The Second Spark Spectrum of Krypton

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The spectrum of krypton was first investigated by E. C. C. Baly [1] in 1904. In recent years, L. and E. Bloch [2] and Dejardin have published a number of lines of krypton, after having classified them in three groups marked as 1, 2, and 3, according to the different stages of excitation at which they had appeared. This list comprises not only the lines given by Baly, but also many new lines observed by Bloch and Dejardin who have extended the observational data to λ 2200 A° on the short wave-length side. Lines marked as " 1 " have been classified by P. K. Kichlu[3] and have been proved to be due to singly ionised krypton. The classification of the lines marked as " 2" has been attempted in the following pages, and the analysis, so far as it has been successful, leaves no doubt that these lines are due to doubly ionised krypton. A preliminary note in this connection was published by the present writer, in " Nature " of February 16, 1929.

Experimental

The data with regard to the lines of krypton have been extended by the present writer, to the extreme ultra-violet as far as the furthest limit of transmission of quartz, *viz.*, λ 1900 A°. The source of light used was a quartz tube filled

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[1] Phil. Trans., 202, 183, 1904.

[2] Ann. de Phys., 2, 461, 1924.

[3] Proc. Roy. Soc., 120, 643, 1928.

with krypton, obtained from Messrs. E. Leybolds Nachfolger of Germany, and so far as has been ascertained, the tube contains the gas of exceptional purity. This was placed end-on in line with the slit of the spectroscope, and was excited by an induction coil working with a 12 volt supply. The usual method of a spark gap in series and a condenser in parallel with the secondary circuit, was used to give the discharge a condensed character. Up to λ 2100 A°, Hilger's E_3 quartz spectrograph was used; below this, lines up to λ 1900 A° were photographed with a small Hilger's E_6 quartz spectrograph. Schumann plates were throughout used. Copper arc lines were employed as standard lines up to λ 2100. Below this, silver spark lines were taken as standard. The lines were measured by an Adam Hilger's micrometer, kindly lent to the laboratory, by Principal D. N. Sen; and wave-lengths were calculated by using Hartmann's three constant dispersion formula. It is believed that the errors in final measurements do not exceed λ·04 A°.

Location of Kr^{++} Spectrum.

The arrangement of electrons in an atom of Kr^{++} may be graphically represented, following Prof. M. N. Saha, in the manner shown below :—

K_1						
2						
	L_1	L_2				
	2	6				
		M_1	M_2	M_3		
		2	6	10		
			N_1	N_2	N_3	N_4
			2	4		
				O_1	O_2	O_3
					P_1	P_2

The most stable structure of a doubly ionised krypton atom, is that when all the four valence electrons are in N_2 level. Other less stable configurations are obtained by putting 3 electrons in N_2 and the fourth one in any of the virtual orbits O_1, O_2, O_3, N_3, etc.

The terms that these different electronic configurations give rise to, may then be calculated on the principles enunciated by Pauli, Heisenberg and Hund. They are given in Table I. We shall here use the notation first proposed by A. Fowler.[1]

TABLE I

Electrons outside rare gas shell.	Configurations.	Prefix Adopted.	Terms.
$4s^2 . 4p^4$	$4N_4$	4p	^3P ^1D ^1S
$4s^2 . 4p^3 . 5s$	$3N_2O_1$	5s	^5S ^3S ^3P ^1P ^3D ^1D
$4s^2 . 4p^3 . 6s$	$3N_2P_1$	6s	
$4s^2 . 4p^3 . 5p$	$3N_2O_2$	5p	^5P ^3P
			^3P ^3D ^3F
			^1P ^1D ^1F
			^3S ^3P ^3D
			^1S ^1P ^1D
$4s^2 . 4p^3 . 5d$	$3N_2O_3$	5d	^5D
$4s^2 . 4p^3 . 4d$	$3N_2N_3$	4d	^3S ^3P ^3D ^3F ^3G
			^1S ^1P ^1D ^1F ^1G
			^3P ^3D ^3F
			^1P ^1D ^1F

To locate the lines which originate from the terms given above, we have to be guided by

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[1] Proc. Roy. Soc., 117, 317, 1928.

(1) The extension of irregular doublet law to optics, by Saha and Kichlu.[1]

(2) The method of horizontal comparison of spectra, by Saha and Majumdar.[2]

In applying the irregular doublet law, we have to compare the spectra of Se, Br^+, and Kr^{++} all of which will have similar structures. In addition to these, we may also compare the more well-known analogous spectra of Ne^{++} and A^{++}, and then from analogy deduce the position of the spectrum of Kr^{++}. The figures for these are provided in Table II.

TABLE II.

	O	F^+	Ne^{++}
$3L_2\ (M_1 \leftarrow M_2)$ $^5S - ^5P$	12863 Fowler's Report, P. 168.	25967 Jog, Ind. J. Phys., 2, 344, 1928.	38545 Jog, Ind. J. Phys., 2, 344. 1928.
$3L_3\ (M_2 \leftarrow M_3)$ $^5P - ^5D$	10788 Fowler's Report, P. 167.	28515 Jog, Unpublished.	46257 Majumdar, Unpublished
	S	Cl^+	A^{++}
$3M_3\ (N_1 \leftarrow N_2)$ $^5S - ^5P$	10851 Fowler's Report, P. 170.	20854 Paschen, Ann. d. Phys., 71, 560, 1923.	[31200]
$3M_4\ (N_2 \leftarrow N_3)$ $^5P - ^5D$	11517 Bungartz, Ann. d. Phys., 76, 723, 1925.	25957 Paschen, Ann. d. Phys., 71, 560, 1923.	[40000]

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[1] Saha and Kichlu, Ind. J. Phys., 2, 320, 1928

[2] Saha and Majumdar, Ind. J. Phys., 3, 67, 1928.

	Se	Br^+	Kr^{++}
$3N_2\,(O_1 \longleftarrow O_2)$ $^5S-^5P$	11431 Fowler's Report, P. 171.	21182 S. C. Deb, Proc. Roy. Soc., 127, 197, 1930	[31000]
$3N_2(O_2 \longleftarrow O_3)$ $^5P-^5D$	[10000]	21179 S. C. Deb, Proc. Roy. Soc., 127, 197, 1930.	[40000]

From this table, we find that 5s ^5S—5p ^5P lines due to the transition $3N_2\,(O_1 \longleftarrow O_2)$ will lie at about 31000. Further, it may also be remarked that ^5D separations for O, F^+ and Ne^{++} have not yet deen determined, being too small to be easily resolvable. Paschen[1] finds that in Cl^+ they are of the order of one frequency unit. In Br^+, Mr. S. C. Deb[2] finds that they are of the order of 30. In Kr^{++}, we should therefore expect that they will be fairly large, especially because the stage of ionisation is increased one step further than in Br^+. In a similar way, the ^5P separations of Br^+, as found by Mr. S. C. Deb, are of the order of 100. The corresponding separations of Kr^{++} may therefore, be expected to be at least of the order of 200.

Further clue to the disentanglement of this spectrum, as has been said before, is supplied by the method of horizontal comparison of Saha and Majumdar, which states that the lines originating from the same transitions of electrons in successive atoms, as given in the periodic table, are in arithmetic progression, provided, however, that the transitions take place between orbits with the same total quantum number.

We compare the spectra of

O^{++}	F^{++}	Ne^{++}
S^{++}	Cl^{++}	A^{++}
Se^{++}	Br^{++}	Kr^{++}

The data are given in Table III.

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[1] Ann. d. Phys., 71, 793, 1923.

[2] Proc. Roy. Soc., 127, 197, 1930.

TABLE III.

	O^{++}	F^{++}	Ne^{++}
XL_2 ($M_1 \leftarrow M_2$)	29925 Fowler, Proc. Roy. Soc., 187, 325, 1928.	34410 Dingle, Proc. Roy. Soc., 122, 144, 1929.	38545 Jog, Ind. J. Phys., 2, 344, 1928.
XL_2 ($M_2 \leftarrow M_3$)	31911 Fowler, Proc. Roy. Soc., 117, 325, 1928.	38748 Dingle, Proc. Roy. Soc., 122, 144, 1929.	46257 Majumdar, Unpublished.
	S^{++}	Cl^{++}	A^{++}
XM_2 ($N_1 \leftarrow N_2$)	26047 J. Gilles, Comp. Ren., 188, 63, 1929.	30030 Bowen, Phys. Rev., 31, 35, 1928.	[31200]
XM_2 ($N_2 \leftarrow N_3$)	36268 J. Gilles, Comp. Ren., 21st Jan., 1929, P. 321.	37504 Bowen, Phys. Rev., 31, 34. 1928	[39000]
	Se^{++}	Br^{++}	Kr^{++}
XN_2 ($O_1 \leftarrow O_2$)	23979 D. K. Bhattacharya, Nature, August 10, 1929.	28068 S. C. Deb, Proc. Roy. Soc., 127, 197, 1930.	[31000]
XN_2 ($O_2 \leftarrow O_3$)	[34000]	37840 S. C. Deb, Proc. Roy. Soc., 127, 197, 1930.	[40000]

Thus from the two tables, we can at once predict that the positions of $5s\ ^5S$—$5p\ ^5P$ and $5p\ ^5P$—$5d\ ^5D$ lines would lie at about 31000 and 40000 frequency units respectively. These lines will be the strongest in the regions where they occur, especially the $5s\ ^5S$—$5p\ ^5P$ lines.

Further, let us compare the spectra of As^{++} and Y^{++}. The term values of O_1, P_1, and O_2 of Y^{++} are given by Millikan and Bowen,[1] The values of the corresponding terms in As^{++} can be calculated from the classification given by Lang.[2]

Thus we have

	As^{++} $(v=0)$	Y^{++} $(x=6)$
xN_2O_1	120000	157822
xN_2P_1	66000	78572
xN_2O_2	95000	122335

For Kr^{++} $(x=3)$, we should therefore, expect that the corresponding terms will lie at the arithmetic means of the above two sets,

Thus

	Kr^{++} $(x=3)$
$3\ N_2O_1$	140000
$3\ N_2P_1$	72000
$3\ N_2O_2$	110000

Hence the transition $3\ N_2\ (O_1 \longleftarrow O_2)$ will give rise to lines at 30000, and lines due to $3N_2\ (O_2 \longleftarrow P_1)$ will lie at 38000.

To locate the lines due to the transition $3N_2\ (N_3 \longleftarrow O_2)$ is rather difficult; because no law has yet been found to be applicable to this transition. Mr. S. C. Deb finds that in Br^{+} these lines are more towards the ultra-violet than the lines due to $3N_2\ (O_1 \longleftarrow O_2)$. We should therefore search for these lines in the region 27000.

[1] Phys. Rev., 28, 923, 1926.

[2] Phys. Rev., 32, 737, 1928.

The most intense line at 31000 is 30801·3 (10). This was therefore taken to be the $5s\ ^5S_2$—$5p\ ^5P_3$ line. The two other strong lines in this region with suitable separations, are 30557·0 (4) and 30424·6 (4). Assuming these to represent the $5s\ ^5S_2$—$^5p_2$ line, the two other strong lines region, with suitable separations are 30557·0 (4) and 30424·6 (4). Assuming these to represent the $5s\ ^5S_2$—$5p\ ^5P_2$ and $5s\ ^5S_2$—$5p\ ^5P_1$ lines, the other multiplets emerged without much difficulty, in the predicted regions.

The Multiplets.

$3N_2O_2 \longrightarrow$	$5p\,^5P_1$	132·6	$5p\,^5P_2$	243·8	$5p\,^5P_3$
$3N_2O_1 \longrightarrow 5s\ ^5S_2$	30424·6 (4)		30557·0 (4)		30801·3 (10)
$3N_2O_2 \longrightarrow 5d\ ^5D_0$	39801·1 (1)		...		...
215·1					
$5d\ ^5D_1$	40016·2 (2)		39883·1 (3)		...
141·6					
$5d\ ^5D_2$	40158·0 (3)		40024·5 (3)		39782·1 (2)
226·5					
$5d\ ^5D_3$	...		40251·7 (3)		40008·0 (1)
200·1					
$5d\ ^5D_4$	...		...		40208·1 (3)
$3N_2P_1 \longrightarrow 6s\ ^5S_2$	37440·8 (1)		37307·5 (3)		37068·0 (5)
$3N_2N_2 \longrightarrow 4d\ ^5D_0$	27162·6 (1)		...		...
118·7					
$4d\ ^5D_1$	27043·9 (1)		27176·4 (2)		...
215·6					
$4d\ ^5D_2$	26828·7 (0)		26960·5 (1)		27204·6 (2)
116·8					
$4d\ ^5D_3$	...		26843·7 (2)		27087·4 (4)
203·9					
$4d\ ^5D_4$	...		...		26883·9 (3)

Ionisation Potential of Kr^{++}.

From the above multiplets, we have,

taking the line $5s\,^5S_2-5p\,^5P_3$, $O_1-O_2=30801$,
and taking the line $5p\,^5P_3-6s\,^5S_2$, $O_2-P_1=37063$,
therefore$\longrightarrow O_1-P_1=67864$.

Thus, assuming $O_1=9N/(2+\sigma)^2$ and $P_1=9N/(3+\sigma)^2$, we have, from the table of Rydberg sequences, given in Fowler's report,

$O_1=142812$ and $P_1=64948$
Hence $O_2=112011$.
If we take $O_2=9N/(2+\pi)^2=112011$,
we must have $N_2=9N/(1+\pi)^2=254718$.

Corresponding to this value of N_2, we have the ionisation potential equal to 31·4 volts.

It seems to be a general rule, as illustrated by the data in the following table taken from Saha and Kichlu's paper,[1] that, as the degree of ionisation is increased, the lines due to transitions between two higher electronic configurations, continuously shift towards the higher frequency side with respect to the lines due to transitions between two preceding electronic levels.

	$M_1\longleftarrow M_2$ $^2S_1-{}^2P_1$	$M_2\longleftarrow M_3$ $^2P_2-{}^2D_3$
Na	16956	12199
Mg^+	35669	35730
Al^{+2}	53680	62037
Si^{+3}	71280	88672
P^{+4}	88649	114755
S^{+5}	105866	146313

This rule is borne out by the quintet-quintet mutiplets of this classification and holds also for the analysis attempted later on.

A reference to the table of theoretical terms given before, will show that in addition to the quintet terms, we expect

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[1] Ind. J. Phys., 2, 324, 1928.

also a large number of triplet and singlet terms. The attempt to discover them, has only been partially successful, inasmuch as though the evidence for the existence of a large number of terms has been obtained, it has not been found possible to effect their identification. Table IV contains a list of all these terms, whose values merely represent differences with respect to the deepest level a_1 of this set. The nomenclature is purely arbitrary.

TABLE IV.

Term values.	Nomenclature.	Term values.	Nomenclature.
0	a_1	40475.3	β_{14}
717.3	a_2	42666.7	β_{15}
2911.6	a_3	42742.5	β_{16}
3346.6	a_4	43351.1	β_{17}
3861.8	a_5	43554.6	β_{18}
4969.2	a_6	44123.9	β_{19}
4999.6	a_7	44253.9	β_{20}
6123.0	a_8	45407.9	β_{21}
8101.3	a_9	...	...
28642.8	β_1	76932.1	γ_1
30801.3	β_2	77402.3	γ_2
33361.6	β_3	77561.7	γ_3
33771.3	β_4	77665.6	γ_4
34825.6	β_5	77803.2	γ_5
35188.6	β_6	78561.6	γ_6
35555.1	β_7	78666.6	γ_7
35858.4	β_8	78972.2	γ_8
35982.5	β_9	79971.2	γ_9
38409.2	β_{10}	81865.2	γ_{10}
39797.8	β_{11}	82126.2	γ_{11}
40385.7	β_{12}	...	...
40419.6	β_{13}	...	...

In this list α's combine with β's and β's combine with γ's.

For reasons stated before, the strong group of lines about the region 31000, are presumably due to transition $3N_2(O_3 \longleftarrow O_2)$, and since the transitions between α's and β's explain a large number of these lines, the former are the terms obtained from the configuration $3N_2O_1$, and the latter from $3N_2O_2$. The probability of some of the α terms coming from $3N_2N_3$, is not excluded. The terms designated as γ_1, γ_2, etc., obviously owe their origin to $3N_2O_3$ or $3N_2P_3$.

Table V contains the complete list of the classified lines, in addition to the new lines measured during the course of the present investigation.

TABLE V.

λ (I.A.)	I	ν (vac.)	Classification	Ob-server	If measured by another observer
4404·30	1	22698·7	$\alpha_9-\beta_2$	B	
4223·06	1	23672·9	$\alpha_6-\beta_1$	Bl	
3957·67	3	25260·3	$\alpha_9-\beta_3$	B	
3952·02	1	25296·5	$\alpha_4-\beta_1$	B	
3884·16	1	25732·1	$\alpha_3-\beta_1$	B	
3740·72	2	26725·2	$\alpha_9-\beta_5$	Bl	
3726·30	0	26828·7	$4d^5D_2-5p^5P_1$	B	
3724·21	2	26843·7	$4d^5D_3-5p^5P_2$	B	
3718·64	8	26883·9	$4d^5D_4-5p^5P_3$	B	
3708·08	1	26960·5	$4d^5D_2-5p^5P_2$	B	
3696·65	1	27043·9	$4d^5D_1-5p^5P_1$	B	
3690·65	4	27087·8	$4d^5D_3-5p^5P_3$	B	
3680·49	1	27162·6	$4d^5D_0-5p^5P_1$	Bl	
3678·62	2	27176·4	$4d^5D_1-5p^5P_2$	Bl	
3674·81	2	27204·6	$4d^5D_2-5p^5P_3$	Bl	
3670·23	1	26238·5	$\alpha_8-\beta_3$	Bl	
3641·33	4	27454·7	$\alpha_4-\beta_2$	B	
3615·82	3	27648·4	$\alpha_8-\beta_4$	B	
3579·96	1	27925·3	$\alpha_9-\beta_1$	Bl	
3524·78	0	28363·5	$\alpha_7-\beta_3$	B	
3521·12	1	28391·9	$\alpha_8-\beta_3$	B	
3474·64	6	28771·7	$\alpha_7-\beta_4$	B	
3471·01	1	28801·8	$\alpha_5-\beta_4$	Bl	
3439·46	6	29066·0	$\alpha_8-\beta_6$	B	
3396·58	3	29433·0	$\alpha_8-\beta_7$	B	
3388·92	3	29499·5	$\alpha_5-\beta_3$	B	

λ (I.A.)	I	ν (vac.)	Classification	Observer	If measured by another observer
3351·93	8	29825·0	$\alpha_7-\beta_5$	B	
3348·14	1	29858·8	$\alpha_6-\beta_5$	B	
3342·45	6	29909·6	$\alpha_5-\beta_4$	B	
3330·74	6	30014·8	$\alpha_4-\beta_3$	B	
3311·45	5	30189·5	$\alpha_7-\beta_6$	B	
3308·14	3	30219·8	$\alpha_6-\beta_6$	B	
3285·87	4	30424·6	$5s^5S_2-5p^5P_1$	B	
3271·63	4	30557·0	$5s^5S_2-5p^5P_2$	B	
3268·47	6	30586·6	$\alpha_6-\beta_7$	B	
3245·69	10	30801·3	$5s^5S_2-5p^5P_3$	B	
3239·51	7	30860·0	$\alpha_7-\beta_8$	B	
3223·53	1	31013·0	$\alpha_6-\beta_9$	B	
3191·20	5	31327·1	$\alpha_5-\beta_6$	B	
3175·65	1	31480·5	$\alpha_4-\beta_5$	B	
3170·93	3	31527·3	$\beta_{21}-\gamma_1$	B	
3139·58	2	31842·1	$\alpha_4-\beta_6$	B	
3124·40	5	31996·9	$\alpha_5-\beta_8$	B	
3112·24	5	32120·9	$\alpha_5-\beta_9$	B	
3103·88	0	32208·4	$\alpha_4-\beta_7$	B	
3097·15	5	32278·3	$\alpha_3-\beta_6$	B	
3096·47	1	32285·4	$\alpha_9-\beta_{12}$	B	
3063·14	5	32636·7	$\alpha_4-\beta_9$	B	
3062·43	1	32644·3	$\alpha_3-\beta_7$	B	
3046·93	5	32810·3	$\beta_{19}-\gamma_1$	B	
3024·45	6	33054·3	$\alpha_2-\beta_4$	B	
2996·64	2	33361·0	$\alpha_1-\beta_3$	B	
2992·24	5	33410·0	$\alpha_7-\beta_{10}$	B	
2979·83	1	33549·1	$\beta_{20}-\gamma_5$	B	
2968·32	3	33679·2	$\beta_{19}-\gamma_5$	B	

λ (I.A.)	I	ν (vac.)	Classification	Observer	If measured by another observer
2960·15	0	33772·2	$\alpha_1-\beta_4$	B	
2930·92	2	34109·0	$\alpha_2-\beta_5$	B	
2930·61	2	34112·6	$\beta_{18}-\gamma_4$	B	
2917·70	2	34263·6	$\alpha_3-\beta_{13}$	B	
2913·24	0	34316·0	$\beta_{17}-\gamma_4$	B	
2900·08	4	34471·7	$\alpha_2-\beta_8$	B	
2893·70	5	34547·7	$\alpha_5-\beta_{10}$	B	
2892·19	8	34565·7	$\alpha_9-\beta_{15}$	B	
2872·88	1	34798·0	$\alpha_7-\beta_{11}$	B	
2870·62	6	34825·4	$\alpha_1-\beta_5$	B	
2856·09	1	35002·3	$\beta_{15}-\gamma_4$	B	
2851·18	5	35062·9	$\alpha_4-\beta_{10}$	B	
2840·99	5	35188·6	$\alpha_1-\beta_6$	B	
2835·97	1	35250·8	$\alpha_9-\beta_{17}$	B	
2822·64	1	35417·3	$\alpha_6-\beta_{13}$	B	
2819·89	0	35451·8	$\alpha_5-\beta_{12}$	B	
2811·80	8	35555·1	$\alpha_1-\beta_7$	B	
2784·9	0	35897·	$\beta_{15}-\gamma_5$	B	
2781·9	0	35936·	$\alpha_5-\beta_{11}$	B	
2778·24	1	35983·4	$\alpha_1-\beta_9$	B	
2742·57	8	36451·4	$\alpha_4-\beta_{12}$	B	
2742·03	0	36458·6	$\beta_{21}-\gamma_{10}$	B	
2736·9	0	36527·	$\alpha_5-\beta_{13}$	B	
2730·45	1	36613·2	$\alpha_5-\beta_{14}$	B	
2729·93	1	36620·2	$\alpha_6-\beta_{16}$	Bl	
2710·27	1	36885·8	$\alpha_3-\beta_{11}$	Bl	
2700·68	1	37017·5	$\beta_{12}-\gamma_8$	Bl	
2697·31	5	37063·0	$5p^5P_3-6s^5S_2$	B	
2696·61	5	37072·6	$\alpha_4-\beta_{13}$	B	
2692·55	2	37128·5	$\alpha_4-\beta_{14}$	B	

λ (I.A.)	I	ν (vac.)	Classification	Observer	If measured by another observer
2691·84	1	37137·3	$\beta_{11}-\gamma_1$	B	
2679·63	3	37307·5	$5p^5P_2-6s^5S_2$	B	
2670·68	5	37432·5	$\alpha_8-\beta_{18}$	B	
2670·09	1	37440·8	$5p^5P_1-6s^5S_2$	B	
2661·24	1	37565·3	$\alpha_3-\beta_{14}$	Bl	
2653·97	1	37668·2	$\alpha_7-\beta_{15}$	B	
2648·70	4	37743·1	$\alpha_7-\beta_{16}$	B	
2639·76	6	37870·9	$\beta_{20}-\gamma_{11}$	B	
2630·66	4	38001·8	$\alpha_8-\beta_{19}$	B	
2624·82	2	38086·6	$\beta_{14}-\gamma_8$	B	
2609·41	0	38311·4	$\beta_{18}-\gamma_{10}$	B	
2606·61	0	38352·5	$\alpha_7-\beta_{17}$	B	
2604·63	8	38381·7	$\alpha_6-\beta_{17}$	B	
2596·74	1	38498·4	$\beta_{14}-\gamma_8$	B	
2590·74	1	38587·5	$\alpha_6-\beta_{18}$	Bl	
2578·9	0	38764·	$\beta_{11}-\gamma_6$	B	
2571·21	8	38880·6	$\alpha_5-\beta_{16}$	B	
2557·99	2	39081·5	$\alpha_2-\beta_{11}$	B	
2555·14	4	39125·1	$\alpha_7-\beta_{19}$	B	
2553·17	8	39155·3	$\alpha_6-\beta_{19}$	B	
2544·70	1	39285·6	$\alpha_8-\beta_{21}$	B	
2538·34	1	39284·1	$\beta_{16}-\gamma_{11}$	B	
2537·58	3	39395·7	$\alpha_4-\beta_{16}$	B	
2517·93	2	39703·2	$\alpha_2-\beta_{13}$	B	
2512·94	2	39782·1	$5p^5P_3-5d^5D_2$	B	
2511·74	1	39801·1	$5p^5P_1-5d^5D_0$	B	
2506·57	8	39883·1	$5p^5P_2-5d^5D_1$	B	
2498·75	1	40008·0	$5p^5P_3-5d^5D_3$	B	

λ (1.A.)	I	ν (vac.)	Classification	Observer	If measured by another observer
2498·23	2	40016·2	$5p^5\mathrm{P}_1 - 5d^5\mathrm{D}_1$	B	
2497·72	3	40024·5	$5p^5\mathrm{P}_2 - 5d^5\mathrm{D}_3$	B	
2489·42	3	40158·0	$5p^5\mathrm{P}_1 - 5d^5\mathrm{D}_2$	B	
2486·31	3	40208·1	$5p^5\mathrm{P}_3 - 5d^5\mathrm{D}_4$	B	
2483·62	3	40251·7	$5p^5\mathrm{P}_2 - 5d^5\mathrm{D}_2$	B	
2483·23	3	40258·0	$\beta_{10} - \gamma_7$	B	
2483·00	1	40261·7	$\alpha_5 - \beta_{19}$	B	
2478·81	2	40329·8		A	
2477·76	0	40346·8		A	
2474·91	3	40393·5	$\alpha_5 - \beta_{20}$	B	
2474·79	2	40395·2		A	2474·71 (B)
2473·98	2	40408·7	$\alpha_7 - \beta_{21}$	B	
2473·53	0	40415·8		A	
2473·31	1	40419·6	$\alpha_1 - \beta_{13}$	B	
2472·18	0	40437·9	$\alpha_6 - \beta_{22}$	A	2472·16 (B)
2470·59	0	40463·9		A	2470·42 (B)
2468·60	1	40496·5		A	2468·48 (B)
2467·05	0	40522·0		A	2466·92 (B)
2464·72	9	40560·8		A	
2463·35	0	40582·8		A	
2462·57	0	40595·7		A	
2459·66	2	40643·9	$\alpha_3 - \beta_{22}$	B	
2456·01	8	40704·1		A	
2455·20	0	40717·5		A	
2454·32	0	40732·1		A	
2453·32	0	40748·8		A	
2452·30	3	40765·7		A	2452·30 (B)

λ (I.A.)	I	ν (vac.)	Classification	Observer	If measured by another observer
2451·62	2	40777·0	$\alpha_4-\beta_{19}$	B	
2446·36	5	40864·6		A	
2439·70	3	40976·2		A	2439·56 (Bl)
2436·49	1	41030·2		A	
2429·84	1	41142·5		A	2429·72 (B)
2428·28	8	41168·9		A	
2426·24	7	41203·5		A	
2425·08	1	41223·2		A	2425·07 (B)
2422·50	0	41267·1		A	2422·42 (B)
2420·20	2	41306·3		A	
2418·29	3	41338·9		A	
2418·05	3	41343·1	$\alpha_3-\beta_{20}$	B	
2414·86	5	41397·7		A	
2413·63	3	41418·8	$\beta_9-\gamma_2$	A	
2409·04	4	41497·7		A	
2408·43	1	41508·4		A	
2406·34	2	41544·3	$\alpha_5-\beta_{21}$	B	
2400·22	1	41650·1	$\beta_{14}-\gamma_{11}$	B	
2399·09	1	41669·7		A	
2398·37	1	41682·3		A	2398·30 (B)
2397·01	2	41705·9	$\beta_{13}-\gamma_{11}$	B	
2394·82	0	41744·1	$\beta_6-\gamma_1$	B	
2392·79	4	41779·4		A	
2390·49	3	41819.6	$\beta_9-\gamma_5$	A	
2382·12	6	41966·6		A	
2376·77	0	42061·1	$\alpha_4-\beta_{21}$	B	
2373·69	2	42115·6		A	
2368·89	2	42201·0		A	
2368·22	1	42212·9	$\beta_6-\gamma_3$	B	

λ (I.A.)	I	ν(vac.)	Classification	Observer	If measured by another observer
2365·60	2	42259·6		A	
2362·69	4	42311·7		A	
2353·60	10	42475·1		A	
2352·66	1	42492·0		A	
2348·06	0	42575·3		A	
2344·29	8	42643·8		A	
2343·03	1	42666·7	$\alpha_1-\beta_{15}$	B	
2340·85	1	42706·4	$\beta_9-\gamma_6$	B	
2339·07	0	42738·9	$\beta_5-\gamma_3$	B	
2320·88	1	43073·9		A	2320·84 (B)
2316·25	6	43159·9	$\beta_4-\gamma_1$	A	2316·21 (B)
2315·46	6	43174·7		A	2315·37 (B)
2311·96	6	43240·0		A	2311·89 (B)
2301·76	3	43457·9	$\beta_{10}-\gamma_{10}$	A	2301·61 (B)
2291·19	2	43632·0	$\beta_4-\gamma_2$	B	
2287·76	7	43697·3		A	2287·68 (B)
2283·00	7	43788·5		A	
2282·85	3	43791·3	$\beta_4-\gamma_3$	A	2282·85 (B)
2276·67	1	43910·2		A	
2273·22	4	43976·8		A	2273·08 (B)
2263·81	0	44159·6		A	
2250·21	2	44426·5		A	2250·15 (B)
2245·44	2	44520·9		A	
2236·68	0	44695·2		A	
2234·61	0	44736·6		A	
2232·19	0	44784·9	$\beta_6-\gamma_9$	B	
2227·98	4	44869·7		A	2227·89 (B)
2225·19	1	44925·9		A	
2221·88	0	44992·9		A	
2215·78	0	45116·7		A	

λ (I.A.)	I	γ (vac.)	Classification	Observer	If measured by another observer
2211·86	1	45196·7		A	
2211·68	8	45200·4	$\beta_1-\gamma_8$	A	
2208·42	1	45267·1		A	
2206·57	0	45305·0	$\beta_2-\gamma_7$	A	
2202·61	1	45386·5		A	
2301·80	1	45413·5		A	
2107·46	3	45492·8		A	
2186·79	0	45714·8		A	
2182·10	0	45813·0		A	
2177·94	0	45900·5		A	
2178·68	1	45990·5		A	
2172·04	0	46025·2		A	
2170·69	0	46053·8		A	
2169·14	1	46086·7		A	
2167·69	1	46117·5		A	
2165·95	0	46154·6		A	
2161·00	0	46260·3		A	
2150·72	1	46481·4		A	
2147·56	0	46549·7		A	
2145·00	2	46605·3		A	
2144·75	6	46610·8	$\beta_3-\gamma_9$	A	
2143·38	0	46640·5		A	
2139·34	2	46728·6		A	
2134·00	0	46845·5		A	
2132·84	1	46871·0		A	
2131·15	0	46908·1		A	
2129·81	0	46937·7	$\beta_5-\gamma_{11}$	A	
2129·67	2	46940·7		A	
2128·81	2	46959·7		A	

λ (I.A.)	I	γ (vac.)	Classification	Observer	If measured by another observer
2124·88	0	47046·5		A	
2119·95	0	47155·0		A	
2118·71	4	47183·5		A	
2117·78	9	47204·2		A	
2114·19	0	47284·4		A	
2112·38	0	47324·9		A	
2110·79	0	47360·6		A	
2109·78	2	47384·4		A	
2106·04	0	47467·4		A	
2100·59	0	47590·5		A	
2099·41	1	47617·2		A	
2096·90	8	47674·2		A	
2095·84	1	47698·8		A	
2094·41	6	47730·9		A	
2093·07	0	47761·4	$\beta_3-\gamma_6$	A	
2091·55	0	47796·1		A	
2089·94	10	47833·0		A	
2088·57	5	47864·3	$\beta_3-\gamma_7$	A	
2086·87	1	47903·3		A	
2086·29	0	47916·6		A	
2084·10	2	47967·0		A	
2083·46	1	47981·7		A	
2081·72	6	48021·8		A	
2078·58	0	48094·4	$\beta_4-\gamma_{10}$	A	
2078·19	0	48103·4		A	
2077·57	0	48117·7		A	
2076·46	1	48143·5		A	
2075·63	0	48162·9		A	
2073·88	8	48203·3		A	

λ (I.A.)	I	ν (vac.)	Classification	Observer	If measured by another observer
2071·05	0	48269·2		A	
2068·89	0	48319·6		A	
2066·13	3	48384·1		A	
2065·28	0	48404·0		A	
2064·01	0	48433·8		A	
2063·00	0	48457·5		A	
2062·20	0	48476·3		A	
2062·05	1	48479·8		A	
2060·71	0	48511·4		A	
2059·45	1	48541·0		A	
2058·75	4	48557·8		A	
2057·29	0	48592·0		A	
2056·74	0	48605·0		A	
2054·47	0	48659·7		A	
2053·38	1	48685·7		A	
2052·49	0	48705·6		A	
2050·00	3	48764·8	$\beta_3-\gamma_{11}$	A	
2047·19	1	48831·6		A	
2040·24	2	48998·0		A	
2036·64	0	49084·6		A	
2035·15	0	49120·6		A	
2033·18	2	49169·4	$\beta_3-\gamma_9$	A	
2018·93	3	49515·4		A	
2005·41	0	49848·9		A	
2004·33	2	49875·8		A	
1992·96	0	50160·2		A	
1981·96	0	50438·5		A	
1974·59	3	50626·7		A	
1973·47	1	50655·5		A	
1962·70	2	50933·4		A	

γ (I.A.)	I	ν (vac.)	Classification	Observer	If measured by another observer
1961·84	1	50955·7		A	
1947·75	2	51324·2	$\beta_2-\gamma_{11}$	A	
1932·92	0	51718·0		A	
1931·38	2	51760·6		A	
1930·39	2	51785·8		A	

Explanation of the table:—

In the 1st column, the wave-lengths of all classified lines and also of all new lines measured by the present writer, are given in international Angstrom. The 2nd column gives the intensity of the lines. In the 3rd column, the wave-numbers of the lines are given, after having reduced them to vacuum. The 4th column gives the classification. The name of the observer is given in the 5th column. "B" denotes Bloch, "Bl" Baly, and "A" the present writer. The 6th column shows if any line has been measured by any other observer.

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