02	3		28,760.35			
372	3,472.89	5	4, IV	28,786.25	$a^3P_2-v^3F^\circ_2$		
373	3,472.72	2		28,787.67	$a^3P_1-u^3F^\circ_2$		
354	3,471.18	25	100, II	28,800.43	$a^3F_2-v^3D^\circ_1$		
361	3,470.18	2		28,808.73	$z^5F^\circ_4-f^5G_4$		
351	3,469.06	4	4, II	28,818.03	$a^3F_2-y^5F^\circ_3$		
	3,468.31	2		28,824.26			
374	3,465.63	7	10, II	28,846.54	$a^3F_4-x^5D^\circ_3$		
361	3,464.30	2		28,857.61	$z^5F^\circ_5-f^5G_5$		
375	3,461.09	10	30, II	28,884.37	$a^1G_4-t^3G^\circ_3$	(0.00) 1.24	(**0.00**, 0.25, ---) ---- 1.25, 1.50, **1.75**
371	3,457.19	10	20, II	28,916.97	$a^3P_0-x^3S^\circ_1$	(0.00) 1.78	(0.00) 2.00
371	3,455.90	15	30, II	28,927.73	$a^3P_2-x^3S^\circ_1$	(0.00) 0.53	(**0.00**, 0.50) **1.00**, 1.50, 2.00
373	3,449.91	6	6, IV	28,977.99	$a^3P_2-u^3F^\circ_2$		
	3,449.40	2		28,982.32			
376	3,447.36	30	100, II	28,999.44	$a^3F_2-z^1P^\circ_1$	(0.00) 0.59	(**0.00**, 0.33) **0.33**, 0.67, 1.00
372	3,446.61	15	30, II	29,005.73	$a^3P_2-v^3F^\circ_3$	(0.00) 0.79	(**0.00**, 0.42, 0.83) **0.25**, 0.67, 1.08, ---
362	3,442.70	1		29,038.70	$a^5F_3-w^5D^\circ_4$		
354	3,440.43	12	30, II	29,057.84	$a^3F_2-v^3D^\circ_2$	(1.00) 0.00*w*	(0.50, **1.00**) 0.17, **0.67**, **1.17**, 1.67
368	3,430.94	3		29,138.21	$a^1D_2-u^3D^\circ_3$		
374	3,430.29	6	8, II	29,143.72	$a^2F_4-x^5D^\circ_4$		
	3,430.02	1		29,146.02			
375	3,426.93	4		29,172.30	$a^1G_4-v^3G^\circ_4$		

TABLE 3.—*Wave lengths in the arc spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities, temperature class, and notes		Wave No.	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
		B. S.	King				
361	3,421.42	3		29,219.28	$z^5F^\circ_3-f^5G_4$		
373	3,419.65	12	20, II	29,234.38	$a^3P_2-u^3F^\circ_3$	(0.00) 0.74	(0.00, 0.42, 0.83) 0.25, 0.67, 1.08, ---
377	3,417.07	1		29,256.45	$a^3P_1-w^5D_2$		
	3,416.68	4		29,259.82			
354	3,414.94	2		29,274.78	$a^3F_2-v^3D^\circ_3$		
374	3,414.66	12	20, II	29,277.13	$a^3F_3-x^5D^\circ_2$		
361	3,411.78	2		29,301.84	$z^5F^\circ_4-f^5G_5$		
	3,409.40	2		29,322.33			
378	3,408.54	4		29,329.74	$a^5P_2-r^3D^\circ_3$		
379	3,401.79	3	3, V	29,387.88	$a^3P_1-u^3D^\circ_2$		
	3,400.75	2		29,396.90			
361	3,397.92	4	5, V	29,421.37	$z^5F^\circ_5-f^5G_6$		
	3,389.26	1		29,496.52			
380	3,387.10	2		29,515.33	$a^1D_2-y^5P^\circ_1$		
374	3,386.90	2		29,517.07	$a^3F_3-x^5D^\circ_3$		
	3,385.80	5	5, V	29,526.67			
381	3,379.92	7	10, III	29,578.03	$z^3F^\circ_4-f^5G_5$		
379					$a^3P_2-u^3D^\circ_2$		
380	3,370.60	10	20, III	29,659.82	$a^1D_2-y^5P^\circ_2$	(0.00) 1.38	(0.83, 1.67) 0.17, 1.00, 1.83, 2.67
374	3,368.63	5	5, II	29,677.16	$a^3F_2-x^5D^\circ_1$		
	3,365.00	1		29,709.21			
377	3,363.08	1		29,726.17	$a^3P_2-w^5D^\circ_3$		
382	3,360.45	15	25, II	29,749.40	$a^1D_2-w^1D^\circ_2$	(0.00) 1.35	(0.00) 1.00
381	3,355.01	2		29,797.65	$z^3F^\circ_3-f^5G_4$		
383	3,353.65	12	20, II	29,809.63	$a^3F_4-y^1G^\circ_4$		
374	3,353.15	3		29,814.17	$a^3F_3-x^5D^\circ_4$		
384	3,351.23	3		29,831.25	$b^3F_3-t_3P^\circ_2$		
	3,347.08	1		29,868.23			
381	3,343.71	3 Cb?		29,898.32	$z^3F^\circ_2-f^5G_3$		
385	3,340.20	2		29,929.72	$b^3F_4-t^3G^\circ_4$		
	3,334.07	2		29,984.73			
380	3,333.56	6	4, IV	29,989.36	$a^1D_2-y^5P^\circ_3$		
	3,329.11	3		30,029.49			
379	3,326.43	6		30,053.68	$a^3P_2-u^3D^\circ_3$		
	3,322.29	6	5, V	30,091.12			
385	3,316.21	5	4, V	30,146.26	$b^3F_3-t^3G^\circ_3$		
386	3,315.12	3		30,156.18	$z^5G^\circ_6-f^5G_5$		
	3,310.55	3		30,197.80			
	3,305.90	2		30,240.26			
	3,300.81	1		30,286.88			
385	3,297.64	2		30,315.98	$b^3F_3-t^3G^\circ_4$		
	3,297.00	2		30,321.87			
386	3,296.73	3		30,324.34	$z^5G^\circ_5-f^5G_4$		
	3,293.58	2		30,353.34			
387	3,293.45	2		30,354.54	$a^1D_2-w^3P^\circ_2$		
	3,292.25	1		30,365.60			
388	3,285.18	3		30,431.02	$a^3P_2-y^5P^\circ_1$		
389	3,282.73	7	15, II	30,453.71	$a^3F_4-w^3G^\circ_4$		
385	3,281.87	1		30,461.71	$b^3F_2-t^3G^\circ_3$		
390	3,280.46	2		30,474.80	$a^3P_1-w^1D^\circ_2$		
386					$z^5G^\circ_3-f^5G_3$		
385	3,278.58	1		30,492.26	$b^3F_4-t^3G^\circ_5$		
391	3,277.38	1		30,503.42	$a^3G_5-q^3F^\circ_4$		
391	3,276.95	2		30,507.43	$a^3G_4-q^3F^\circ_3$		
388	3,269.66	12	40, III	30,575.44	$a^3P_2-y^5P^\circ_2$	(0.00) 1.24	(0.33, 0.67) 1.17, 1.50, 1.83, 2.17
386	3,267.35	3		30,597.04	$z^5G^\circ_5-f^5G_2$		
392	3,261.06	2		30,656.04	$b^3F_2-q^3D^\circ_1$		
	3,260.91	1		30,657.45			
390	3,260.11	15	40, III	30,665.00	$a^3P_2-w^1D^\circ_2$		
393	3,256.00	2		30,703.66	$a^1D_2-f^3F^\circ_3$		
386	3,254.28	10	15, IV	30,719.94	$z^5G^\circ_6-f^5G_6$		
389	3,250.42	15	35, III	30,756.46	$a^3F_3-w^3G^\circ_3$		
386	3,243.98	10	8, V	30,817.50	$z^5G^\circ_5-f^5G_5$		

TABLE 3.—*Wave lengths in the arc spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities, temperatures class, and notes		Wave No.	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
		B. S.	King				
394	3,242.75	1		30,829.16	$a^3P_1-w^3P_1^\circ$		
388	3,234.80	5	5, III	30,904.92	$a^5P_2-y^5P_3^\circ$		
389	3,234.12	30	100, II	30,911.42	$a^3F_4-w^3G_5^\circ$	(0.00) 1.07	(0.00, 0.05, ---) **1.00**, 1.05, 1.10, ---
386	3,233.11	5	5, V	30,921.07	$z^5G_4^\circ-f^5G_4$		
386	3,225.47	4		30,994.30	$z^5G_3^\circ-f^5G_3$		
386	3,223.34	3		31,014.78	$z^5G_2^\circ-f^5G_2$		
394	3,216.57	3		31,080.03	$a^3P_1-w^3P_2^\circ$		
395	3,212.57	7	8, III	31,118.77	$a^1D_2-t^3D_3^\circ$		
389	3,212.02	30	100, II	31,124.14	$a^3F_3-w^3G_4^\circ$	(0.00) 1.00	(0.00, 0.03, ---) **0.95**, 0.98, 1.02, ---
395	3,204.90	10	12, III	31,193.24	$a^1D_2-t^3D_2^\circ$		
394	3,197.04	5		31,269.92	$a^3P_2-w^3P_2^\circ$		
389	3,191.23	25	100, II	31,326.85	$a^5F_2-w^3G_3^\circ$	(0.00) 0.84	(0.00, 0.08, 0.17)---0.75, 0.83, 0.92
396	3,191.05	3		31,328.62	$a^3P_2-t^5F_2^\circ$		
386	3,185.68	2		31,381.41	$z^5G_5^\circ-f^5G_6$		
397	3,185.08	3		31,387.32	$a^1D_2-v^3P_1^\circ$		
386	3,182.37	2		31,414.04	$z^5G_4^\circ-f^5G_5$		
386	3,179.72	3		31,440.24	$z^5G_3^\circ-f^5G_4$		
398	3,166.62	2		31,570.34	$c^3P_2-o^3D_3^\circ$		
399	3,162.23	2		31,614.16	$a^3P_1-y^5S_2^\circ$		
400	3,157.82	15	50, III	31,658.28	$a^1D_2-w^1F_3^\circ$	(0.00) 0.86	(0.00) 1.00
401					$a^3P_1-v^3P_0^\circ$		
402	3,149.05	3		31,746.43	$a^1G_4-e^1F_3^\circ$		
403	3,148.81	10	25, III	31,748.86	$a^3P_1-t^3D_1^\circ$		
	3,146.30	1		31,774.18			
404	3,143.94	1		31,798.02	$a^1G_4-y^1H_5^\circ$		
	3,143.47	1		31,802.77			
405	3,139.79	10	20, III	31,840.04	$a^1D_2-o^3G_3^\circ$		
406	3,136.95	12	30, III	31,868.85	$a^1D_2-u^3P_1^\circ$	(0.00) 1.29	(0.00, 0.50) 0.50, 1.00, 1.50
397	3,133.23	10	20, III	31,906.78	$a^1D_2-v^3P_2^\circ$		
403	3,132.06	15	50, III	31,918.65	$a^3P_1-t^3D_2^\circ$	(0.00) 1.00	(0.00, 0.35) 0.83, 1.17, 1.50
403	3,131.11	12	25, III	31,928.33	$a^3P_0-t^3D_1^\circ$	(0.00) 0.00*w*	(0.00) 0.50
403	3,130.05	5	8, III	31,939.19	$a^3P_2-t^3D_1^\circ$		
407	3,121.95	2		32,022.03	$a^1D_2-s^3F_2^\circ$		
403	3,120.74	30	125, III	32,034.42	$a^3P_2-t^3D_3^\circ$	(0.00) 1.19	(0.00, 0.17, 0.33) **1.00**, 1.17, 1.33, ---
403	3,113.50	8	8, III	32,108.81	$a^3P_2-t^3D_2^\circ$		
408	3,108.36	8	10, III	32,162.01	$a^3P_1-u^3P_0^\circ$		
	3,101.06	2		32,237.69			
409	3,099.65	3	2, V	32,252.34	$a^5F_1-s^3F_2^\circ$		
401	3,095.82	10	12, III	32,292.23	$a^3P_0-v^3P_1^\circ$		
401	3,094.79	10	15, III	32,303.02	$a^3P_2-v^3P_1^\circ$		
410	3,093.29	3	2, III	32,318.63	$a^3F_4-u^3F_4^\circ$		
	3,092.25	3	2, V	32,329.50			
406	3,090.44	6	6, III	32,348.54	$a^1D_2-u^3P_2^\circ$		
411	3,085.34	10	12, III	32,401.96	$a^3F_3-v^3F_2^\circ$		
408	3,067.12	4		32,594.43	$a^3P_1-u^3P_1^\circ$		
410					$a^3F_3-u^3F_2^\circ$		
412	3,066.74	2		32,598.45	$a^3F_4-z^1H_5^\circ$		
401	3,063.58	5	8, III	32,632.09	$a^3P_1-v^3P_2^\circ$		
413	3,052.80	2		32,747.37	$a^3P_1-s^3F_2^\circ$		
414	3,052.00	2		32,755.95	$a^3P_2-v^3G_3^\circ$		
408	3,050.33	2		32,773.83	$a^3P_0-u^3P_1^\circ$		
408	3,049.33	6	6, III	32,784.58	$a^3P_2-u^3P_1^\circ$		
401	3,045.82	6	10, III	32,822.36	$a^3P_2-v^3P_2^\circ$		
410	3,043.23	4	3, III	32,850.29	$a^3F_3-u^3F_3^\circ$		
415	3,029.52	20	300, II	32,998.95	$a^3F_4-u^3D_3^\circ$	(0.00) 1.11	(0.00, 0.08, ---) **1.00**, 1.08, 1.17, ---
408	3,022.66	1		33,073.81	$a^3P_1-u^3P_2^\circ$		
410	3,014.44	5	15, III	33,164.02	$a^3F_3-u^3F_2^\circ$		
415	3,011.73	20	250, II	33,193.86	$a^3F_3-u^3D_2^\circ$	(0.00) 1.00	(0.00, 0.08, 0.17) **0.92**, 1.00, 1.08, ---
416	3,005.50	5	60, IV	33,262.67	$a^1G_4-w^1G_4^\circ$		
408	3,005.36	4	40, IV	33,264.21	$a^3P_2-u^3P_2^\circ$		
415	2,985.36	10	200, II	33,487.06	$a^3F_3-u^3D_1^\circ$	(0.00) 0.68	(0.00, 0.17) 0.50, 0.67, **0.83**
415	2,969.18	4	40, IV	33,669.56	$a^3F_3-u^3D_3^\circ$		

TABLE 3.—*Wave lengths in the arc spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities, temperatures class, and notes		Wave No.	Term combinations	Observed Zeeman effects	Theoretical Zeeman effect
		B. S.	King				
415 417	2, 960. 86	6	60, IV	33, 764. 14	$a^3F_2-u^3D_2^\circ$ $b^3F_2-p^3D_1^\circ$	(0. 75) 1. 32 E_1	(0. 50, 1. 00) 0. 17, 0. 67, 1. 17, 1. 67
418	2, 933. 02	1		34, 084. 61	$a^3P_2-s^3D_1^\circ$		
419	2, 923. 86	4	10, IV	34, 191. 38	$a^3F_3-y^5P_2^\circ$		
420	2, 916. 23	2	10, IV	34, 280. 85	$a^3F_3-w^1D_2^\circ$		
	2, 901. 64	2		34, 453. 20			
421	2, 892. 26	6	30, IV	34, 564. 93	$a^3F_4-t^3F_3^\circ$		
422	2, 889. 15	2		34, 602. 13	$a^1D_2-x^1P_1^\circ$		
423	2, 880. 83	3	5, V	34, 702. 06	$a^1D_2-v^1F_3^\circ$		
421	2, 875. 98	12	200, IV	34, 760. 58	$a^3F_4-t^3F_4^\circ$	(0. 46) 1, 18 E_1	(0. 00) 1. 25
420	2, 868. 48	3		34, 851. 46	$a^3F_2-w^1D_2^\circ$		
421	2, 860. 85	6	30, IV	34, 944. 41	$a^3F_3-t^3F_2^\circ$	(0. 00) 1. 46 E_1	(0. 00, 0. 42, 0. 83)—1.08, 1.50, 1. 92
424	2, 857. 97	1	2, V	34, 979. 62	$a^3F_4-t^3D_3^\circ$		
425	2, 848. 50	6	150, IV	35, 095. 91	$a^3F_4-x^1G_4^\circ$		
421	2, 837. 23	15	200, IV	35, 235. 31	$a^3F_3-t^3F_3^\circ$	(0. 00) 0. 96 E_1	(0. 00) 1. 08
426	2, 836. 49	3	4, V	35, 244. 51	$a^1D_2-r^3D_3^\circ$		
427	2, 831. 33	2		35, 308. 73	$a^5F_3-v^1D_2^\circ$		
428	2, 829. 80	6	8, IV	35, 327. 82	$a^3P_1-x^1P_1^\circ$		
429	2, 827. 55	6	8, IV	35, 355. 93	$a^3F_4-x^3H_5^\circ$		
430	2, 824. 82	3		35, 390. 22	$a^3P_1-r^3D_2^\circ$		
421	2, 821. 56	6	8, IV	35, 430. 98	$a^3F_3-t^3F_4^\circ$		
431 432	2, 819. 56	5	10, IV	35, 456. 11	$a^1D_2-v^1D_2^\circ$ $a^3F_2-w^3P_2^\circ$		
428	2, 815. 49	3	2, V	35, 507. 36	$a^3P_0-x^1P_1^\circ$		
421	2, 814. 91	12	150, IV	35, 514. 67	$a^3F_2-t^3F_2^\circ$	(0. 00) 0. 60 E_1	(0. 00) 0. 67
428	2, 814. 71	2		35, 517. 20	$a^3P_2-x^1P_1^\circ$		
433	2, 806. 77	6	12, IV	35, 617. 67	$a^3P_2-v^1F^\circ$		
424	2, 798. 30	6		35, 725. 47	$a^3F_3-t^3D_2^\circ$		
425	2, 795. 14	5	8, V	35, 765. 86	$a^3F_3-x^1G_4^\circ$		
	2, 793. 40	7	8, V	35, 788. 14			
421	2, 792. 05	10	20, IV	35, 805. 44	$a^3F_2-t^3F_3^\circ$		
434	2, 790. 14	12		35, 829. 95	$a^1D_2-w^1P_1^\circ$		
435	2, 786. 90	6		35, 871. 60	$a^1D_2-t^3P_1^\circ$		
436	2, 777. 64	1		35, 991. 18	$a^3F_2-y^5S_2^\circ$		
429	2, 774. 03	2		36, 038. 02	$a^3F_3-x^3H_4^\circ$		
	2, 771. 35	1		36, 072. 87			
	2, 770. 88	1		36, 078. 98			
424 437	2, 767. 38	4		36, 124. 61	$a^3F_2-t^3D_1^\circ$ $b^3F_2-o^3D_1^\circ$		
	2, 766. 50	2		36, 136. 10			
430 438	2, 764. 68	2		36, 159. 89	$a^3P_2-r^3D_3^\circ$ $a^3P_1-t^3P_0^\circ$		
439 440	2, 763. 01	6		36, 181. 75	$a^3P_1-v^1D_2^\circ$ $a^3F_4-v^3G_5$		
	2, 761. 18	2		36, 205. 72			
441	2, 759. 46	3		36, 228. 29	$a^3F_4-s^3F_3^\circ$		
439 437 440	2, 748. 59	2		36, 371. 56	$a^3P_2-v^1D_2^\circ$ $b^3F_3-o^3D_4$ $a^3F_3-v^3G_3^\circ$		
	2, 737. 86	5		36, 514. 08			
440	2, 727. 00	5		36, 659. 50	$a^3F_3-v^3G_4^\circ$		
441	2, 725. 45	8		36, 680. 34	$a^3F_4-s^3F_4^\circ$	(0. 00) 1. 12 E_1	(0. 00) 1. 25
435	2, 725. 01	2		36, 686. 26	$a^1D_2-t^3P_2^\circ$		
442	2, 719. 52	4		36, 760. 35	$a^3F_2-w^1F_3^\circ$		
438	2, 718. 28	4		36, 777. 09	$a^3P_0-t^3P_1^\circ$		
438	2, 717. 48	5		36, 787. 94	$a^3P_2-t^3P_1^\circ$		
	2, 709. 76	4		36, 892, 72			
441	2, 709. 33	8		36, 898. 58	$a^3F_3-s^3F_3^\circ$		
440	2, 706. 15	10		36, 941. 94	$a^3F_2-v^3G_3^\circ$		
443	2, 701. 83	3		37, 000. 99	$a^1D_2-t^3G_3^\circ$		
441	2, 692. 91	4		37, 123. 55	$a^3F_2-s^3F_2^\circ$		
444	2, 687. 74	7		37, 194. 95	$a^3F_4-s^3D_3^\circ$		
	2, 685. 91	3		37, 220. 29			
445	2, 683. 79	3		37, 249. 67	$a^5P_1-o^3D_2^\circ$		

TABLE 3.—*Wave lengths in the arc spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities, temperatures class, and notes		Wave No.	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
		B. S.	King				
	2,681.39	2		37,283.03			
446	2,677.88	1		37,331.89	$a^1D_2-q^3D^\circ_2$		
441	2,676.54	4		37,350.58	$a^3F_3-s^3F^\circ_4$		
438	2,672.17	1		37,411.60	$a^3P_1-t^3P^\circ_2$		
	2,662.78	1		37,543.58			
438	2,658.66	6		37,601.76	$a^3P_2-t^3P^\circ_2$		
447	2,655.84	3		37,641.68	$a^3F_4-r^3F^\circ_3$		
	2,649.84	2		37,726.91			
444	2,647.77	4		37,756.40	$a^3F_3-s^3D^\circ_2$		
444	2,640.13	4		37,865.66	$a^3F_3-s^3D^\circ_3$		
448	2,636.56	1		37,916.92	$a^3P_2-t^3G^\circ_3$		
	2,636.38	1		37,919.50			
447	2,635.40	8		37,933.61	$a^3F_4-r^3F^\circ_4$		
	2,634.56	3		37,945.70			
	2,633.11	1		37,966.60			
	2,630.33	6		38,006.73			
	2,625.98	2		38,069.67			
449	2,625.18	1		38,081.27	$a^1D_2-w^3S^\circ_1$		
	2,624.83	3		38,086.36			
	2,620.83	5		38,144.48			
450	2,619.81	2		38,159.34	$a^5F_2-w^3S^\circ_1$		
	2,613.05	2		38,258.04			
463	2,612.18	4		38,270.78	$a^1G_4-u^1F^\circ_3$		
444					$a^3F_2-s^3D^\circ_1$		
447	2,609.40	6		38,311.55	$a^3F_3-r^3F^\circ_3$		
444	2,608.37	3		38,326.68	$a^3F_2-s^3D^\circ_2$		
451	2,592.39	2		38,562.92	$a^3F_4-v^1F^\circ_3$		
447	2,592.18	3		38,566.04	$a^3F_2-r^3F^\circ_2$		
447	2,589.62	5		38,604.17	$a^3F_3-r^3F^\circ_4$		
452	2,583.64	6		38,693.51	$a^3F_4-u^3G^\circ_4$		
	2,580.45	2		38,741.34			
	2,579.54	8		38,755.01			
453	2,579.40	1		38,757.11	$a^1S_0-v^1P^\circ_1$		
454	2,576.08	5		38,807.05	$a^3P_1-w^3S^\circ_1$		
	2,573.50	1		38,845.95			
452	2,567.44	7		38,937.64	$a^3F_4-u^3G^\circ_5$		
454	2,564.26	3		38,985.93	$a^3P_0-w^3S^\circ_1$		
454	2,563.56	4		38,996.57	$a^3P_2-w^3S^\circ_1$		
	2,561.91	2		39,021.69			
455	2,556.38	6		39,106.09	$a^3F_4-r^3D^\circ_3$		
	2,554.84	1		39,129.67			
	2,554.30	5		39,137.93			
	2,551.70	2		39,177.81			
455	2,550.50	4		39,196.24	$a^3F_3-r^3D^\circ_2$		
	2,547.10	2		39,248.56			
452	2,539.62	10		39,364.15	$a^3F_3-u^3G^\circ_4$		
452	2,538.00	6		39,389.28	$a^3F_2-u^3G^\circ_3$		
	2,533.98	1		39,451.76			
	2,533.18	2		39,464.22			
	2,527.10	1		39,559.16			
	2,524.84	2		39,594.57			
	2,519.94	4		39,671.55			
451	2,511.56	2		39,803.91	$a^3F_2-v^1F^\circ_3$		
	2,505.98	4		39,892.53			
	2,504.79	3		39,911.48			
456	2,504.54	2		39,915.46	$a^1D_2-s^3P^\circ_2$		
	2,495.26	5		40,063.90			
	2,493.73	2		40,088.48			
	2,481.92	1		40,279.22			
	2,481.42	4		40,287.34			
	2,481.22	1		40,290.59			
457	2,478.27	1		40,338.54	$a^5F_3-p^3D^\circ_2$		
	2,478.06	2		40,341.96			
	2,474.14	2		40,405.97			
	2,474.00	3		40,408.16			
	2,471.96	2		40,441.51			
	2,470.29	1		40,468.84			

TABLE 3.—*Wave lengths in the arc spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities, temperatures class, and notes		Wave No.	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
		B. S.	King				
458	2,468.03	5		40,505.90	$a^3P_1-s^3P^\circ_1$		
459	2,461.79	2		40,608.56	$a^1D_2-p^3D^\circ_3$		
	2,461.02	4		40,619.61			
458	2,459.84	3		40,640.75	$a^3P_1-s^3P^\circ_2$		
	2,459.27	2		40,650.17			
458	2,456.50	2		40,696.00	$a^3P_2-s^3P^\circ_1$		
	2,454.96	1		40,721.53			
	2,451.97	2		40,771.18			
460	2,450.98	1		40,787.65	$a^5F_4-u^1F^\circ_3$		
	2,449.32	3		40,815.29			
458	2,448.37	4		40,831.12	$a^3P_2-s^3P^\circ_2$		
	2,446.94	1		40,854.99			
	2,445.71	1		40,875.53			
	2,444.04	1		40,903.46			
	2,441.30	8		40,949.36			
	2,440.34	3		40,965.47			
	2,439.49	2		40,979.74			
461	2,437.41	1		41,014.71	$a^5P_1-v^1P^\circ_1$		
	2,434.29	1		41,067.27			
	2,430.54	1		41,130.63			
	2,429.19	4		41,153.48			
	2,428.19	1		41,170.43			
	2,427.82	1		41,176.71			
	2,427.54	1		41,181.45			
462	2,424.89	1		41,226.45	$a^1D_2-u^1F^\circ_3$		
	2,423.76	3		41,245.68			
	2,415.91	2		41,379.69			
	2,415.67	2		41,383.79			
	2,415.58	0		41,385.34			
464	2,414.60	3		41,402.13	$a^3P_2-p^3D^\circ_2$		
	2,413.51	2		41,420.83			
	2,411.92	4		41,448.13			
	2,410.78	1		41,467.73			
	2,407.90	3		41,517.32			
464	2,407.52	1		41,523.88	$a^3P_2-p^3D^\circ_3$		
465	2,407.03	1		41,532.33	$a^3F_3-t^3G^\circ_3$		
466	2,405.52	10		41,558.40	$a^3F_4-q^3D^\circ_3$		
465	2,403.44	5		41,594.36	$a^3F_4-t^3G^\circ_5$		
	2,402.93	4		41,603.19			
	2,402.20	2		41,615.83			
	2,400.81	5		41,639.92			
	2,398.17	3		41,685.75			
	2,397.95	1		41,689.59			
	2,397.70	1		41,693.93			
465	2,397.23	7		41,702.10	$a^3F_3-t^3G^\circ_4$		
	2,396.30	1		41,718.28			
	2,391.88	2		41,795.37			
	2,391.75	3		41,797.64			
	2,391.04	1		41,810.05			
	2,390.15	2		41,825.62			
	2,389.21	8		41,842.07			
466	2,388.00	8		41,863.27	$a^3F_3-q^3D^\circ_2$		
	2,384.84	3		41,918.74			
	2,384.16	12		41,930.69			
	2,381.55	2		41,976.64			
	2,380.55	9		41,994.28			
467	2,378.68	1		42,027.28	$a^3F_4-q^3F^\circ_3$		
467	2,378.25	4		42,034.88	$a^3F_4-q^3F^\circ_4$		
465	2,374.43	10		42,102.50	$a^3F_2-t^3G^\circ_3$		
467	2,372.57	5		42,135.51	$a^3F_3-q^3F^\circ_2$		
	2,372.33	3		42,139.77			
	2,371.70	2		42,150.96			
	2,371.14	1		42,160.92			
	2,370.42	3		42,173.72			
466	2,367.33	8		42,228.76	$a^3F_3-q^3D^\circ_3$		
466	2,363.52	10		42,296.83	$a^3F_2-q^3D^\circ_1$		

TABLE 3.—*Wave lengths in the arc spectrum of Zr*—Continued

Key No.	λ I. A.	Intensities, temperatures class, and notes		Wave No.	Term combinations	Observed Zeeman effects	Theoretical Zeeman effects
		B. S.	King				
	2,363.05	2		42,305.24			
	2,360.41	1		42,352.65			
	2,356.24	1		42,427.50			
466	2,355.90	7		42,433.62	$a^5F_2-q^5D_3^2$		
	2,354.65	1		42,466.97			
	2,349.58	2		42,547.75			
467	2,341.32	3		42,697.35	$a^5F_3-q^5F_4^3$		
467	2,340.87	5		42,706.05	$a^5F_3-q^5F_4^4$		
467					$a^5F_2-q^5F_3^2$		
	2,334.64	1		42,820.01			
	2,330.72	2		42,892.01			
468	2,330.55	1		42,895.14	$a^5F_1-o^5D_1^2$		
	2,321.64	1		43,059.75			
	2,320.78	2		43,075.71			
	2,316.20	1		43,160.87			
468	2,315.56	1		43,172.80	$a^5F_4-o^5D_3^3$		
467	2,310.44	2		43,268.47	$a^5F_2-q^5F_3^3$		
	2,285.25	6		43,745.33			
	2,269.43	5		44,059.28			
	2,253.27	3		44,366.16			
	2,250.73	3		44,416.23			
469	2,248.05	4		44,469.17	$a^3F_4-p^3D_3^3$		
	2,239.19	3		44,645.10			
	2,230.88	5		44,811.39			
	2,224.97	3		44,930.41			
470	2,220.68	5		45,017.20	$a^5F_2-s^5F_2^2$		
469					$a^5F_3-p^3D_3^3$		
469	2,214.63	4		45,140.16	$a^3F_3-p^3D_3^3$		
	2,214.20	5		45,148.93			
469	2,201.69	3		45,405.43	$a^3F_2-p^3D_1^2$		
469	2,192.89	3		45,587.63	$a^3F_2-p^3D_2^3$		
	2,181.50	3		45,725.62			
	2,178.97	5		45,878.82			
	2,173.02	3		45,991.73			
	2,160.23	4		46,276.78			
	2,157.78	5		46,329.32			
	2,149.15	6		46,515.33			
471	2,136.16	7		46,798.15	$a^1D_2-v^1P_1^2$		
	2,119.14	6		47,173.96			
	2,110.53	7		47,366.40			
	2,109.42	4		47,391.31			
	2,108.56	6		47,410.64			
472	2,105.83	5		47,472.10	$a^3F_4-o^3D_3^3$		
	2,103.31	5		47,528.97			
472	2,101.80	5		47,563.11	$a^3F_3-o^3D_2^3$		
472	2,092.88	4		47,765.80	$a^3F_2-o^3D_1^2$		
	2,089.57	5		47,841.45			
	2,088.89	3		47,857.02			

TABLE 4.—*Key to the term combinations of Zr I*

Odd terms \ Even terms	a^1S	a^1P	a^1D	b^1D	a^1F	a^1G	b^1G	a^1H	a^3P	b^3P	c^3P	a^3D	a^3F	b^3F	c^3F	e^3F	a^3G	a^3H	a^5P	a^5D	a^5F	e^5F	f^5F	e^5G	f^5G	e^5H^1
z^1P°	93		232						300				376								283					
y^1P°	169		343						365																	
x^1P°			422	234					428		237															
w^1P°	347		434																							
v^1P°	453		471																461							
z^1D°			34						47				107								29					
y^1D°			116						134				222													
x^1D°			227						259																	
w^1D°			382										420	255					269	38						
v^1D°			431	258					439		262			367							427					
z^1F°			118			76							223													
y^1F°			154			102			167				252	27					46		149					
x^1F°			192			123			215			24	311	67			53	12	77		178					
w^1F°			400			369							442	295			285									
v^1F°			423	239		402	216		433		243	319	451													
u^1F°			462			463															460					
z^1G°						147							323	71			66				187					
y^1G°						247	50	31					383													
x^1G°						360	135	114					425	284			266	202								
w^1G°						416	267	240																		
v^1G°																										
z^1H°						325	99	81					412					144								
y^1H°						404	218	191										305								
x^1H°								268																		
z^1I°								161										261								
z^3S°			106						115				214									49				
y^3S°			334						341																	
x^3S°			353						371	109									217							
w^3S°			449						454		327										450					
z^3P°			83						94												79					
y^3P°			232						254			42	337													
x^3P°			273	19					293		11		370								274					
w^3P°			337						394	152		179	432	279					294							
v^3P°			397						401		150	212		306					324							
u^3P°			406						408		169	228														
t^3P°			435						438		272	331		384												
s^3P°			456						458		350		470													
z^3D°			32						43				108			162					33	110				
y^3D°			124			88			136				229	10					30		119	18				
x^3D°			188						207			23	326	69			63				193					

$w^3D°$			208						235			36	330	80			73				211					
$v^3D°$			276						296		13	70	354						127		277					
$u^3D°$			368						379	128	104		415	210			196	157	233		364					
$t^3D°$			395			358			403		141	200	424	281			264		310							
$s^3D°$									418		197	278	444	328			322									
$r^3D°$			426						430			321	455						378							
$q^3D°$			446								317	359	466	392				352								
$p^3D°$			459						464		363		469	417							457					
$o^3D°$											398		472	437					445		468					
$z^3F°$			6						25				89			175					9	129			381	
$y^3F°$			133			86			151				248	8		64	4		39		122					
$x^3F°$			185			131			205			20	316	65			55	16	78		181					
$w^3F°$			245						275				335	91			84	51			241					
$v^3F°$			356			315			372		96	143	411	182			174		213		348					
$u^3F°$			355			318			373			146	410	189			177		226		357					
$t^3F°$			393			345	126	111	396			199	421	265	171		250	194	301							
$s^3F°$			407				166		413			231	441	314			299	244			409					
$r^3F°$												287	447	333			332	288								
$q^3F°$								303					467		349		391									
$z^3G°$			105			57			117				183			87					101					
$y^3G°$			176						201				297	52			41	2	74		163					
$x^3G°$			257			184			290				339	97	40		90	56			246					
$w^3G°$									338				389	155			142	103	170		329					
$v^3G°$			405			375	159	137	413			236	440	308			236	220								
$u^3G°$				221			230	198				312	452	346			340	309								
$t^3G°$			443						448			342	465	385												
$z^3H°$						164							336	95			82	44			224					
$y^3H°$														219			206	158	253							
$x^3H°$						366	145	121					429	292			280	203								
$z^3I°$						344								263			249	186								
$z^5S°$									138										22							
$y^5S°$									399			204	436						304							
$z^5P°$			180						190			7	302	54			48		68		172					
$y^5P°$			380						388			168	419	251					270	37						
$z^5D°$			62						72				130								59	98				
$y^5D°$			132			92			148				242	15			3		28		125	14				
$x^5D°$									320				374				113	85	140		298					
$w^5D°$									377			153		209					225	17	362					
$z^5F°$			26						35				100								21	112		260	361	
$y^5F°$			271						291			58	351								256				120	
$z^5G°$													60								1	156		307	386	289
$y^5G°$						139			195				313	61			45	5	75		173				165	

2. THE ZEEMAN EFFECTS

The observed Zeeman effects for the arc lines of Zr, which are entered in column 7 of Table 3, confirm most of the terms given in Tables 1 and 2. As stated above these results are taken from Moore's published observations, from his more recent observations measured and reduced at the National Bureau of Standards, and from observations made with the recently acquired magnet in conjunction with the spectrographs of the National Bureau of Standards. These newest observations are specially marked in the table, an asterisk (*) indicating those made with the concave grating, and the symbol E_1 those made with the quartz prism spectrograph. For comparison with the observed patterns the theoretical Zeeman effects are entered in the last column of Table 3. These have been taken from the Tables of Theoretical Zeeman Effects,[12] by Kiess and Meggers.

Only a few of the observed Zeeman effects are fully resolved, the majority representing blends of the unresolved components of the magnetic patterns. In some instances the type of blending is evident, and this is indicated in the tables by the symbols A^1, A^2, and B, as used by Back.[13] Lines with unresolved but with definitely widened *p* components are marked with a letter *w*.

In our paper [14] on the classification of Zr II we cited two lines which are members of both the arc and first spark spectra of Zr, as shown by their Zeeman effects, but which had not been resolved with the spectrographs employed in observing them. To these we add the line at 4,304.68 A. Its wave number is given by three pairs of term combinations, of which two, $a^3D_3-s^3F_4$ and $a^3P_1-y^3P_0$, are indicated by the observed pattern (0.00) 1.01, 1.46.

Landé's [15] theory of the anomalous Zeeman effect for weak fields assigns to each spectral term a *g* value which gives the amount by which the components of a term are separated in the magnetic field. For most of the terms of Zr I the *g* values appear to be normal, but for several terms the *g*'s are abnormal. This abnormality was detected early in this work for two of the odd terms, x^3F° and w^3F°, and in a paper by Meggers and Kiess,[16] was interpreted as indicating a deviation from normality with position in the term diagram. But this view, in the light of the additional data we have obtained, is no longer tenable. These data abundantly illustrate the fact that two terms of approximately the same value, with the same inner quantum number *J*, and arising from the same electron configuration, will have *g* values equal to the mean of their theoretical *g*'s. Back [17] was the first to notice this phenomenon for Ca I; subsequently Russell [18] detected instances of it in Ti I, and Shenstone [19] has cited more numerous occurrences of it in Cu I, Cu II, and Ni II. In Table 5 we give the pairs of terms of Zr I which thus affect each other, and in Table 6 we give some of the observed Zeeman patterns resulting from these affected terms, and compare them with patterns calculated with the observed *g*'s according to Landé's rules. There are other terms of Zr I which also exhibit abnormal *g*'s, such as $y^1F_3^\circ$ and $t^3F_4^\circ$, but at

[12] B. S. Jour. Research (RP 23), 1, p. 641; 1928.
[13] Zeit. für Physik, 15, p. 206; 1923.
[14] B. S. Jour. Research (RP 255), 5, p. 1234; 1930.
[15] Zeit. für Physik, 5, p. 231; 1921; 15, p. 189; 1923.
[16] J. Opt. Soc. Am. & Rev. Sci. Inst., 12, p. 443; 1926.
[17] Zeit. für Physik, 33, p. 581; 1925.
[18] Astrophys. J., 66, p. 411; 1927.
[19] Phys. Rev., 28, p. 453; 1926; 29, p. 384; 1927; 30, p. 258; 1927.

the present time the observations are not sufficient to show whether the abnormality is produced by a near-by perturbing term of like inner quantum number and electronic origin or by some other cause.

TABLE 5.—*Zr I terms with abnormal g values*

Term	ν	Theoretical g	Observed g	Electron configuration
a^3P_2	4,186.11	1.500	1.25	$4d^2.5s^2$
a^1D_2	5,101.68	1.000		
b^3F_4	12,342.37	1.250	1.15	$4d^3.5s$
a^3G_4	12,760.66	1.050		
$z^1G^\circ_4$	26,931.35	1.000	1.13	$4d^2.5s.5p$
$x^3F^\circ_4$	26,938.42	1.250		
$w^3F^\circ_4$	28,528.36	1.250	1.15	$4d^2.5s.5p$
$x^3G^\circ_4$	28,749.80	1.050		
$v^3D^\circ_1$	28,800.51	0.500	0.75	$4d^2.5s.5p$
$z^1P^\circ_1$	28,999.46	1.000		
$y^5P^\circ_2$	34,761.52	1.833	1.42	$4d^3.5p$
$w^1D^\circ_2$	34,850.96	1.000		
$w^1F^\circ_3$	36,759.90	1.000	0.87	$4d^3.5p$
$v^3G^\circ_3$	36,941.65	0.750		

TABLE 6.—*Zeeman effects from abnormal g values*

Term combination	λ	Observed Zeeman effect	Calculated Zeeman effect
a^1D_2–$z^3P^\circ_2$	6,506.39	(0.46) 1.46	(0.25, **0.50**) 1.00, **1.25**, **1.50**, 1.75
a^3P_2–$z^3P^\circ_2$	6,140.50	(0.48) 1.44	
a^1D_2–$y^1D^\circ_2$	5,664.55	(0.51) 1.09	(0.25, **0.50**) 0.75, **1.00**, **1.25**, 1.50
a^3P_2–$y^1D^\circ_2$	5,385.14	(0.45) 1.10	
a^1D_2–$y^3D^\circ_3$	5,386.65	(0.00) 1.32	(**0.00**, 0.08, 0.17) 1.17, 1.25, 1.33, 1.42, **1.50**
a^3P_2–$y^3D^\circ_3$	5,133.42	(0.00) 1.23	
a^1D_2–$w^3D^\circ_3$	4,466.90	(0.00) 1.44	
a^3P_2–$w^3D^\circ_3$	4,291.34	(0.00) 1.47	
a^1D_2–$x^1F^\circ_3$	4,732.34	(0.00*w*) **0.61**, 1.07	(**0.00**, 0.25, 0.50) **0.50**, 0.75, 1.00, 1.25, **1.50**
a^3P_2–$x^1F^\circ_3$	4,535.75	(0.00*w*) 0.67 A[1]	
a^1D_2–$x^3P^\circ_1$	4,234.63	(0.00*w*) 1.13	(**0.00**, 0.25) **1.00**, 1.25, 1.50
a^3P_2–$x^3P^\circ_1$	4,076.53	(0.60) 1.13	
a^1D_2–$v^3D^\circ_1$	4,218.44	(0.00) 1.68	(**0.00**, 0.50) 0.75, 1.25, **1.75**
a^3P_2–$v^3D^\circ_1$	4,061.53	(**0.00**, 0.46) 1.60	
a^1D_2–$z^1P^\circ_1$	4,183.31	(**0.00**, 0.47) 1.26, **1.76**	
a^3P_2–$z^1P^\circ_1$	4,028.95	(0.00) 1.57	
a^1D_2–$x^3P^\circ_2$	4,199.08	(0.42) 1.39 B	(0.25, **0.50**) 1.00, **1.25**, **1.50**, 1.75
a^3P_2–$x^3P^\circ_2$	4,043.57	(0.49) 1.33	
a^1D_2–$v^3F^\circ_3$	3,558.95	(0.00) 0.72	(**0.00**, 0.17, 0.33) **0.75**, 0.92, 1.08, 1.25, **1.42**
a^3P_2–$v^3F^\circ_3$	3,446.61	(0.00) 0.79	
a^1D_2–$y^5P^\circ_2$	3,370.60	(0.00) 1.38	(0.17, **0.34**) 1.08, **1.25**, **1.42**, 1.59
a^3P_2–$y^5P^\circ_2$	3,269.66	(0.60) 1.24	
a^3G_4–$x^3D^\circ_3$	6,966.49	(0.00) 0.64	(**0.00**, 0.18, 0.37, 0.55) **0.60**, 0.78, 0.97, 1.15, 1.33, 1.52, 1.70
b^3F_4–$x^3D^\circ_3$	6,769.16	(0.60*w*) 0.72	
a^3G_4–$z^3H^\circ_5$	6,470.25	(0.00) 0.79	(**0.00**, 0.12, 0.23, 0.35, 0.47) **0.57**, 0.68, 0.80, 0.92, 1.03, 1.15, 1.27, 1.38, 1.50
b^3F_4–$z^3H^\circ_5$	6,299.72	(0.00) 0.78	
a^3G_4–$x^3G^\circ_5$	6,155.56	(0.00) 1.36	(**0.00**, 0.05, 0.10, 0.15, 0.20) 1.00, 1.05, 1.10, 1.15, 1.20, 1.25, 1.30, 1.35, **1.40**
b^3F_4–$x^3G^\circ_5$	6,001.03	(0.00) 1.36	
a^3G_4–$w^3G^\circ_5$	5,155.46	(0.00) 1.30	
b^3F_4–$w^3G^\circ_5$	5,046.61	(0.00) 1.25	
a^3F_4–$z^1G^\circ_4$	3,891.39	(0.63) 1.15	(0.12, 0.24, 0.36, **0.48**) 0.77, 0.89, 1.01, **1.13**, **1.25**, 1.37, 1.49, 1.61
a^3F_4–$z^3F^\circ_4$	3,890.32	(0.26) 1.16	

TABLE 6.—*Zeeman effects from abnormal g values*—Continued

Term combination	λ	Observed Zeeman effect	Calculated Zeeman effect
$a^3F_3-z^1G^\circ_4$ $a^3F_3-x^3F^\circ_4$	3,792.40 3,791.39	(0.00) 1.24 (0.00) 1.37	(0.00, 0.05, 0.09, 0.14) 0.99, 1.04, 1.08, 1.13, 1.18, 1.22, 1.27
$a^3F_4-w^3F^\circ_4$ $a^3F_4-x^3G^\circ_4$	3,663.64 3,634.14	(0.38) 1.14 (0.31) 1.22	(0.10, 0.20, 0.30, 0.40) 0.85, 0.95, 1.05, 1.15, 1.25, 1.35, 1.45, 1.55
$a^3F_3-w^3F^\circ_4$ $a^3F_3-x^3G^\circ_4$	3,575.79 3,547.69	(0.00) 1.21 (0.00) 1.25	(0.00, 0.07, 0.13, 0.20) 0.95, 1.02, 1.08, 1.15, 1.22, 1.28, 1.35
$a^5P_3-y^5P^\circ_2$ $a^5P_3-w^1D^\circ_2$	4,253.56 4,237.42	(0.00) 1.96 A [2] (0.00) 1.96	(0.00, 0.25, 0.50) 1.17, 1.42, 1.67, 1.92, 2.16
$a^5P_1-y^5P^\circ_2$ $a^5P_1-w^1D^\circ_2$	4,187.12 4,171.47	(0.00) 0.32 (0.00, 1.07) 0.29	(0.00, 1.08) 0.34, 1.42, 2.50
$a^1G_4-w^1F^\circ_3$ $a^1G_4-v^3G^\circ_3$	3,483.01 3,461.09	(0.00) 1.24 (0.00) 1.24	(0.00, 0.13, 0.26, 0.39) 0.61, 0.74, 0.87, 1.00, 1.13, 1.26, 1.39

3. THE INTENSITIES

No quantitative measurements of line intensities in the Zr spectra have as yet been published. But the estimates made at the National Bureau of Standards, as described above, and those of King and Miss Carter, are considered sufficiently reliable to illustrate the combination behavior of the terms. Indeed, Russell [20] has shown that King's intensity estimates, based on an extensive series of observations, are quite homogeneous, and are nearly proportional to the square roots of the theoretical intensities. We have, therefore, based the discussion which follows almost entirely on the Mt. Wilson intensities, supplementing them only where necessary with our own estimates.

For many of the Zr I multiplets, and especially those of the quintet system, the intensities appear to follow the requirements of the rules derived independently from quantum theoretical considerations by Russell,[21] by Hönl and Sommerfeld,[22] and by Kronig.[23] According to these rules those lines within a multiplet are strongest which represent a transition for which the change in the inner quantum number J is in the same direction as that of the term quantum number L, lines exhibiting the same ΔJ increasing in intensity with J. Kronig's formulas show further that the total intensities of a triad of multiplets having a common term will differ, that being strongest for which the change ΔL in the term quantum number is in the same direction as the change Δk in the azimuthal quantum number of the current electron.

But there are many Zr I lines which individually show abnormal intensities, and, in the triplet system, there are several multiplets which appear to be in contradiction with the first of the above rules. Most of the individual lines with intensities too high or too low represent combinations of which at least one of the combining terms is perturbed by a near-by term with the same inner quantum number. The perturbing terms also belong, apparently, to the same electron configuration. The effect is entirely analogous to that of the abnormal Zeeman effects described above, two related terms sharing their transition probabilities as well as their g values. All the singlet-

[20] Proc. Nat. Acad. Sci., **11**, p. 322; 1925.
[21] Proc. Nat. Acad. Sci., **11**, p. 314; 1925.
[22] Sitz. Ber. Akad. Wiss. Berlin, p. 141; 1925.
[23] Zeit. für Physik, **31**, p. 885; 1925; **33**, p. 261; 1925.

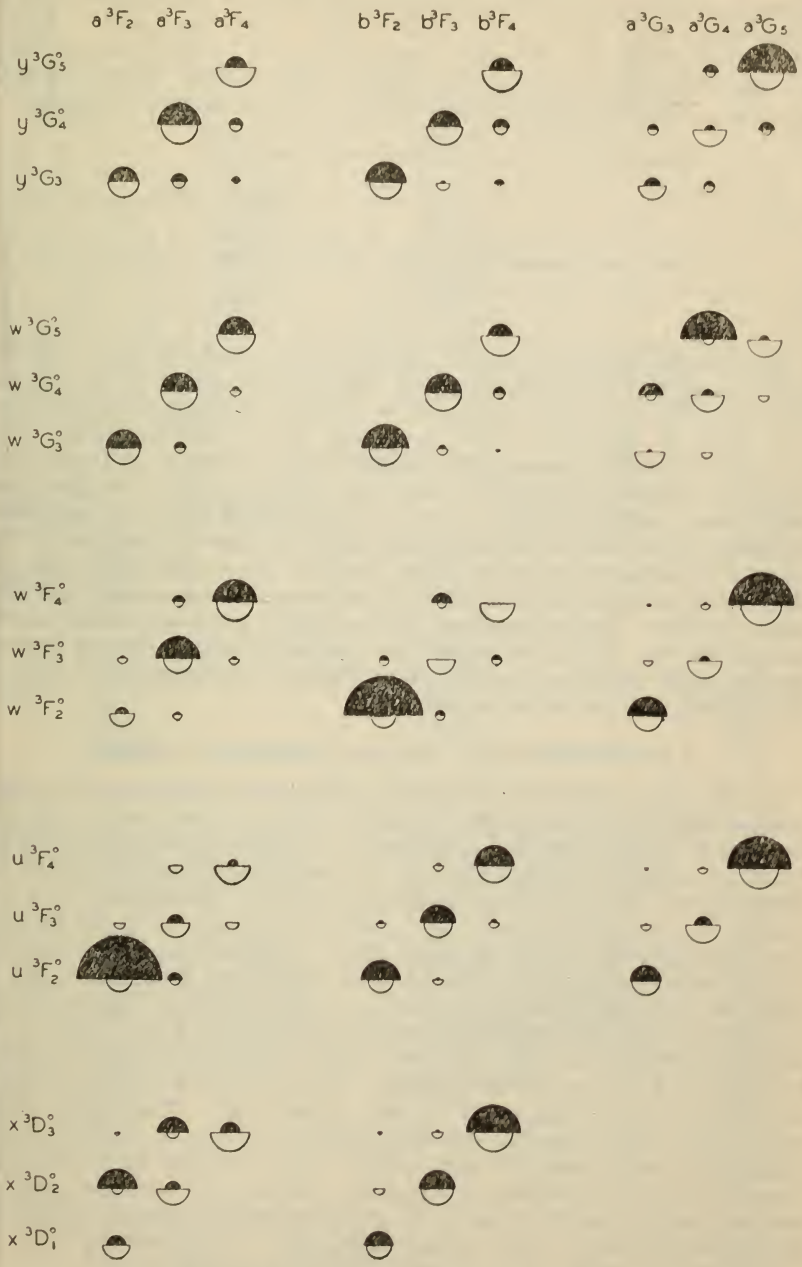

FIGURE 4.—*Abnormal intensities of Zr I*

Black semicircles, observed intensities
Open semicircles, theoretical intensities

quintet intersystem combinations may be thus accounted for. For example, the low term a^1D_2 participates with its companion a^3P_2 in combining with z^5P°, y^5P°, z^5D°, y^5D°, z^5F°, and y^5F°. Again, a^1G and a^5F each combine with high terms of the other system which are undoubtedly perturbed by terms with which they normally combine. The data illustrating this may be summarized as follows:

$$a^1G \text{ combines with} \begin{Bmatrix} y^5D^\circ_3 \\ y^5G^\circ_5 \end{Bmatrix} \text{perturbed by} \begin{Bmatrix} y^1F^\circ_3 \\ y^3G^\circ_5 \end{Bmatrix}$$

$$a^5F \text{ combines with} \begin{Bmatrix} z^1P^\circ_1 \\ z^1D^\circ_2 \\ v^1D^\circ_2 \\ y^1F^\circ_3 \\ x^1F^\circ_3 \\ u^1F^\circ_3 \\ z^1G^\circ_4 \end{Bmatrix} \text{perturbed by} \begin{Bmatrix} x^3P^\circ_1, \quad v^3D^\circ_1 \\ z^3D^\circ_2 \\ r^3D^\circ_2 \\ y^5D^\circ_3 \\ y^3G^\circ_3 \\ p^3D^\circ_3 \\ x^3F^\circ_4 \end{Bmatrix}$$

The second type of intensity abnormality is to be found in certain triplet system multiplets resulting from combinations of a common high term with low terms arising from different electron configurations. The effect is displayed most markedly in several multiplets with a^3F and b^3F as final terms, and consists of an inversion of the normal intensity relations within the multiplet; that is, the strongest lines result from combinations of terms of lowest inner quantum numbers. In Figure 4 the data illustrating this effect are shown graphically, the areas of the semicircles being drawn proportional to the intensities, the black ones representing the observed values and the open ones the theoretical values. For comparison the multiplets involving the term a^3G are also shown. It is to be noted that the graph is not intended to show the intensity relations between the different multiplets, but only of the individual lines within a multiplet.

4. INTERPRETATION OF THE OBSERVED TERMS

All the terms which have been observed for Zr I can be accounted for satisfactorily by means of the quantum theory of the atom. According to this theory, the final formulation of which is due to Hund,[24] the terms on which a spectrum is built up represent the resultants of the interaction of the valence electrons of an atom. The neutral Zr atom, atomic No. 40, has 40 electrons outside the nucleus of which 36 form the closed groups of the krypton shell. The 4 remaining electrons are the series or valence electrons, 2 of which are assigned to the 4_3 orbits of the N shell, and 2 to 5_1 orbits of the O shell. The configuration of these electrons is designated by the symbol $4d^2 \cdot 5s^2$. But it can so happen that 3 or all 4 of the valence electrons occupy 4_3 orbits leaving but 1 or none in the 5_1 orbits. In such cases the configurations are symbolically designated as $4d^3 \cdot 5s$ and $4d^4$. The terms which result from these electron configurations are given in Table 7. For comparison with them the terms which have actually been found are given in the third column of the table. Thus it is seen that the low and metastable terms of Zr I all originate in the electron configurations just described, the configuration $4d^2 \cdot 5s^2$ representing the state of minimum energy or the normal state of the neutral atom.

With the absorption of energy by the atom, an electron is removed from one of the configurations just described to an outer orbit. New electron configurations ensue, of which the most conspicuous are those

[24] Linienspektren und periodisches System der Elemente, Julius Springer, Berlin; 1927.

in which one of the original $5s$ or $4d$ electrons is raised to a 5_2 orbit. The configurations containing one $5p$ electron will produce groups of odd terms, as shown in the table, which will combine strongly with the low and metastable terms. Nearly all the terms required by theory for the configurations $4d^2 \cdot 5s \cdot 5p$, $4d^3 \cdot 5p$, and $4d \cdot 5s^2 \cdot 5p$, except some of the singlets, have actually been found for Zr I.

As the energy of the atom increases, the migrating electron will enter the 5_3 and 6_1 orbits and the new configurations will be $4d^2 \cdot 5s \cdot 6s$, $4d^2 \cdot 5s \cdot 5d$, etc. The terms will be even, and will combine with the odd terms of the middle group. Owing to their origin in configurations similar to those giving the low and metastable terms, they will form Rydberg series with the corresponding terms of the low group. As Table 7 shows, only a few of these high, series-forming terms have been identified. The limits of these series will be the low terms of Zr II coming from the configurations $4d^2 \cdot 5s$, $4d^3$, and $4d \cdot 5s^2$, which result when the neutral atom has lost one of its electrons. From our work on the analysis of Zr II are taken the limits given in the last column of Table 7.

TABLE 7.—*Theoretical and observed terms of Zr I*

Electro configuration	Theoretical terms	Observed terms	Limit in Zr II
$4d^2 \cdot 5s^2$	^5F ^3P ^1G ^1D ^1S	a^3F a^3P a^1G a^1D a^1S	a^4F, a^2F a^4P, a^2P b^3G a^2D a^2S
$4d^2 \cdot 5s$	$^5F, {}^3F$ $^5P, {}^3P$ $^3H, {}^1H$ $^3G, {}^1G$ $^3F, {}^1F$ $^3D, {}^1D$ $^3P, {}^1P$ $^3D, {}^1D$	a^5F, b^5F a^5P, b^3P a^3H, a^1H a^3G, b^1G c^3F a^3D, b^1D c^3P	b^4F b^4P a^2H a^2G b^2F b^2D b^2P c^2D
$4d^3$	$^5D, {}^3H, {}^3G, {}^3F, {}^3D, {}^3P, {}^1I, {}^1G, {}^1F$, *etc.*	a^5D	
$4d^2 \cdot 5s \cdot 5p$	$^5G^\circ, {}^5F^\circ, {}^5D^\circ, {}^3G^\circ, {}^3F^\circ, {}^3D^\circ$ $^5D^\circ, {}^5P^\circ, {}^5S^\circ, {}^3D^\circ, {}^3P^\circ, {}^3S^\circ$ $^3H^\circ, {}^3G^\circ, {}^3F^\circ, {}^1H^\circ, {}^1G^\circ, {}^1F^\circ$ $^3G^\circ, {}^3F^\circ, {}^3D^\circ, {}^1G^\circ, {}^1F^\circ, {}^1D^\circ$ $^3F^\circ, {}^3D^\circ, {}^3P^\circ, {}^1F^\circ, {}^1D^\circ, {}^1P^\circ$ $^3D^\circ, {}^3P^\circ, {}^3S^\circ, {}^1D^\circ, {}^1P^\circ, {}^1S^\circ$ $^3P^\circ, {}^1P^\circ$	$z^5G^\circ, z^5F^\circ, z^5D^\circ, z^3G^\circ, z^3F^\circ, z^3D^\circ$ $y^5D^\circ, z^5P^\circ, z^5S^\circ, y^3D^\circ, y^3P^\circ, y^3S^\circ$ $x^3H^\circ, w^3G^\circ, t^3F^\circ, z^1H^\circ, x^1G^\circ$ $x^3G^\circ, w^3F^\circ, w^3D^\circ, z^1G^\circ, y^1F^\circ$ $x^3F^\circ, v^3D^\circ, x^3P^\circ, z^1F^\circ, z^1D^\circ, z^1P^\circ$ $x^3D^\circ, z^3P^\circ, z^3S^\circ, y^1D^\circ, y^1P^\circ$ v^1P°	a^4F a^4P b^2G a^2F a^2D a^2P a^2S
$4d^3 \cdot 5p$	$^5G^\circ, {}^5F^\circ, {}^5D^\circ, {}^3G^\circ, {}^3F^\circ, {}^3D^\circ$ $^5D^\circ, {}^5P^\circ, {}^5S^\circ, {}^3D^\circ, {}^3P^\circ, {}^3S^\circ$ $^3I^\circ, {}^3H^\circ, {}^3G^\circ, {}^1I^\circ, {}^1H^\circ, {}^1G^\circ$ $^3H^\circ, {}^3G^\circ, {}^3F^\circ, {}^1H^\circ, {}^1G^\circ, {}^1F^\circ$ $^3G^\circ, {}^3F^\circ, {}^3D^\circ, {}^1G^\circ, {}^1F^\circ, {}^1D^\circ$ $^3F^\circ, {}^3D^\circ, {}^3P^\circ, {}^1F^\circ, {}^1D^\circ, {}^1P^\circ$ $^3D^\circ, {}^3P^\circ, {}^3S^\circ, {}^1D^\circ, {}^1P^\circ, {}^1S^\circ$ $^3F^\circ, {}^3D^\circ, {}^3P^\circ, {}^1F^\circ, {}^1D^\circ, {}^1P^\circ$	$y^5G^\circ, y^5F^\circ, x^5D^\circ, y^3G^\circ, y^3F^\circ, w^3D^\circ$ $w^5D^\circ, y^5P^\circ, y^5S^\circ, t^3D^\circ, w^3P^\circ, x^3S^\circ$ $z^3I^\circ, y^3H^\circ, t^3G^\circ, z^1I^\circ, x^1H^\circ, w^1G^\circ$ $z^3H^\circ, z^3G^\circ, s^3F^\circ, y^1H^\circ, y^1G^\circ, v^1F^\circ$ $w^3G^\circ, v^3F^\circ, s^3D^\circ, u^1F^\circ, v^1D^\circ$ $u^3F^\circ, r^3D^\circ, t^3P^\circ, x^1F^\circ, x^1D^\circ, x^1P^\circ$ $p^3D^\circ, s^3P^\circ, w^3S^\circ$ $r^3F^\circ, q^3D^\circ, u^3P^\circ, w^1F^\circ, w^1D^\circ, w^1P^\circ$	b^4F b^4P a^2H a^2G a^2F a^2D a^2P c^2D
$4d \cdot 5s^2 \cdot 5p$	$^2F^\circ, {}^2D^\circ, {}^2P^\circ, {}^1F^\circ, {}^1D^\circ, {}^1P^\circ$	$q^3F^\circ, o^3D^\circ, t^3P^\circ$	d^2D
$4d^2 \cdot 5s \cdot 6s$	$^5F, {}^3F$ $^5P, {}^3P$ $^3G, {}^1G$ $^3F, {}^1F$ $^3D, {}^1D$ $^3P, {}^1P$ $^3S, {}^1S$	e^5F, e^3F	a^4F a^4P b^2G a^2F a^2D a^2P a^2S
$4d^2 \cdot 5s \cdot 5d$	$^5H, {}^5G, {}^5F, {}^5D, {}^5P, {}^3H, {}^3G, {}^3F, {}^3D, {}^3P$ $^3H, {}^3G, {}^3F, {}^3D, {}^3P, {}^1H, {}^1G, {}^1F, {}^1D, {}^1P$ $^5F, {}^5D, {}^5P, \quad {}^3F, {}^3D, {}^3P$ $^3F, {}^3D, {}^3P, \quad {}^1F, {}^1D, {}^1P$ $^3I, {}^3H, {}^3G, {}^3F, {}^3D, {}^1I, {}^1H, {}^1G, {}^1F, {}^1D$ $^3G, {}^3F, {}^3D, {}^3P, {}^3S, {}^1G, {}^1F, {}^1D, {}^1P, {}^1S$ $^1D, \quad {}^1D$	e^5H, e^5G	a^4F a^4F a^4P a^2P b^2G a^2D a^2S
$4d^2 \cdot 5p^2$	$^5G, {}^5F, {}^3D$, etc.	f^5G	a^3F (Zr III)

There are no definitely established rules for tracing the observed terms of a complex spectrum back to their parent terms in the ion. Therefore, the assignment of the terms to their proper electron configurations is attended with some uncertainty. However, there are certain properties of complex terms and their combinations which give important clues as to their origin. For example, the quintet terms of Zr I can arise only from the addition of s and p electrons to the quartets of Zr II, and similarly, the singlets can arise only from the doublets of Zr. II. The triplets, however, are derived from both doublet and quartet terms. The relative positions of the terms in the term diagram and their separations will, in general, follow those exhibited by the parent terms of the ion. And further, the intensities of the term combinations will indicate the nature of the transitions involved in accordance with Kronig's rule as stated above, those being strongest for which the change ΔL in the term quantum number is the same as the change Δk in the azimuthal quantum number of the series electron.

It was on the basis of these principles that the assignment of the observed terms to their electron configurations was made, as shown in Table 7. The quintets fall into such clearly defined groups that there seems to be no uncertainty in allocating them. Among the triplets and singlets no such unmistakable groupings occur, and the assignments which have been made are admittedly open to revision. However, a partial check on the correctness of these assignments is afforded by the characteristic, noted above, of mutual perturbations exerted on each other by related terms. And conversely, it seems from the data at hand for Zr I, that neighboring terms of the same inner quantum number are unrelated, that is, have different electronic origins, if they fail to exhibit mutual perturbations. A further check on the correctness of the term assignments would be furnished by the application of the irregular doublet law to the Zr I terms and the corresponding terms of Cb II. Progress in the analysis of the first spark spectrum of Cb is not sufficiently advanced, however, to permit this at the present time. In Figures 1, 2, and 3, the terms which have been grouped together in Table 7 are connected with dotted lines.

The origin of the term f^5G is not certain. It lies too close to e^5G, and its combinations are much too strong to consider it as a second series member of the $4d^2 \cdot 5s \cdot md$ configurations. Russell [25] has found an analogous term in Ti I, which, owing to its association with similarly situated ^{5}D and ^{5}F terms, he has assigned to the configuration $3d^2 \cdot 4p^2$ with a^3F of Ti III as limit. We have found no trace of the corresponding D and F terms in Zr I, but because of its position in the term diagram we assign the term f^5G provisionally to the configuration $4d^2 \cdot 5p^2$.

We may now consider the *raies ultimes* of Zr I. In his discussion of the spectra of the elements of the Fe group Russell [26] has pointed out that the *raies ultimes* and resonance lines for the arc spectra originate in the transition $d^{n-2} \cdot s^2 \rightarrow d^{n-2} \cdot s \cdot p$, in which n is the number of electrons outside the argon shell. Except for K and Cr the resonance lines are invariably intersystem combinations of long wave length, whereas the ultimate rays are of much shorter wave length

[25] Astrophys. J., 66, p. 415; 1927.

[26] Astrophys. J., 66, p. 212; 1927.

falling generally in the blue or violet. An apparent exception to these rules in the case of Ti I has been shown by Harrison and Engwicht [27] to be unreal. These rules give physical meaning to the empirical rule stated several years ago by Meggers, Kiess, and Walters,[28] and subsequently elaborated by Meggers and Laporte,[29] that the *raies ultimes* originate in the lowest term of the spectrum and result from its combination with a term of the same multiplicity but of L value one unit greater, whereas the resonance lines represent an intersystem combination between the lowest term and a term of higher multiplicity. For Zr I we find that the resonance lines and *raies ultimes* conform to these rules, the former being given by the combination $a^3F—z^5F°$, and the latter by $a^3F—z^3G°$, of which the principal lines are: 4,688.45, 4,633.99, and 4,575.52 A. These three lines, of Temperature Class I, appear in the fully developed spectrum with intensities much lower than do the neighboring blue lines, 4,687.8 to 4,815.6 A, also of Class I, which were designated by de Gramont [30] as sensitive lines in the visible region for spectrochemical analysis; and they are definitely weaker than the lines 3,601.18, 3,547.69, 3,519.60 A which are among the most intense of the entire arc spectrum and form the main diagonal of the multiplet $a^3F—x^3G°$. But on spectrograms obtained at the National Bureau of Standards, of elements containing Zr as a minute impurity, the lines cited above as the ultimate rays prove to be the most sensitive ones, whereas the others, which must be classed as penultimate rays following Russell's [31] terminology, appear much more faintly or not at all. Thus, both the resonance lines and the *raies ultimes* of Zr I result from the electron transition requiring the minimum transfer of energy, and the terms which combine to produce the lines all have a^4F of Zr II as parent term.

5. SERIES AND IONIZATION POTENTIAL

Only six terms of the third group have been identified combining with odd terms of the middle group. Of these only two, e^3F and f^5F, form sequences with the low terms a^3F and a^5F. These sequences represent the migration of an s electron from the O shell to the P shell, and are satisfactorily represented by a simple Rydberg formula, owing to the loose binding of the s electron in its orbits. The ^3F terms will have a^4F of Zr II as limit, but the ^5F terms will converge to b^4F, the component series of each sequence approaching their different limits in the manner shown by Hund.[32] In Table 8 are the results obtained from six series for the distance between the lowest terms of Zr I and Zr II. The individual determinations are in good agreement and their mean, 56,077 cm^{-1}, is adopted as the value of $a^3F_2—a^4F_{1\frac{1}{2}}$. This represents the work required to remove an s electron from the atom and corresponds to an ionization potential of 6.92 volts.

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[27] J. Opt. Soc. Am. & Rev. Sci. Inst., **18**, p. 296; 1929.
[28] J. Opt. Soc. Am. & Rev. Sci. Inst., **9**, p. 372; 1924.
[29] J. Opt. Soc. Am. & Rev. Sci. Inst., **11**, p. 460; 1925.
[30] Compt. Rend., **166**, p. 367; 1918.
[31] Astrophys. J., **61**, p. 223; 1925.
[32] Linienspektren, p. 184.

TABLE 8.—*Series limits of Zr I*

Term	a^3F_2	a^3F_3	a^3F_4	a^5F_3	a^5F_4	a^5F_5
Distance from limit, cm^{-1}	56,636	56,226	55,888	54,064	53,787	53,952
Reduction to $a^4F_{1\frac{1}{2}}$, Zr II	−315	−763	−1,323	−2,895	−3,758	−3,300
Reduction to a^3F_2, Zr I	0	+570	+1,241	+5,023	+5,889	+5,540
$a^4F_{1\frac{1}{2}}-a^3F_2$	56,321	56,033	55,806	56,192	55,918	56,192

Mean ($a^4F_{1\frac{1}{2}}-a^3F_2$) = 56,077 cm^{-1}
Ionization potential = 56,077 × 1.2345 × 10^{-4} = 6.92 *v*

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

Observed		Solar			Observed		Solar		
λ	Intensity	λ	Intensity	Identification	λ	Intensity	λ	Intensity	Identification
9,276.94	1	6.92	−1		4,414.14	4	.121	−1	Ti
8,296.54	2	.571	−2		4,390.15	2	.116	−2	
6,994.38	12	.385	−3		4,389.61	2	.644	0	CH
6,853.85	3	.863	−3		4,346.53	5	.563	2	Fe
6,849.29	8	.314	−2 N		4,345.58	2	.608	−1 N	
6,762.38	20	.407	−2		4,325.44	10	.489	−2	
6,160.27	2	.234	−3		4,321.44	2	.424	0 N	
5,984.24	6	.279	−2		4,304.68	8	.724	0	
5,735.70	12	.712	−1	Ca?	4,225.25	3	.220	0	V^+
5,555.38	2	.357	−3		4,220.65	3	.654	−1	Sa^+
5,545.42	8	.430	−3		4,166.51	4	.534	−2	
5,518.06	2	.099	−2		4,134.32	4	.343	3	Fe
5,487.52	2	.524	−1 N		4,087.68	4	.707	−2	
5,460.71	3	.701	−3 *d* ?		4,053.67	2	.691	−1	
5,407.63	10	.619	−1	Cr^+	4,050.48	5	.495	−1	
5,405.13	4	.141	−2		4,028.95	7	.991	−2	
5,280.06	10	.071	−1	Fe	4,007.59	8	.614	−1 *d* ?	Fe
5,243.46	5	.472	−3		4,004.87	4	.919	1	
5,224.94	9	.941	0	Cr Ti	4,001.22	2	.243	−2	
5,223.62	2	.632	−2	Ti	4,001.09	3	.112	0	
5,215.58	2	.577	−2 N		3,989.50	6	.450	−1 N	Ce^+
5,165.97	8	.966	−3		3,981.59	10	.622	0	
5,161.01	7	.026	−2	(C−)	3,978.73	6	.777	−2	
5,158.68	6	.665	−3	(C−)	3,976.17	2	.187	−2	
5,145.46	1	.470	0	Ti	3,963.79	5	.806	−2	
5,136.78	3	.802	−2		3,926.78	5	.779	−2	
5,120.44	7	.425	0	Ti	3,901.49	3	.486	−1	
5,105.56	5	.547	4	Fe−Cu	3,892.02	5	.017	−2	Mg?
5,070.27	12	.297	−3	(C−)	3,780.53	18	.518	−1	CN
5,032.42	2	.385	−2 N		3,714.13	10	.158	−2 N	
4,996.35	10	.383	−2		3,656.88	5	.859	−3 N	
4,962.30	5	.294	−2	Sr?	3,612.55	2	.520	−2	
4,933.66	7	.673	−2 *d* ?		3,596.29	2	.314	−3	
4,881.25	8	.269	−3		3,577.55	6	.566	−3	CN
4,789.12	5	.139	−2		3,558.95	4	.985	−3	CN
4,707.78	5	.764	−1	Cr?	3,549.73	5	.766	−3 *d* ?	CN
4,640.12	3	.108	−2	V?	3,548.68	2	.652	−3	CN
4,634.63	3	.607	−2		3,535.16	8	.159	−3 N	
4,624.07	1	.092	−1		3,512.35	1	.382	−2	
4,584.57	1	.559	−3		3,503.27	2	.304	−2 N	
4,582.29	5	.313	0 N		3,494.44	4	.413	−3	
4,574.94	2	.905	−1 *d* ?	La^+	3,493.66	3	.696	1	Fe
4,570.59	1	.611	−2 *d* ?		3,487.81	3	.821	−2	
4,539.98	8	0.001	−1 N	V	3,483.01	7	.018	4	Fe
4,513.34	2	.327	−2		3,478.78	8	.786	0	Fe
4,482.49	3	.441	−3		3,476.02	3	.027	−2 N	
4,455.43	5	.452	−2 N	Cr?	3,472.89	5	.905	−2	Cr
4,450.27	7	.237	−2		3,472.72	2	.715	−3 N	
4,448.94	3	.950	−1 N		3,465.63	7	.646	1	Ti^+
4,420.25	1	.288	0		3,430.94	3	.956	−2	

TABLE 9.—*Identification of Fraunhofer lines with Zr*—Continued

Observed		Solar			Observed		Solar		
λ	Intensity	λ	Intensity	Identification	λ	Intensity	λ	Intensity	Identification
3,426.93	4	.913	−3	NH	3,243.98	10	4.030	−3 N	
3,416.68	4	.677	0	Fe	3,225.47	4	.463	−1 N	Cb+
3,411.78	2	.752	−2		3,223.34	3	.365	−1	OH
3,409.40	2	.399	−2 N		3,216.57	3	.547	0	
3,408.54	4	.506	−2 *d* ?		3,212.02	30	.006	2	Fe
3,386.90	2	.879	−2		3,185.68	2	.675	0	
3,326.43	6	.424	0	NH	3,185.08	3	.093	−3	
3,316.21	5	.198	−2 *d* ?		3,132.06	15	.056	4	Cr
3,297.64	2	.667	−2		3,121.95	2	.970	−1	
3,293.45	2	.479	−1						
					3,092.25	3	.234	−3	
3,285.18	3	.199	1	−Ce+?	3,085.34	10	.332	1	Fe?
3,261.06	2	.066	−1 *d* ?	Cd	3,052.80	2	.787	0	
3,260.11	15	.146	−2		3,052.00	2	1.987	−2 N	
3,256.00	2	5.983	−3						
3,254.28	10	.262	4	Ti+					

IV. ZIRCONIUM IN THE SUN

In our paper on the first spark spectrum of Zr we showed that many faint lines in the solar spectrum, whose origins are unknown or doubtful, can be accounted for by combinations of terms of Zr II. These include lines which are theoretically possible, but do not appear in laboratory sources in emission. We have carried out a similar survey for Zr I.

The wave lengths of Table 3 have been compared with those of the Fraunhofer lines listed by St. John and his associates in their recent Revision of Rowland's Preliminary Table of Solar Spectrum Wave-Lengths.[33] All coincidences which are not already assigned by them to Zr are given in Table 9. No doubt some of these will prove to be blends, especially those coinciding with lines already assigned to other atomic origins. There are many problems of physics and astrophysics which are based on such characteristics of the absorption lines which appear in the spectra of the sun and stars, as their wave lengths and contours. It is of importance, therefore, to know with certainty the chemical origins of the lines and the extent to which they are affected by blending.

It is a well-established fact that stellar spectra exhibit features that have not been duplicated in the laboratory. For example, more members of the Balmer series have been observed in absorption in the stars than have been observed in absorption or in emission in laboratory sources. And likewise, multiplet lines which appear only faintly or not at all in artificial sources may appear in stellar spectra with intensities revealing higher transition probabilities than those given by the quantum theory, as shown by the recent work of Woolley [34] and of Struve.[35] Many of the Zr I multiplets fail to show their full complement of lines in the laboratory and some which represent permissible transitions do not appear at all. We have calculated the wave lengths of these lines from the terms given above, and have compared them with the solar lines, with the results shown in Table 10.

[33] Carnegie Institution of Washington, Publication No. 396; 1928.
[34] Astrophys. J., 72, p. 256; 1930.
[35] Astrophys. J., 72, p. 267; 1930.

Again we recognize the possibility of fortuitous coincidences, but in cases where two or more lines of the same multiplet appear we believe the identifications are real.

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

Calculated λ	Solar			Term combination
	λ	Intensity	Identification	
6, 224. 17	4. 206	−3		$a^3H_5-y^1G^\circ_4$
6, 176. 48	. 463	−3		$b^3F_4-w^3F^\circ_4$
6, 148. 67	. 668	−2		$a^3H_4-y^1G^\circ_4$
5, 904. 19	. 208	−3	At m?	$b^3F_4-v^3D^\circ_3$
5, 772. 58	. 589	−2	At m	$b^3F_3-v^3D^\circ_3$
5, 535. 06	. 065	−3N		$a^5F_2-z^5S^\circ_2$
5, 466. 01	. 035	−3N		$a^3G_4-y^1G^\circ_4$
5, 440. 96	. 984	−2		$a^3D_2-y^1P^\circ_1$
5, 374. 90	. 895	−3		$a^3D_1-y^1P^\circ_1$
5, 366. 43	. 428	−1		$a^3H_4-u^3F^\circ_3$
5, 304. 42	. 438	−3		$a^5F_4-y^1F^\circ_3$
5, 219. 90	. 887	−3		$c^3P_2-t^3D^\circ_2$
5, 197. 40	. 376	−3N		$c^3P_1-t^3D^\circ_2$
5, 167. 49	. 510	5	Fe	$c^3P_2-v^3P^\circ_1$
5, 162. 76	. 734	−3		$a^5F_2-y^1F^\circ_3$
5, 020. 04	. 033	2	Ti	$a^3H_4-y^3H^\circ_5$
4, 901. 34	. 321	−3N		$a^5F_3-z^5P^\circ_2$
4, 848. 47	. 472	−2	Ti	$a^5F_1-z^5P^\circ_1$
4, 823. 06	. 086	−3		$a^3D_1-w^1D^\circ_2$
4, 757. 33	. 325	−2	−Cr?	$a^3H_4-t^3F^\circ_3$
4, 723. 30	. 349	−2		$a^3D_2-t^3F^\circ_2$
4, 682. 98	. 962	−2*d*?		$a^3H_5-x^1G^\circ_4$
4, 673. 44	. 446	−1N		$a^3D_1-t^3F^\circ_2$
4, 642. 56	. 593	−1N	Fe	$a^5F_2-x^3D^\circ_2$
4, 398. 30	. 303	0	Ti+	$a^5F_1-y^3P^\circ_0$
4, 374. 62	. 619	−1N		$a^5F_2-w^3F^\circ_2$
4, 364. 00	3. 978	−2		$a^5F_3-w^3F^\circ_3$
4, 229. 43	. 410	0		$a^1G_4-w^3G^\circ_4$
4, 197. 48	. 510	−2		$a^3F_3-y^1F^\circ_3$
4, 185. 35	. 366	−1N	Cr?	$a^5F_2-x^3P^\circ_2$
4, 149. 86	. 900	−1		$a^3H_4-r^3F^\circ_3$
4, 149. 10	. 129	0	CN	$a^1G_4-w^3G^\circ_5$
4, 100. 54	. 510	−2		$b^3F_3-x^1G^\circ_4$
4, 064. 23	. 215	1	Ti	$a^3H_4-u^3G^\circ_3$
3, 996. 88	. 859	−2		$a^3H_4-v^1F^\circ_3$
3, 990. 56	. 569	0N*d*?	V	$b^3F_3-v^3P^\circ_2$
3, 979. 90	. 904	−1		$b^3F_2-w^1F^\circ_3$
3, 968. 72	. 717	1N		$a^3H_5-u^3G^\circ_5$
3, 947. 13	. 135	0	Co	$a^3F_3-z^5P^\circ_3$
3, 946. 79	. 815	−2N		$b^3F_2-u^3P^\circ_1$
3, 923. 13	. 109	0	Ce+	$b^3F_2-s^3F^\circ_2$
3, 922. 02	. 022	−1		$a^3F_2-z^5P^\circ_1$
3, 921. 40	. 430	1	Ti	$b^3F_3-u^3P^\circ_1$
3, 918. 54	. 575	0		$b^3F_3-s^3F^\circ_3$
3, 908. 42	. 413	0	Ce+Pr+?	$b^3F_4-s^3F^\circ_4$
3, 870. 65	. 666	0	CN	$b^3F_2-s^3F^\circ_3$
3, 830. 31	. 305	−1	CN	$b^3F_3-s^3F^\circ_4$
3, 827. 25	. 215	−1	CN?	$a^3G_4-r^3F^\circ_3$
3, 811. 79	. 809	2		$a^3F_2-x^1F^\circ_3$
3, 789. 93	. 923	−2	CN	$a^3G_3-r^3F^\circ_3$
3, 787. 77	. 786	0		$a^1G_4-y^3H^\circ_4$
3, 786. 54	. 524	0		$a^3G_5-r^3F^\circ_4$
3, 751. 48	. 451	−1N		$a^1G_4-y^3H^\circ_5$
3, 748. 83	. 801	−2		$a^3F_4-z^3H^\circ_4$
3, 696. 76	. 754	−2		$a^3G_4-v^1F^\circ_3$
3, 691. 38	. 396	−3		$a^3G_5-y^1H^\circ_5$
3, 689. 73	. 701	−3		$a^3G_4-y^1H^\circ_5$
3, 676. 83	. 815	−3		$a^3H_6-x^1H^\circ_5$
3, 633. 30	. 309	−3N	Co?	$a^3F_2-x^1D^\circ_2$
3, 625. 77	. 754	−2		$a^3F_2-y^3P^\circ_1$

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

Calculated λ	Solar			Term combination
	λ	Intensity	Identification	
3,612.94	2.942	3	Fe	$a^5F_5-u^3F_4^\circ$
3,606.06	.040	−2	Ti?	$a^5F_3-v^3F_2^\circ$
3,589.98	.969	−1	Mn, CN	$b^3F_3-v^1F_3^\circ$
3,577.72	.746	−3	CN	$a^5F_3-v^3F_3^\circ$
3,568.02	.009	−3	CN	$a^5F_4-u^3F_4^\circ$
3,557.48	.465	−3	CN	$a^5F_1-v^3F_2^\circ$
3,551.68	.660	1	CN–Co	$a^5F_4-v^3F_4^\circ$
3,549.75	.766	−3*d*?	CN	$b^3F_3-v^1F_3^\circ$
3,531.28	.283	−3N		$a^5F_3-u^3F_3^\circ$
3,505.92	.900	0	Ti+?	$a^5F_3-w^3D_2^\circ$
3,504.58	.595	−3		$a^3P_0-y^1P_1^\circ$
3,495.99	.963	−3	CrTi	$a^3P_1-v^3F_2^\circ$
3,483.42	.415	3	Co	$a^5F_4-u^3D_3^\circ$
3,478.39	.367	0	Fe	$a^5F_2-u^3D_2^\circ$
3,476.94	.960	−3		$a^5F_2-v^3F_3^\circ$
3,460.58	.608	−3N		$a^5F_2-w^5D_3^\circ$
3,458.02	.011	−2	Ti?	$a^5F_4-y^3H_4^\circ$
3,449.97	.939	−2*d*?		$b^3F_4-w^1G_4^\circ$
3,448.39	.360	−3N	Co	$a^5F_3-u^3D_3^\circ$
3,427.75	.766	−2N		$a^5F_4-y^3H_5^\circ$
3,426.93	.913	−3	NH	$a^1G_4-v^3G_3^\circ$
3,423.50	.535	−1N	NH	$a^5F_3-y^3H_4^\circ$
3,418.28	.317	−3N		$a^5F_5-y^3H_6^\circ$
3,404.60	.585	0	Pd	$b^3F_3-w^1G_4^\circ$
3,404.44	.449	−3N		$a^1G_4-v^3G_5^\circ$
3,387.43	.419	2	Fe	$a^5F_3-y^5P_2^\circ$
3,384.67	.647	−1	Ti?	$a^3G_5-x^1H_5^\circ$
3,383.28	.314	−2		$a^3G_4-x^1H_5^\circ$
3,383.09	.097	−3N		$a^5F_4-y^5P_3^\circ$
3,350.04	.082	−2N		$a^5F_3-y^5P_3^\circ$
3,344.53	.524	2	Ca–La+	$a^5F_1-y^5P_2^\circ$
3,322.86	.875	1		$a^3F_4-w^3G_3^\circ$
3,322.70	.705	−1		$a^3F_2-x^5D_1^\circ$
3,309.52	.531	2N	Ti–	$a^5F_3-w^3P_2^\circ$
3,280.47	.499	−3N		$a^3P_1-w^1D_2^\circ$
3,255.49	.498	1N	OH	$a^5F_5-x^3H_5^\circ$
3,218.97	.985	−2	Co?	$a^5F_4-x^3H_5^\circ$
3,207.90	.894	−2	Ti	$a^5F_1-v^3P_0^\circ$
3,187.93	.900	−3		$a^5F_3-x^3H_4^\circ$
3,154.40	.421	1		$a^5F_3-v^3G_3^\circ$
3,147.77	.785	1	Fe	$a^5F_3-v^3P_2^\circ$
3,104.58	.572	2N	La+	$a^5F_3-u^3P_2^\circ$
3,081.02	.006	1		$a^3F_4-v^3F_4^\circ$

V. CONCLUSION AND ACKNOWLEDGMENTS

The structure of Zr I as portrayed in the preceding pages beautifully illustrates the effectiveness of the quantum theory of the atom to account for a complex spectrum. Not all the terms postulated by the theory have been established, but there is hardly room for doubt that among the lines of Zr I remaining unclassified or unobserved will be found the clues to the missing terms. Most of the unclassified lines lie in the ultra-violet, and probably result from the binding of an electron in a 4_4 orbit. We have sought for evidence of the terms coming from the $4f$ electron, both in Zr I and in Zr II, but without success, although both Zr III and Zr IV possess groups of lines representing the transition $4f \longrightarrow 4d$. In each of these spectra, however, energy of the order of 15 or 20 volts is required to remove an electron

from a 4_3 orbit to a 4_4 orbit, which is far in excess of that required to ionize the Zr atom.

In conclusion, we take this opportunity to express our thanks to all those who have aided us in the investigations of the Zr spectra described in this and in the preceding papers. To Dr. A. S. King and Miss Carter, to the late Prof. B. E. Moore, and to Prof. H. N. Russell we are particularly indebted for placing at our disposal unpublished observations and results of their investigations. To Mrs. F. J. Stimson, E. Z. Stowell, D. D. Laun, and B. F. Scribner, former and present members of the bureau's staff, we are indebted for the assistance they have given us in making the observations and calculations upon which this work is based.

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