HIGHLY IONIZED POTASSIUM AND CALCIUM SPECTRA.

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Abstract

Part I: K III—Ca IV

42 lines in the spectrum of K III, and 35 lines in the spectrum of Ca IV have been classified from wave lengths published by Ekefors. The term assignments found by Ram were questioned on the ground of irregular doublet rule, intensity, and law of multiplet separation. A satisfactory reassignment has been found by the author.

Part II: K IV—Ca V

7 singlets and 5 triplet lines for K IV, and 5 singlets for Ca V have been identified. The relative position of $s^2p^4\ {}^3P$, ^1D, ^1S terms of the isoelectronic sequence S I, Cl II, A III, K IV, and Ca V is discussed.

Part III: K V—Ca VI

Many pairs of doublet lines of the separations 237($s^2p^3\ {}^2D$) and 319($s^2p^3\ {}^2P$) in K V, and 417($s^2p^3\ {}^2D$) and 556($s^2p^3\ {}^2P$) in Ca VI have been found and identified. The $s^2p^2(^3P)3d\,^4P$, ^4D, ^4F for K V have also been recognized by the application of irregular doublet law.

Part IV: K VIII—Ca IX

$sp^3P-p^2\ {}^3P$ of Ca IX, sp^2P-sd^1D, $s^2\ {}^1S-sp^1P$ of K VIII and Ca IX are obtained.

Part V: K IX—Ca X

The present work is supplementary to Edlen's, and gives the identification of eight additional lines for K IX and six additional lines for Ca X.

Highly Ionized Potassium and Calcium Spectra. Part I.
K III — Ca IV

The third spectrum of potassium (K III) has been studied by de Bruin[1] and I. S. Bowen[2]. Bowen has identified the lines

130609 (6)

128445 (7)

as belonging to the transition $3s^2 3p^5\ ^2P^\circ_{\frac{1}{2},1\frac{1}{2}} — 3s3p^6\ ^2S_{\frac{1}{2}}$, giving a difference of 2164 units between the fundamental ^2P. A term table consisting of all the $s^2p^4(^3P)4p$ and $s^2p^4(^3P)4s$ terms has been given by de Bruin. The absolute value of the lowest state $3s^2 3p^5\ ^2P_{1\frac{1}{2}}$ has been estimated by de Bruin to be about 377000 cm^{-1} with respect to $3p^4\ ^3P$ of K IV.

The fourth spectrum of calcium Ca IV has been studied by I. S. Bowen[2] in the extreme Schumann region. He has found two transitions $3s^2 3p^5\ ^2P^\circ_{\frac{1}{2},1\frac{1}{2}} — 3s3p^6\ ^2S_{\frac{1}{2}}$, giving a difference of 3115.2 units between the fundamental ^2P.

With the help of the Ekefors's data[3] in extreme Schumann region, below λ 1100 for potassium and calcium in successive stages of ionization. Mela Ram[4] has found 14 pairs of doublet in K III with the separation of 2164 units, and 11 pairs of doublet in Ca IV with the separation of 3116 units. After a careful analysis of Ekefors' data, three more pairs of doublet in K III, and one more pair in Ca IV of above separations are now found. Examination of the configuration assignments given by Ram shows the fact that for the sequence Cl I, A II, K III, and Ca IV there is no consistent and reasonable regularity. One of these inconsistent assignments concerns the terms 221944.6 and 228431.5 Of Ca IV which were assigned by Ram to the configuration $(^3P)4s\ ^2P$. Now the abnormally large separation (–6489) of these two terms, when compared with the corresponding separations in Cl I, A II, and K II , namely

1. de Bruin, Zeits, f. Physik 53, 658 (1929).
2. L. S. Bowen, Phys. Rev. 31, 497 (1928).
3. Ekefors, Zeits. f. Physik 71, 53 (1931).
4. Mela Ram, Indian J. of Phys., 8, 151, (1933).

–639.8,–1014, and –1502, seems to be unreasonable. A satisfactory reassignment of these two terms has been found by the author. According to Ram's assignment, the separation of $(^3P)5s\,^2P$ of K III amounts to 3510 units which is much larger than the separation 1502 of $(^3P)4s\,^2P$ of the same spectrum. This is certainly impossible. The 3d terms for K III, and Ca IV assigned by Ram were questioned on the ground of irregular doublet rule. For instance, following his assignment, the corresponding lines $s^2p^5\ ^2P^{\circ}_{1\frac{1}{2}} — s^2p^4(^3P)3d\ ^2P_{1\frac{1}{2}}$ are

A II[5]	145667 (1)	
		(95372)
K III	241039.4(6)	
		(51825)
Ca IV	292864 (8)	

and the corresponding lines $s^2p^5\ ^2P^{\circ}_{1\frac{1}{2}} — s^2p^4(^1D)3d\,^2D_{1\frac{1}{2}}$ are

A II[5]	172830 (4)	
		(90940)
K III	263770.1(6)	
		(40074)
Ca IV	303844 (5)	

Since the differences recorded in the last column are far from being equal, the irregular doublet rule is obviously violated.

A reassignment of these terms gives much more satisfactory results. Additional evidence in favor of the new assignment came from the intensities of the lines associated with these terms, since comparison can be made by using A II lines of same nature[5] (Table I).

In the present analysis 42 lines of K III were classified (Table IIa), 35 lines being marked with N=3 (in Ekefors' data, there are 75 lines marked with N=3), 2 lines with N=2, 1 line with N=4, and 4 lines not assigned any N value. 26 term values have been identified. These term values are

5. J. C. Boyce Phys. Rev. 48, 398, (1935).

tabulated in Table IIIa togather with de Bruin's term values, which for $(^3P)4s\ ^4P$ and $(^3P)4p^2P_{1\frac{1}{2}}$ seem to be 130 units too large. All these term values are given with respect to the ground term $s^2p^5\ ^2P_{1\frac{1}{2}}$ as zero.

35 lines of Ca IV were classified (Table IIb), 29 lines being marked with N=4 (There are 52 lines marked with N=4) 1 with N=5, 4 with N=5, 4 with N=3, and 1 line with no N value. In the table IIIb, there are 23 terms, of which 20 terms are reinterpreted during the present analysis.

In this analysis, the following points have been considered: intensity, irregular doublet rule, and rule of multiplet separations. The intensities of all the analyzed lines are tabulated in Table I togather with that of A II lines of same nature for comparison. The interbinations between $s^2p^5\ ^2P^\circ$, and $4s^4P$, $3d^4D$, ^4F have been found for Ca IV completely, but only partially for K III.

$sp^6\ ^2S$

It can be observed that the lines $s^2p^5\ ^2P$ — $sp^6\ ^2S_{\frac{1}{2}}$ obey the irregular doublet law very well

	$s^2p^5\ ^2P^\circ_{\frac{1}{2}}$ —$sp^6\ ^2S_{\frac{1}{2}}$		$s^2p^5\ ^2P^\circ_{\frac{1}{2}}$ —$sp^6\ ^2S_{\frac{1}{2}}$	$sp^6\ ^2S_{\frac{1}{2}}$
Cl I	———		———	———
A II[5]	108722 (15)	(1431)	107291 (10)	108722
			(21887)	
K III	130609.0(6)	(2161.5)	128447.5(7)	130609
			(21821)	
Ca IV	152430.2(15)	(3115.2)	149315.0(10)	152430

In the sequence Cl — A — K — Ca, there exist perfect regularities in the strongest group of lines belonging to the transitions of type s^2p — sp^{n+1}.

	Cl[6]	A[5]	K	Ca
$s^2p^2\ {}^3P_2 - sp^3\ {}^3D^\circ_3$	IV 101528	V 119778	VI 138041	VII ———
	(3008)	(2214)	(1402)	( )
$s^2p^3\ {}^4S^\circ_{1\frac{1}{2}} - sp^4\ {}^4P_{2\frac{1}{2}}$	III 98520	IV 117564	V 136639	VI 155792
	(5153)	(3764)	(2458)	(1128)
$s^2p^4\ {}^3P_2 - sp^5\ {}^3P^\circ_2$	II 93367	III 113800	IV 134181	V 154664
	( )	(5078)	(3572)	(2234)
$s^2p^5\ {}^2P^\circ_{1\frac{1}{2}} - sp^6\ {}^2S_{\frac{1}{2}}$	I ———	II 108722	III 130609	IV 152430

$s^2p^4({}^3P)4s\,{}^4P,\ {}^2P$

In the following table. de Bruin's term values for K III, are compared with those obtained in present analysis. It is noted that de Bruin's values for ^4P are generally 100 units larger.

	ν_B de Bruin's values	ν_P present values	$\nu_B - \nu_P$
$^4P_{2\frac{1}{2}}$	206755.9	206623.5	132.4
	—1265.9	—1291.8	
$^4P_{1\frac{1}{2}}$	208021.8	207915.3	106.5
	— 773.5	— 772.4	
$^4P_{\frac{1}{2}}$	208795.3	208687.7	107.6
$^2P_{1\frac{1}{2}}$	212727.1	212725.7	1.4
	—1506.9	—1502	
$^2P_{\frac{1}{2}}$	214234.0	214227.7	6.3

The term separations of this isoelectronic sequence are tabulated in the following:

	$^4P_{2\frac{1}{2},1\frac{1}{2}}$	$^4P_{1\frac{1}{2},\frac{1}{2}}$	$^2P_{1\frac{1}{2},\frac{1}{2}}$	$^4P_{2\frac{1}{2},1\frac{1}{2}} : {}^4P_{1\frac{1}{2},\frac{1}{2}}$
Cl I	— 530	— 338	— 639.8	1.568
A II	— 844	— 517	—1014	1.632
K III	—1291.8	— 772.4	—1502	1.672
Ca IV	—1691	—1006	—2124	1.681
The ratio calculated theoretically			$=5/2:3/2$	1.667

6. Bacher and Goudsmit, Atomic Energy States, P. 137.

$s^2p^4(^1D)4s^2D$ and $(^3P)3d^2D$

For Cl I spectrum, no terms of such nature have been found by Kiess and de Bruin[7] in their analysis. For A II, de Bruin classified 147186 (8), 148622 (3), and 148842 (10) as $s^2p^5\ ^2P^\circ$—$(^1D)4s^2D$, and 149043 (10), 150476 (6), 151088 (15) as $s^2p^5\ ^2P^\circ$—$(^3P)3d^2D$. Later, Boyce[8] reversed this interpretation. This reassignment, according to Boyce, is supported by the fact that "the two groups of de Bruin term values were not consistent with any reasonable estimate of the relative positions of the ^3P, ^1D, and ^1S states arising from the s^2p^4 electron configuration of A III. These states constitute the limits upon which the terms of A II are built". But in the present analysis, from the verification of irregular doublet rule, some of the strong evidence in support of the de Bruin's assignment has been found. From the intensity distribution, and doublet separations we see that the groups of lines should be analysed in the following way:

		a^2D_1		a^2D_2	b^2D_1		b^2D_2
A II							
$s^2p^5\ ^2P^\circ_{1\frac{1}{2}}$	0	148622(3)		148842(10)	150476(6)		150188(15)
			(220)			(612)	
$^2P^\circ_{\frac{1}{2}}$	1432	147286(8)			149043(10)		
K III							
$s^2p^5\ ^2P^\circ_{1\frac{1}{2}}$	0	231684(1)		230032(15)	190915(5)		192082(10)
			(—1652)			(1167)	
$^2P^\circ_{\frac{1}{2}}$	2164	229528(10)			188752(8)		
Ca IV							
$s^2p^5\ ^2P^\circ_{1\frac{1}{2}}$	0	304343(1)		301712(4)	228429(5)		230112(12)
			(—2631)			(1682)	
$^2P^\circ_{\frac{1}{2}}$	3115	301213(5)			225316(15)		

It is well known that the wave numbers for the irregular doublet sequence $s^2p^5\ ^2P^\circ$ — $s^2p^4(^3P)3d^2D$ when plotted against atomic numbers should fall on a straight line, while those for $s^2p^5\ ^2P$ — $s^2p^4(^1D)4s^2D$ need not. It therefore seems reason-

7. Kiess and de Bruin, Bur. Stand. J. Res. 2, 1117 (1929).
8. Boyce, Phys. Rev. 48, 397 (1935).

able to assign $(^1D)4s^2D$ to a^2D, and $(^3P)3d^2D$ to b^2D because of the facts shown in the following table:

	$b^2D_{1\frac{1}{2}}$		$a^2D_{1\frac{1}{2}}$	
A II	150476		148623	
		(40439)		(83062)
K III	190915		231685	
		(37513)		(72658)
Ca IV	228428		304343	

Furthermore, if we reverse the assignment, the relative positions of the ^3P, ^1D states arising from the s^2p^4 electron configuration of K IV and Ca V will not be consistent. Actually, for the case of A II, the relative positions of these two pairs of doublet are slightly displaced due to their mutual perturbation. Here it should be noted that the $(^3P)3d^2$ D states gradually become deeper than the 4s states when atomic number increase from Cl to Ca.

$(^1S)4s^2S_{\frac{1}{2}}$

The lines 337207(5), and 334096(4) of Ca IV are interpreted here as the transitions $s^2p^5\ ^2P^\circ — (^1S)4s^2S_{\frac{1}{2}}$. The appearance of this terms in the sequence A II — K III — Ca — IV can be observed from the following table:

	$s^2p^5\ ^2P_{1\frac{1}{2}} — (^1S)4s^2S_{\frac{1}{2}}$	
A II	167309	
		(74358)
K III	241667.3	
		(95540)
Ca IV	337207	

$(^3P)3d^4F, ^4D$

The intercombination lines $s^2p^5\ ^2P^\circ — (^3P)3d^4F, ^4D$ can be obtained for Ca IV only.

$(^1D)3d^2D$, ^2P, ^2S

For K III, all these terms have been obtained in the analysis, but for Ca IV only a part of which can be recognized.

$(^1S)3d^2D$

These terms have not been found for Ca IV.

5s terms

For K III, we have found two doublet terms, namely $(^1D)5s^2D$, $(^3P)5s\ ^2P$. For Ca IV, only $(^3P)5s^2P$ have been found. The doublet 307429(0), 305246(1) in K III spectra seems corresponding to the transition $s^2p^5\ ^2P$ — $(^1S)5s^2S_{\frac{1}{2}}$.

Terms combined with $3s3p^6\ ^2S_{\frac{1}{2}}$

$(^3P)4p^2P^\circ$: The lines 114637.8(4⁻) in K III, and 187015.5 (4) and 189291.4(8) in Ca IV have been analyzed as the transitions $sp^6\ ^2S$ — $(^3P)4p^2P^\circ$. A comparison should be made with the A II lines of same nature

	$^2S_{\frac{1}{2}}$ — $^2P_{\frac{1}{2}}$		$^2S_{\frac{1}{2}}$ — $^2P_{1\frac{1}{2}}$	
A II	50985.1(2)	(533.1)	5158.2(2)	
				(63119.6)
K III			114637.8(4)	
				(74653.6)
Ca IV	187015.5(4)	(2275.9)	189291.4(8)	

The de Bruin's term value for K III $(^3P)4p^2P_{1\frac{1}{2}}$ is equal to 245384.0, which is 117.2 units higher than the present value 245246.8

Table I. Intensities in multiplets of A II, K III, and Ca IV.

		A II		K III		Ca IV	
		^2P		^2P		^2P	
	J	1½	½	1½	½	1½	½
sp^6 ^2S	½	15	10	6	7	15	10
$s^2p^4(^3P)4s$ ^4P	2½	5		R3		4	
	1½	12	4	1	—	4	4
	½	1	5	3	1	4	5
^2P	1½	14	8	20	9	4	4
	½	4	9	15	15	4	5
$s^2p^4(^1S)4s$ ^2D	2½	10		15		4	
	1½	3	8	1	10	1	5
$s^2p^4(^1S)4s$ ^2s	½	5	4	10	6	5	4
$s^2p^4(^3P)3d$ ^4F	4½						
	3½						
	2½	4		—		10	
	1½	2	3	—	—	—	5
^1D	3½						
	2½	3		—		5	
	1½	—	2	—	—	4	1
	½	—	—	—	—	2	—
^4P	2½	—	—	—		—	
	1½	—	—	—	—	—	—
	½	—	—	—	—	—	—
^2F	3½						
	2½	10		15		5	
^2D	2½	15		10		12	
	1½	6	10	5	8	5	15
^2P	1½	—	—	—	—	—	—
	½	—	—	—	—	—	—

Table I. — *Continued*

		A II		K III		Ca IV	
		^2P		^2P		^2P	
	J	1½	½	1½	½	1½	½
$s^2p^4(^1D)3d$							
^2D	2½	8		8		—	
	1½	4	8	6	8	3	3
^2P	1½	6	4	6	6	—	—
	½	5	5	5	6	—	—
^2S	½	4	4	3R	4	5	5
$s^2p^4(^1S)3d$							
^2D	2½	6		5		—	
	1½	2	4	2	1	—	—
$s^2p^4(^3P)5s$							
^2P	1½	4	2	5	—	—	—
	½	3	1	8	6	—	—
$s^2p^4(^1D)5s$							
^2D	2½	} 3		2		3R	
	1½		(2)	2	3R	3	3

Table IIa. Analyzed K III lines

I	λ	ν	N	Combinations
4	872.313	114637.8	3	$sp^6\ {}^2S_{\frac{1}{2}}$ — $({}^3P)4p\ {}^2P^\circ_{1\frac{1}{2}}$
7	778.528	128447.5	3	$s^2p^5\ {}^2P^\circ_{\frac{1}{2}}$ — $sp^6\ {}^2S_{\frac{1}{2}}$
6	765.644	130609.0	3	${}^2P^\circ_{1\frac{1}{2}}$ ${}^2S_{\frac{1}{2}}$
8	529.796	188751.9	3	$s^2p^5\ {}^2P^\circ_{\frac{1}{2}}$ — $({}^3P)3d\ {}^2D_{1\frac{1}{2}}$
5	523.792	190915.5	2	${}^2P^\circ_{1\frac{1}{2}}$ — ${}^2D_{1\frac{1}{2}}$
10	520.611	192082.0	3	${}^2P^\circ_{1\frac{1}{2}}$ — ${}^2D_{2\frac{1}{2}}$
15	497.104	201165.1	3	$s^2p^5\ {}^2P^\circ_{1\frac{1}{2}}$ — $({}^3P)3d\ {}^2F_{2\frac{1}{2}}$
1	484.200	206526.8	3	$s^2p^5\ {}^2P^\circ_{\frac{1}{2}}$ — $({}^3P)4s\ {}^4P_{\frac{1}{2}}$
R3	483.972	206623.5	3	${}^2P^\circ_{1\frac{1}{2}}$ — ${}^4P_{2\frac{1}{2}}$
1	480.965	207915.3		${}^2P^\circ_{1\frac{1}{2}}$ — ${}^4P_{1\frac{1}{2}}$
3	479.185	208687.7	3	${}^2P^\circ_{1\frac{1}{2}}$ — ${}^4P_{\frac{1}{2}}$
9	474.920	210561.8	3	$s^2p^5\ {}^2P^\circ_{\frac{1}{2}}$ — $({}^3P)4s\ {}^2P_{1\frac{1}{2}}$
15	471.569	212058.1	3	${}^2P^\circ_{\frac{1}{2}}$ — ${}^2P_{\frac{1}{2}}$
20	470.089	212725.7	3	${}^2P^\circ_{1\frac{1}{2}}$ — ${}^2P_{1\frac{1}{2}}$
15	466.793	214227.7	3	${}^2P^\circ_{1\frac{1}{2}}$ — ${}^2P_{\frac{1}{2}}$
10	435.676	229528.4	3	$s^2p^5\ {}^2P^\circ_{\frac{1}{2}}$ — $({}^1D)4s\ {}^2D_{1\frac{1}{2}}$
15	434.722	230032.1	3	${}^2P^\circ_{1\frac{1}{2}}$ — ${}^2D_{2\frac{1}{2}}$
1	431.622	231684.2		${}^2P^\circ_{1\frac{1}{2}}$ — ${}^2D_{1\frac{1}{2}}$
6	418.623	238878.4	3	$s^2p^5\ {}^2P^\circ_{\frac{1}{2}}$ — $({}^1D)3d\ {}^2P_{1\frac{1}{2}}$
6	417.535	239500.9	3	$s^2p^5\ {}^2P^\circ_{\frac{1}{2}}$ — $({}^1S)4s\ {}^2S_{\frac{1}{2}}$
6	416.001	240384.0	3	$s^2p^5\ {}^2P^\circ_{\frac{1}{2}}$ — $({}^1D)3d\ {}^2P_{\frac{1}{2}}$
6	414.870	241039.4	3	s ${}^2P^\circ_{1\frac{1}{2}}$ — ${}^2P_{1\frac{1}{2}}$
10	413.792	241667.2	3	$s^2p^5\ {}^2P^\circ_{1\frac{1}{2}}$ — $({}^1S)4s\ {}^2S_{\frac{1}{2}}$
5	412.289	242548.3	3	$s^2p^5\ {}^2P^\circ_{1\frac{1}{2}}$ — $({}^1D)3d\ {}^2P_{\frac{1}{2}}$
8	410.102	243841.8	3	$s^2p^5\ {}^2P^\circ_{\frac{1}{2}}$ — $({}^1D)3d\ {}^2D_{1\frac{1}{2}}$
8	408.959	244523.3	3	${}^2P^\circ_{1\frac{1}{2}}$ — ${}^2D_{2\frac{1}{2}}$
6	406.484	246012.3	3	${}^2P^\circ_{1\frac{1}{2}}$ — ${}^2D_{1\frac{1}{2}}$
4	402.104	248691.9	3	$s^2p^5\ {}^2P^\circ_{\frac{1}{2}}$ — $({}^1D)3d\ {}^2S_{\frac{1}{2}}$
8	400.210	249868.8	3	$s^2p^5\ {}^2P^\circ_{\frac{1}{2}}$ — 1
3R	398.633	250857.3	2	$s^2p^5\ {}^2P^\circ_{1\frac{1}{2}}$ — $({}^1D)3d\ {}^2S_{\frac{1}{2}}$
R0d	396.763	252039.6	3	$s^2p^5\ {}^2P^\circ_{1\frac{1}{2}}$ — 1
6	382.229	261623.3	3	$s^2p^5\ {}^2P^\circ_{\frac{1}{2}}$ — $({}^3P)5s\ {}^2P_{\frac{1}{2}}$
5	380.477	262828.0	3	${}^2P^\circ_{1\frac{1}{2}}$ — ${}^2P_{1\frac{1}{2}}$
8	379.118	263770.1	4	${}^2P^\circ_{1\frac{1}{2}}$ — ${}^2P_{\frac{1}{2}}$

Table IIa. — *Continued.*

I	λ	ν	N	Combinations
3R	347.999	287357	3	$s^2p^5\ ^2P^\circ_{\frac12}$ — $(^1D)\,5s\ ^2D_{1\frac12}$
2	345.545	289400	3	$^2P^\circ_{1\frac12}$ — $^2D_{2\frac12}$
2	345.405	289515	3	$^2P^\circ_{1\frac12}$ — $^2D_{1\frac12}$
1	331.416	301736	3	$s^2p^5\ ^2P^\circ_{\frac12}$ — $(^1S)\,3d\ ^2D_{1\frac12}$
5	330.684	302404	3	$^2P^\circ_{1\frac12}$ — $^2D_{2\frac12}$
2	329.053	303902	3	$^2P^\circ_{1\frac12}$ — $^2D_{1\frac12}$
1	327.605	305246	3	$s^2p^5\ ^2P^\circ_{\frac12}$ — 2
0	325.278	307429		$s^2p^5\ ^2P^\circ_{\frac12}$ — 2

Table IIb. Analyzed Ca IV lines

I	λ	ν	N	Combinations
10	669.725	149315.0	3	$s^2p^5\ ^2P^\circ_{\frac12}$ — $sp^6\ ^2S_{\frac12}$
15	656.038	152430.2	3	$^2P^\circ_{1\frac12}$ — $^2S_{\frac12}$
3	565.463	176846.8	4	$sp^6\ ^2S_{\frac12}$ — $(^3P)\,4p\ ^2P^\circ_{1\frac12}$
5	456.981	218827.5		$s^2p^5\ ^2P^\circ_{\frac12}$ — $(^3P)\,3d\ ^4F_{1\frac12}$
10	450.565	221943.6	4	$^2P^\circ_{1\frac12}$ — $^4F_{1\frac12}$
1	445.018	224710.0		$s^2p^5\ ^2P^\circ_{\frac12}$ — $(^3P)\,3d\ ^4D_{1\frac12}$
15	443.821	225316.1	4	$s^2p^5\ ^2P^\circ_{\frac12}$ — $(^3P)\,3d\ ^2D_{1\frac12}$
5	439.700	227427.5	4	$s^2p^5\ ^2P^\circ_{1\frac12}$ — $(^3P)\,3d\ ^4D_{2\frac12}$
4	438.930	227826.8	4	$^2P^\circ_{1\frac12}$ — $^4D_{1\frac12}$
5	437.273	228428.9	4	$s^2p^5\ ^2P^\circ_{1\frac12}$ — $(^3P)\,3d\ ^2D_{1\frac12}$
2	437.271	228691.0	4	$s^2p^5\ ^2P^\circ_{1\frac12}$ — $(^3P)\,3d\ ^4D_{\frac12}$
12	434.570	230112.5	4	$s^2p^5\ ^2P^\circ_{1\frac12}$ — $(^3P)\,3d\ ^2D_{2\frac12}$
5	374.744	266848.8	4	$s^2p^5\ ^2P^\circ_{1\frac12}$ — $(^3P)\,3d\ ^2F_{2\frac12}$
4	345.130	289746	4	$s^2p^5\ ^2P^\circ_{\frac12}$ — $(^3P)\,4s\ ^4P_{1\frac12}$
4	344.958	289890	4	$^2P^\circ_{\frac12}$ — $^2P_{1\frac12}$
5	343.933	290754	4	$s^2p^5\ ^2P^\circ_{\frac12}$ — $(^3P)\,4s\ ^4P_{\frac12}$
4	343.438	291173	4	$^2P^\circ_{1\frac12}$ — $^4P_{2\frac12}$
5	342.447	292016	4	$^2P^\circ_{\frac12}$ — $^2P_{\frac12}$
4	341.455	292864	4	$^2P^\circ_{1\frac12}$ — $^4P_{1\frac12}$
4	341.284	293011	4	$^2P^\circ_{1\frac12}$ — $^2P_{1\frac12}$
4	340.286	293870	4	$^2P^\circ_{1\frac12}$ — $^4P_{\frac12}$
4	338.828	295135	4	$^2P^\circ_{1\frac12}$ — $^2P_{\frac12}$

Table IIb. — *Continued.*

I	λ	ν	N	Combinrations
3	332.808	300474	4	$s^2p^5\ {}^2P^\circ_{1\frac{1}{2}}$ — $({}^1D)\,3d\ {}^2D_{1\frac{1}{2}}$
5	332.531	300725	4	${}^2P^\circ_{\frac{1}{2}}$ — ${}^2S_{\frac{1}{2}}$
5	331.991	301213	4	$s^2p^5\ {}^2P^\circ_{1\frac{1}{2}}$ — $({}^1D)\,4s\ {}^2D_{1\frac{1}{2}}$
4	331.442	301712	4	${}^2P^\circ_{1\frac{1}{2}}$ — ${}^2D_{2\frac{1}{2}}$
3	329.391	303591	3	$s^2p^5\ {}^2P^\circ_{1\frac{1}{2}}$ — $({}^1D)\,3d\ {}^2D_{1\frac{1}{2}}$
5	329.116	303844	4	${}^2P^\circ_{1\frac{1}{2}}$ — ${}^2S_{\frac{1}{2}}$
1	328.577	304343	4	$s^2p^5\ {}^2P^\circ_{1\frac{1}{2}}$ — $({}^1D)\,4s\ {}^2D_{1\frac{1}{2}}$
4	299.315	334096	5	$s^2p^5\ {}^2P^\circ_{\frac{1}{2}}$ — $({}^1S)\,4s\ {}^2S_{\frac{1}{2}}$
5	296.554	337207	4	${}^2P^\circ_{1\frac{1}{2}}$ — ${}^2S_{\frac{1}{2}}$
3	251.354	397845		$s^2p^5\ {}^2P^\circ_{\frac{1}{2}}$ — $({}^1D)\,5s\ {}^2D_{1\frac{1}{2}}$
R3	250.153	399755	4	${}^2P^\circ_{1\frac{1}{2}}$ — ${}^2D_{2\frac{1}{2}}$
3	249.408	400949		${}^2P^\circ_{1\frac{1}{2}}$ — ${}^2D_{1\frac{1}{2}}$

Table IIIa. Term values of K III

s^2p^5 $^2P^o_{1\frac{1}{2}}$ 0 $^2P^o_{\frac{1}{2}}$ 2164		sp^6 $^2S_{\frac{1}{2}}$ 130609	
Limit in X IV	s^2p^4 $^3P_2$ 0 $^3P_1$ 1673 $^3P_0$ 2324	$^1D_2$ 16386	$^1S_0$ 37784
4s	$^4P_{2\frac{1}{2}}$ 206623 $^4P_{1\frac{1}{2}}$ 207915 $^4P_{\frac{1}{2}}$ 208688 $^2P_{1\frac{1}{2}}$ 212728 $^2P_{\frac{1}{2}}$ 214228	$^2D_{2\frac{1}{2}}$ 230032 $^2D_{1\frac{1}{2}}$ 231694	$^2S_{\frac{1}{2}}$ 241667
3d	^4P ^4D ^4F $^2D_{1\frac{1}{2}}$ 190916 $^2D_{2\frac{1}{2}}$ 192082 ^2F 201165	$^2P_{1\frac{1}{2}}$ 241039 $^2P_{\frac{1}{2}}$ 242548 $^2D_{2\frac{1}{2}}$ 244523 $^2D_{1\frac{1}{2}}$ 246012 $^2S_{\frac{1}{2}}$ 250657	$^2D_{2\frac{1}{2}}$ 302404 $^2D_{1\frac{1}{2}}$ 303902
4p	$^4P^0_{2\frac{1}{2}}$ 236846 $^4P^0_{1\frac{1}{2}}$ 237246 $^4P^0_{\frac{1}{2}}$ 237789 $^4D^0_{3\frac{1}{2}}$ 240164 $^4D^0_{2\frac{1}{2}}$ 240778 $^4D^0_{1\frac{1}{2}}$ 247499 $^4D^0_{\frac{1}{2}}$ 241860 $^2D^0_{2\frac{1}{2}}$ 242455 $^2D^0_{\frac{1}{2}}$ 243450 $^2P^0_{1\frac{1}{2}}$ 245246 $^2P^0_{\frac{1}{2}}$ $^4S^0_{1\frac{1}{2}}$ 245960		
5s	$^2P_{1\frac{1}{2}}$ 262828 $^2P_{\frac{1}{2}}$ 263770	$^2D_{2\frac{1}{2}}$ 289400 $^2D_{1\frac{1}{2}}$ 289515	
Terms of unknown nature:		1 252040 2 307429	

Table IIIb. Term values of Ca IV

s^2p^5 $^2P^o_{1\frac{1}{2}}$ 0
$^2P^o_{\frac{1}{2}}$ 3115

sp^6 $^2S_{\frac{1}{2}}$ 152430

Limit in Ca V s^2p^4			
	$^3P_2$ 0 $^3P_1$ 2404 $^3P_0$ 3276	$^1D_2$ 18831	$^1S_0$ 43847
3d	$^4D_{2\frac{1}{2}}$ 227427 $^4D_{1\frac{1}{2}}$ 227827 $^4D_{\frac{1}{2}}$ 228691 $^4F_{1\frac{1}{2}}$ 221944 $^2D_{1\frac{1}{2}}$ 228429 $^2D_{2\frac{1}{2}}$ 230113 $^2F_{2\frac{1}{2}}$ 266840	^2P $^2D_{2\frac{1}{2}}$ $^2D_{1\frac{1}{2}}$ 303591 $^2S_{\frac{1}{2}}$ 303844	^2D
4s	$^4P_{2\frac{1}{2}}$ 291173 $^4P_{1\frac{1}{2}}$ 292864 $^4P_{\frac{1}{2}}$ 293870 $^2P_{1\frac{1}{2}}$ 293011 $^2P_{1\frac{1}{2}}$ 295135	$^2D_{2\frac{1}{2}}$ 301712 $^2D_{1\frac{1}{2}}$ 304343	$^2S_{\frac{1}{2}}$ 337207
4p	$^2P^o_{1\frac{1}{2}}$ 329277		
5s	$^2P_{1\frac{1}{2}}$ $^2P_{\frac{1}{2}}$	$^2D_{2\frac{1}{2}}$ 399755 $^2D_{1\frac{1}{2}}$ 400949	

Highly Ionized Potassium and Calcium Spectra. Part II

K IV — Ca V

In both K IV and Ca V, Ram[1] classified 30 to 40 lines each as triplet transitions on the basis of Ekefors' data. Later, Bowen[2] has found 20 to 30 additional lines on his long exposure plates in the region below 600 A. Ram's assignment of the term configurations was much questioned by Bowen. The reassigned configuration of these terms by Bowen are used here.

1. Ind. J. of Phys. 151, 1933.
2. Phys. Rev. 40, 791, 1934.

After a careful analysis of Ekefors' data, 7 singlets and 5 triplet lines for K IV, 3 more singlets for Ca V have been identified (Table I). The terms are tabulated in Table II.

According to the theory of Coudsmit and Humphreys[3], the relative position of s^2p^4 ^3P, ^1D, ^1S terms must approximately satisfy the relation $(^1S - {}^1D)/(^1D - {}^3P) = 1.50$. The following table shows that the agreement is fairly good for this isoelectronic sequence.

	^1S	^1D	^3P	$(^1S - {}^1D)/(^1D - {}^3P)$
S I[4]	19034	9241	524	1.098
Cl II	——	——	——	——
A III[5]	31963	14000	894	1.363
K IV	37784	16386	1332	1.421
Ca V	43847	18831	1893	1.477

This regular character shows that the identification of s^2p^4 $^1S_0 - sp^5$ $^1P^0_1$, strong line has not been found in both spectra. It should be noted that there are many yet unanalysed strong lines, which are believed to belong to the X IV and Ca V spectrum (as 222918.2(15), 225050.9(15), 227051.2(15), 234969(10), 236866.9(8), for K, and 184403.2(10) for Ca).

3. Phys. Rev. 31, 960, 1928.
4. Zeit. f. Physik 86, 54, 1933.
5. Phys. Rev. 48, 793, 1935.

Table I. Analysis of Singlets

	K IV		Ca V	
	$s^2p^4\ {}^1D_2$ 16386	$s^2p^4\ {}^1S_0$ *37784	$s^2p^4\ {}^1D_2$ 18831	$s^2p^4\ {}^1S_0$ 43847
$sp^5\ {}^1P_1^\circ$		*154753.7(15)		*179018.3(10)
$({}^2P)\ 4s^1p_1^\circ$	281748.0(6)	*260352.3(5)	373458.(8)	348496 (5)
$({}^2D)3d^1P_1^\circ$	*219140.6(8)	*197721.8(1)		
$({}^2P)3d^1P_1^\circ$	245052.4(5)	*223671.1(3)	283360.00(8)	258344.5(4)
$({}^2P)3d^1D_1^\circ$	*257023.8(5)		*310399 (10)	
$({}^2D)3d^1F_3^\circ$	*206033.9(R2)	•	*235294.1(15)	

Analysis of Triplets

For K IV	$s^2p_0^4\ {}^3P_2$	$s^2p^4\ {}^3P_1$ 1673	$s^2p^4\ {}^3P_0$ 2324
$s^2p^3({}^4S)3d\ {}^3D_1^\circ$ *191403	———	*189730 (2)	*189079.2(1)
$s^2p^3({}^4S)3d\ {}^3D_1^\circ$ *191204	*191204.2(5)	*189531.4(3)	
$s^2p^3({}^4S)3d\ {}^3D_3^\circ$ *189952	*189952.3(4)		
$s^2p^3({}^2D)3d\ {}^3P_2^\circ$ *225445	*225445.1(6)	———	
$s^2p^3({}^2D)3d\ 3P_1^\circ$ *226090	*226090.9(4)	*224413.0(R4d)	*223750.7(2)
$s^2p^3({}^2D)3d\ {}^3P_0^\circ$ *227652		*225979.5(2)	

Table IIa. Term values of K IV.

	$s^2p^4\ ^3P_2$	0		sp^5	$^3P^\circ_2$	134181
	$^3P_1$	1673			$^3P^\circ_1$	135659
	$^3P_0$	2324			$^3P^\circ_0$	136453
	$^1D_2$	16386			$^1P^\circ_1$	192538*
	$^1S_0$	37784				
Limit in K V			$^2D^\circ_{1\frac{1}{2}}$	24000	$^2P^\circ_{\frac{1}{2}}$	39745
	$s^2p^3\ ^4S^\circ_{1\frac{1}{2}}$	0	$^2D^\circ_{2\frac{1}{2}}$	24237	$^2P^\circ_{1\frac{1}{2}}$	40064
3d	$^5D^\circ$		$^3F^\circ$		$^3P^\circ_2$	256034
					$^3P^\circ_1$	257124
	$^3D^\circ_1$	191403*	$^1F^\circ_3$	222420	$^3P^\circ_0$	257881
	$^3D^\circ_2$	191204*				
	$^3D^\circ_3$	189952*	$^3G^\circ$		$^1P^\circ_1$	261445
			$^1G^\circ$		$^3D^\circ_3$	262350*
					$^3D^\circ_2$	262831*
			$^3D^\circ$		$^3D^\circ_1$	263659
			$^1D^\circ$		$^1D^\circ_2$	273409*
			$^3P^\circ_2$	225445*		
			$^3P^\circ_1$	226090*		
			$^3P^\circ_0$	227652*		
			$^1P^\circ_1$	235527		
4s	$^5S^\circ_2$		$^3D^\circ_1$	277795	$^3P^\circ_0$	293384
			$^3D^\circ_2$	277851	$^3P^\circ_1$	293473
	$^3S^\circ_1$	249869	$^3D^\circ_3$	277986	$^3P^\circ_2$	293720
			$^1D^\circ_2$	272373	$^1P^\circ_1$	298134
5s	$^3S^\circ_1$	367890				

Table IIb. Term values of Ca V.

s^2p^4	$^3P_2$	0	sp^5	$^3P^\circ_2$	154664
	$^3P_1$	2404		$^3P^\circ_1$	156756
	$^3P_0$	3276		$^3P^\circ_0$	157897
	$^1D_2$	18831		$^1P^\circ_1$	222865*
	$^1S_0$	43847			

Limit in Ca VI s^2p^3	^4S	0	$^2D^\circ_{1\frac{1}{2}}$	27000	$^2P^\circ_{\frac{1}{2}}$	44754
			$^2D^\circ_{2\frac{1}{2}}$	27417	$^2P^\circ_{1\frac{1}{2}}$	44754
3d	$^5D^\circ$		$^3F^\circ$	254125	$^3P^\circ_2$	298204
					$^3P^\circ_1$	299535
	$^3D^\circ$		$^1F^\circ_3$	254125	$^3P^\circ_0$	301680
			$^{3,1}G^\circ$		$^1P^\circ_1$	302184
			$^{3,1}D^\circ$		$^3D^\circ_3$	309384
					$^3D^\circ_2$	309834
			$^{3,1}P^\circ$		$^3D^\circ_1$	310945
					$^1D^\circ_2$	329230*
4s	$^5S^\circ$		$^3D^\circ_1$	369590	$^3P^\circ_0$	387039
			$^3D_2$	369696	$^3P^\circ_1$	387226
	$^3S^\circ_1$	350914	$^3D^\circ_3$	369959	$^3P^\circ_2$	387652
			$^1D^\circ_2$	374728	$^1P^\circ_1$	392283
5s	$^5S^\circ$		$^3D^\circ_1$	524651	$^3P^\circ_0$	
			$^3D^\circ_2$	524770	$^3P^\circ_1$	542249
	$^3S^\circ_1$	501127	$^3D^\circ_3$	525053	$^3P^\circ_2$	542650
			$^1D^\circ_2$	526523	$^1P^\circ_1$	544143

Highly Ionized Potassium and Calcium Spectra. Part III. K V — Ca VI

The expected terms are like those of P I spectrum. Ram[1] noted one quartet of three lines, $s^2p^3\ ^4S^\circ$ — $sp^4\ ^4P$ of K V in Ekefors' data by applying the irregular doublet law. Bowen[2] measured and classified 26 and 31 lines for K V and Ca VI respectively in the region 200-650. He has identified for K V and Ca VI 19 terms each. The important doublet levels $s^2p^3\ ^2D^\circ$, $^2P^\circ$ should be expected to combine with the 3d and 4s doublet levels. The term values of these levels with respect to $s^2p^3\ ^2S$ are tabulated in Tables IIa and IIb. The separations of $^2D^\circ$ are 237 for K V and 417 for Ca VI, and that of $^2P^\circ$ are 319 for K V and 556 for Ca VI. It has been found that many pairs of doublet lines of above separations actually exist in the region covered by Ekefors' data. The $s^2p^2(^3P)3d\ ^4P$, ^4D, ^4F for K V have also been found by the application of the irregular doublet law. The intensities and separations lend strength to the belief that the identification is correct. Data related to the irregular doublet law are tabulated in Table I.

Table I. The irregular doublet law.

	$s^2p^3\ ^4S^0-3d^4F_{2\frac{1}{2}}$	$s^2p^3\ ^4S^0-3d^4D_{2\frac{1}{2}}$	$s^2p^3\ ^4S^0-3d^4P_{2\frac{1}{2}}$
P II[3]	67053	70778.6	72386.6
	43260	43453	43431
S II[4]	110313	114231	115817(?)
	36437	37617	63678
Cl III[5]	146749.9	151848.6	179495
A IV	2×30208	2×35259	2×39185
K V	207165.4(4)	222366.5(4)	257864.9(6)

1. Ram, Ind. J. of Phys. 8, 151, (1933).
2. I. S. Bowen, Phys. Rev. 46, 791 (1934).
3. Robinson, Phys. Rev. 49, 297 (1936).
4. Gilles, Ann. de. Phys. 15, 267, (1931).
5. I. S. Bowen, Phys. Rev. 45, 401, (1934).

Table IIa. Term Values of K V.

s^2p^3	$^4S^\circ_{1\frac{1}{2}}$	0	sp^4	$^4P_{2\frac{1}{2}}$	136639
				$^4P_{1\frac{1}{2}}$	138042
				$^4P_{\frac{1}{2}}$	138806
	$^2D^\circ_{1\frac{1}{2}}$	24000		$^2P_{1\frac{1}{2}}$	194792
	$^2D^\circ_{2\frac{1}{2}}$	24237		$^2P_{\frac{1}{2}}$	196319
	$^2P^\circ_{\frac{1}{2}}$	39745		$^2D_{1\frac{1}{2}}$	161199
				$^2D_{2\frac{1}{2}}$	161564
	$^2P^\circ_{1\frac{1}{2}}$	40064		$^2S_{\frac{1}{2}}$	205784

Limit in K VI	s^2p^2 $^3P_0$ 0, $^3P_1$ 1131, $^3P_2$ 2924		^1D		^1S	
3d	$^4F_{1\frac{1}{2}}$	206720	$^2F_{2\frac{1}{2}}$	292710	$^2D_{1\frac{1}{2}}$	304461
	$^4F_{2\frac{1}{2}}$	207165	$^2F_{3\frac{1}{2}}$		$^2D_{2\frac{1}{2}}$	305978
	$^4D_{2\frac{1}{2}}$	222367	$^2D_{1\frac{1}{2}}$	281024		
	$^4D_{1\frac{1}{2}}$	222711	$^2D_{2\frac{1}{2}}$			
	$^4P_{2\frac{1}{2}}$	257865	$^2P_{\frac{1}{2}}$			
	$^4P_{1\frac{1}{2}}$	259276	$^2P_{1\frac{1}{2}}$	290772		
	$^4P_{\frac{1}{2}}$	259726				
			$^2S_{\frac{1}{2}}$	292968		
	$^2P_{1\frac{1}{2}}$	259205				
	$^2P_{\frac{1}{2}}$	260865				
	$^2F_{2\frac{1}{2}}$	262487				
	$^2F_{3\frac{1}{2}}$	262874				
	$^2D_{2\frac{1}{2}}$	264741				
	$^2D_{1\frac{1}{2}}$	264932				
4s	$^4P_{\frac{1}{2}}$	336628				
	$^4P_{1\frac{1}{2}}$	337645				
	$^4P_{2\frac{1}{2}}$	339172				
	$^2P_{\frac{1}{2}}$	343726				
	$^2P_{1\frac{1}{2}}$	345526				
	$^2D_{2\frac{1}{2}}$	356993				
	$^2D_{1\frac{1}{2}}$	357033				

Terms of unknown nature:

1	169703
2	169886
3	268043
4	274375
5	307717
6	310120

Table IIb. Term values of Ca VI.

s^2p^3	$^4S^\circ_{1\frac{1}{2}}$	0	sp^4	$^4P_{2\frac{1}{2}}$	155792
				$^4P_{1\frac{1}{2}}$	157775
	$^2D^\circ_{1\frac{1}{2}}$	27000		$^4P_{\frac{1}{2}}$	158833
	$^2D^\circ_{2\frac{1}{2}}$	27417		$^2P_{1\frac{1}{2}}$	
				$^2P_{\frac{1}{2}}$	233506
	$^2P^\circ_{\frac{1}{2}}$	44754		$^2D_{1\frac{1}{2}}$	193412
				$^2D_{2\frac{1}{2}}$	193613
	$^2P^\circ_{1\frac{1}{2}}$	45310			
				$^2S_{\frac{1}{2}}$	231318

Limit in Da VII	s^2p^2	$^3P_0$ 0 $^3P_1$ 1629 $^3P_2$ 4070		^1D		^1S	
3d		$^2D_{1\frac{1}{2}}$	383743	^2F		$^2D_{1\frac{1}{2}}$	360821
		$^2D_{2\frac{1}{2}}$					
				$^2D_{2\frac{1}{2}}$	321089		
		$^2P_{1\frac{1}{2}}$	294798	$^2D_{1\frac{1}{2}}$	321583		
		$^2P_{\frac{1}{2}}$	297250				
				$^2P_{\frac{1}{2}}$	332138		
		$^2F_{2\frac{1}{2}}$	291165	$^2P_{1\frac{1}{2}}$	333492		
				$^2S_{\frac{1}{2}}$	320397		
4s		$^4P_{\frac{1}{2}}$	433849				
		$^4P_{1\frac{1}{2}}$	435286				
		$^4P_{\frac{1}{2}}$	437392				
		$^2P_{\frac{1}{2}}$	442423				
		$^2P_{1\frac{1}{2}}$	444890				
		$^2D_{2\frac{1}{2}}$	457458				
		$^2D_{1\frac{1}{2}}$	457525				

Terms of unknown nature:

1	175758 ($^2D_{2\frac{1}{2}}$)
2	176157 ($^2D_{1\frac{1}{2}}$)
3	303651

Table IIIa. Analyzed lines of K V.

I	λ	ν	N	Combinations
*1	825.559	121130.3	5	$s^2p^3\ {}^2P^\circ_{1\frac{1}{2}}$ — $sp^4\ {}^2D_{1\frac{1}{2}}$
*3	823.358	121453.9		${}^2P^\circ_{\frac{1}{2}}$ — ${}^2D_{1\frac{1}{2}}$
*3	823.047	121499.8	5	${}^2P^\circ_{1\frac{1}{2}}$ — ${}^2D_{2\frac{1}{2}}$
*3	771.456	129638.5	5	$s^2p^3\ {}^2P^\circ_{1\frac{1}{2}}$ — 1
*3	770.287	129821.8	5	${}^2P^\circ_{1\frac{1}{2}}$ — 2
*2	769.402	129971.1	5	${}^2P^\circ_{\frac{1}{2}}$ — 1
12	731.858	136638.5		$s^2p^3\ {}^4S^\circ_{1\frac{1}{2}}$ — $sp^4\ {}^4P_{2\frac{1}{2}}$
8	724.420	138041.5	5	${}^4S^\circ_{1\frac{1}{2}}$ — ${}^4P_{1\frac{1}{2}}$
6	720.402	138805.6	5	${}^4S^\circ_{1\frac{1}{2}}$ — ${}^4P_{\frac{1}{2}}$
0	644.963	155047.7		$s^2p^3\ {}^2P^\circ_{\frac{1}{2}}$ — $sp^4\ {}^2P_{1\frac{1}{2}}$
2	639.982	156254.4	6	${}^2P^\circ_{1\frac{1}{2}}$ — ${}^2P_{\frac{1}{2}}$
5	638.668	156575.9	6	${}^2P^\circ_{\frac{1}{2}}$ — ${}^2P_{\frac{1}{2}}$
*8	603.429	165720.0	5	$s^2p^3\ {}^2P^\circ_{1\frac{1}{2}}$ — $sp^4\ {}^2S_{\frac{1}{2}}$
*5	602.269	166038.8	5	${}^2P^\circ_{\frac{1}{2}}$ — ${}^2S_{\frac{1}{2}}$
10	586.322	170554.8	5	$s^2p^3\ {}^2D^\circ_{2\frac{1}{2}}$ — $sp^4\ {}^2P_{1\frac{1}{2}}$
5	585.510	170791.3	5	${}^2D^\circ_{1\frac{1}{2}}$ — ${}^2P_{1\frac{1}{2}}$
15	580.319	172319.0	5	${}^2D^\circ_{1\frac{1}{2}}$ — ${}^2P_{\frac{1}{2}}$
*4	483.745	206720.5	5	$s^2p^3\ {}^4S^\circ_{1\frac{1}{2}}$ — $({}^3P)3d\ {}^4F_{1\frac{1}{2}}$
*4	482.706	207165.4	6	${}^4S^\circ_{1\frac{1}{2}}$ — ${}^4F_{2\frac{1}{2}}$
8	456.328	219140.6	5	$s^2p^3\ {}^2P^\circ_{1\frac{1}{2}}$ — $({}^3P)3d\ {}^2P_{1\frac{1}{2}}$
5	455.670	219457.1	6	${}^2P^\circ_{\frac{1}{2}}$ — ${}^2P_{1\frac{1}{2}}$
4	452.900	220799.3	5	${}^2P^\circ_{1\frac{1}{2}}$ — ${}^2P_{\frac{1}{2}}$
*4	449.708	222366.5	5	$s^2p^3\ {}^4S^\circ_{1\frac{1}{2}}$ — $({}^3P)3d\ {}^4D_{2\frac{1}{2}}$
*3	449.013	222710.7	5	${}^4S^\circ_{1\frac{1}{2}}$ — ${}^4D_{1\frac{1}{2}}$
*2d	438.647	227973.8	6	$s^2p^3\ {}^2P^\circ_{1\frac{1}{2}}$ — 3
*5	438.023	228298.5	4	${}^2P^\circ_{\frac{1}{2}}$ — 3
10	425.588	234969.0	4	$s^2p^3\ {}^2D^\circ_{2\frac{1}{2}}$ — $({}^2P)3d\ {}^2P_{1\frac{1}{2}}$
6	425.159	235206.1	5	${}^2D^\circ_{1\frac{1}{2}}$ — ${}^2P_{1\frac{1}{2}}$
8	422.178	236866.9	4	${}^2D^\circ_{1\frac{1}{2}}$ — ${}^2P_{1\frac{1}{2}}$
*1	419.731	238247.8	5	$s^2p^3\ {}^2D^\circ_{2\frac{1}{2}}$ — $({}^3P)3d\ {}^2F_{2\frac{1}{2}}$
*2	419.310	238487.0	5	${}^2D^\circ_{1\frac{1}{2}}$ — ${}^2F_{2\frac{1}{2}}$
*2	419.045	238637.9	5	${}^2D^\circ_{2\frac{1}{2}}$ — ${}^2F_{1\frac{1}{2}}$
*4	415.793	240504.3	5	$s^2p^3\ {}^2D^\circ_{2\frac{1}{2}}$ — $({}^3P)3d\ {}^2D_{2\frac{1}{2}}$
*3	415.465	240694.2	5	${}^2D^\circ_{1\frac{1}{2}}$ — ${}^2D_{1\frac{1}{2}}$
*5	415.052	250933.7	5	${}^2D^\circ_{1\frac{1}{2}}$ — ${}^2D_{1\frac{1}{2}}$

Table IIIa. — *Continued.*

I	λ	ν	N	Combinations
*3	414.456	241274.9	5	s^2p^3 ${}^2P^\circ_{\frac{1}{2}}$ — $({}^1D)3d$ ${}^2D_{1\frac{1}{2}}$
*4	399.754	250153.9	5	s^2p^3 ${}^2D^\circ_{2\frac{1}{2}}$ — 4
*3	399.400	250375.6	6	${}^2D^\circ_{1\frac{1}{2}}$ — 4
*4	398.878	250703.2	5	s^2p^3 ${}^2P^\circ_{1\frac{1}{2}}$ — $({}^1D)3d$ ${}^2P_{1\frac{1}{2}}$
*4	398.363	251027.3	5	${}^2P^\circ_{\frac{1}{2}}$ — ${}^2P_{1\frac{1}{2}}$
*5	395.395	252911.6	5	s^2p^3 ${}^2P^\circ_{1\frac{1}{2}}$ — $({}^1D)3d$ ${}^2S_{\frac{1}{2}}$
*3	394.909	253222.9	5	${}^2P^\circ_{\frac{1}{2}}$ — ${}^2S_{\frac{1}{2}}$
*2	389.428	256786.7	5	s^2p^3 ${}^2D^\circ_{2\frac{1}{2}}$ — $({}^1D)3d$ ${}^2D_{1\frac{1}{2}}$
*5	389.069	257023.8	4	${}^2D^\circ_{1\frac{1}{2}}$ — ${}^2D_{1\frac{1}{2}}$
*6	387.800	257864.9	5	s^2p^3 ${}^4S^\circ_{1\frac{1}{2}}$ — $({}^3P)3d$ ${}^4P_{2\frac{1}{2}}$
*2	385.689	259276.3	5	${}^4S^\circ_{1\frac{1}{2}}$ — ${}^4P_{1\frac{1}{2}}$
*1	385.020	259726.8	5	${}^4S^\circ_{1\frac{1}{2}}$ — ${}^4P_{1\frac{1}{2}}$
*3	378.219	264397.1	5	s^2p^3 ${}^2P^\circ_{1\frac{1}{2}}$ — $({}^1S)3d$ ${}^2D_{1\frac{1}{2}}$
*5	377.763	264716.2	5	${}^2P^\circ_{\frac{1}{2}}$ — ${}^2D_{1\frac{1}{2}}$
*3	376.061	265914.3	5	${}^2P^\circ_{1\frac{1}{2}}$ — ${}^2D_{2\frac{1}{2}}$
*2	373.074	269043.3	6	s^2p^3 ${}^4S^\circ_{1\frac{1}{2}}$ — 3
*4	372.462	268483.8	5	s^2p^3 ${}^2D^\circ_{2\frac{1}{2}}$ — $({}^1D)3d$ ${}^2F_{2\frac{1}{2}}$
*10	374.148	268710.3	5	${}^2D^\circ_{1\frac{1}{2}}$ — ${}^2F_{2\frac{1}{2}}$
*0	254.927	281748.1	4	s^2p^3 ${}^2D^\circ_{2\frac{1}{2}}$ — $({}^1S)3d$ ${}^2D_{2\frac{1}{2}}$
*6	254.627	281986.4		${}^2D^\circ_{1\frac{1}{2}}$ — ${}^2D_{2\frac{1}{2}}$
*2	352.750	283486.9	6	s^2p^3 ${}^2D^\circ_{2\frac{1}{2}}$ — 5
*2	352.463	283717.7	6	${}^2D^\circ_{1\frac{1}{2}}$ — 5
*3	349.793	285883.6	6	s^2p^3 ${}^2D^\circ_{2\frac{1}{2}}$ — 6
*R4	349.504	286120		${}^2D^\circ_{1\frac{1}{2}}$ — 6
R1d	329.307	303668	5	s^2p^3 ${}^2P^\circ_{1\frac{1}{2}}$ — $({}^3P)4s$ ${}^2P_{\frac{1}{2}}$
5	327.276	305459	6	s^2p^3 ${}^2P^\circ_{1\frac{1}{2}}$ — $({}^3P)4s$ ${}^2P_{1\frac{1}{2}}$
2	327.031	305781	6	${}^2P^\circ_{\frac{1}{2}}$ — ${}^2P_{1\frac{1}{2}}$
3	315.537	316920	6	s^2p^3 ${}^2P^\circ_{1\frac{1}{2}}$ — $({}^3P)4s$ ${}^2D_{2\frac{1}{2}}$
4	315.181	317278	6	${}^2P^\circ_{\frac{1}{2}}$ — ${}^2D_{1\frac{1}{2}}$
5	312.770	319724	5	s^2p^3 ${}^2D^\circ_{1\frac{1}{2}}$ — $({}^3P)4s$ ${}^2P_{\frac{1}{2}}$
4	311.243	321292	5	${}^2D^\circ_{2\frac{1}{2}}$ — ${}^2P_{1\frac{1}{2}}$
4	300.503	332775	5	s^2p^3 ${}^2D^\circ_{2\frac{1}{2}}$ — $({}^3P)4s$ ${}^2D_{2\frac{1}{2}}$
4	300.252	333054	5	${}^2D^\circ_{1\frac{1}{2}}$ — ${}^2D_{1\frac{1}{2}}$

Table IIIa. — *Continued.*

I	λ	ν	N	Combinations
4-	297.064	336628	5	$s^2p^3\ {}^4S^\circ_{1\frac{1}{2}}$ — $(^3P)\,4s\ {}^4P_{\frac{1}{2}}$
4	296.169	337645	5	$^4S^\circ_{1\frac{1}{2}}$ — $^4P_{1\frac{1}{2}}$
6	294.836	339172	5	$^4S^\circ_{1\frac{1}{2}}$ — $^4P_{2\frac{1}{2}}$

Table IIfb. Analyzed lined of Ca VI.

I	λ	ν	N	Combinations
*1	766.522	130459.4	6	$s^2p^3\ {}^2P^\circ_{1\frac{1}{2}}$ — 1
*3	764.358	130828.7	6	$^2P^\circ_{1\frac{1}{2}}$ — 2
*2	763.344	131002.5	6	$^2P^\circ_{\frac{1}{2}}$ — 1
*2	674.278	148306.8	7	$s^2p^3\ {}^2P^\circ_{1\frac{1}{2}}$ — $sp^4\ {}^2D_{2\frac{1}{2}}$
*1	674.046	148357.8	6	$s^2p^3\ {}^2D^\circ_{2\frac{1}{2}}$ — 1
*0	672.315	148739.8	7	$s^2p^3\ {}^2D^\circ_{2\frac{1}{2}}$ — 2
2	629.594	158832.5	6	$s^2p^3\ {}^4S^\circ_{1\frac{1}{2}}$ — $sp^4\ {}^4P_{\frac{1}{2}}$
*0	602.389	166005.7		$s^2p^3\ {}^2D^\circ_{2\frac{1}{2}}$ — $sp^4\ {}^2D_{1\frac{1}{2}}$
*5	601.700	166195.8	6	$^2D^\circ_{2\frac{1}{2}}$ — $^2D_{2\frac{1}{2}}$
*6	600.917	166412.3	6	$^2D^\circ_{1\frac{1}{2}}$ — $^2D_{1\frac{1}{2}}$
*6	537.613	186007.4	5	$s^2p^3\ {}^2P^\circ_{1\frac{1}{2}}$ — $sp^4\ {}^2S_{\frac{1}{2}}$
*0	536.122	186564.4		$^2P^\circ_{\frac{1}{2}}$ — $^2S_{\frac{1}{2}}$
*2	509.23	196350.6	5	$s^2p^3\ {}^2D^\circ_{1\frac{1}{2}}$ — $sp^4\ {}^2P_{\frac{1}{2}}$
*3	420.191	238980.6	7	$s^2p^3\ {}^2P^\circ_{\frac{1}{2}}$ — $(^3P)\,3d\ {}^2D_{1\frac{1}{2}}$
4	400.827	249484.2	6	$s^2p^3\ {}^2P^\circ_{1\frac{1}{2}}$ — $(^3P)\,3d\ {}^2P_{1\frac{1}{2}}$
1	399.928	250045.0	6	$^2P^\circ_{\frac{1}{2}}$ — $^2P_{1\frac{1}{2}}$
2	396.918	251941.2	7	$^2P^\circ_{1\frac{1}{2}}$ — $^2P_{1\frac{1}{2}}$
2	396.004	252497.2	6	$^2P_{\frac{1}{2}}$ — $^2P_{1\frac{1}{2}}$
*R3	390.137	256320.2	6	$s^2p^3\ {}^2D^\circ_{2\frac{1}{2}}$ — $(^3P)\,3d\ {}^2D_{1\frac{1}{2}}$
*0	389.495	256742.7		$^2D^\circ_{1\frac{1}{2}}$ — $^2D_{1\frac{1}{2}}$
*4	387.080	258344.5	6	$s^2p^3\ {}^2P^\circ_{1\frac{1}{2}}$ — 3
*1	386.254	258897.0	6	$^2P^\circ_{\frac{1}{2}}$ — 3
*2	379.138	263756.2	5	$s^2p^3\ {}^2D^\circ_{2\frac{1}{2}}$ — $(^3P)\,3d\ {}^2F_{2\frac{1}{2}}$
*1	378.551	264165.2	6	$^2D^\circ_{1\frac{1}{2}}$ — $^2F_{2\frac{1}{2}}$
6	374.000	267378.4	5	$s^2p^3\ {}^2D^\circ_{2\frac{1}{2}}$ — $(^3P)\,3d\ {}^2P_{1\frac{1}{2}}$
2	373.417	267797.1	6	$^2D^\circ_{1\frac{1}{2}}$ — $^2P_{1\frac{1}{2}}$
5	370.033	270246.2	6	$^2D^\circ_{1\frac{1}{2}}$ — $^2P_{1\frac{1}{2}}$

Table IIIb. — *Continued.*

I	λ	ν	N	Combinations
*2	363.525	275084.2	7	$s^2p^3\ {}^4S^o_{1\frac{1}{2}}$ — $({}^1D)3d\ {}^2S_{\frac{1}{2}}$
*1	362.788	275643.1	7	${}^4S^o_{\frac{1}{2}}$ — ${}^2S_{\frac{1}{2}}$
2	362.617	275773.1	6	$s^2p^3\ {}^2P^o_{1\frac{1}{2}}$ — $({}^1D)3d\ {}^2D_{2\frac{1}{2}}$
0	361.241	276823.5		${}^2P^o_{\frac{1}{2}}$ — ${}^2D_{1\frac{1}{2}}$
*1	348.650	286821	6	$s^2p^3\ {}^2P^o_{1\frac{1}{2}}$ — $({}^1D)3d\ {}^2P_{\frac{1}{2}}$
*R3d	347.976	288738	6	${}^2P^o_{\frac{1}{2}}$ — ${}^2P_{1\frac{1}{2}}$
*4	347.005	288180	6	${}^2P^o_{1\frac{1}{2}}$ — ${}^2P_{1\frac{1}{2}}$
*2d	346.335	288738	6	${}^2P^o_{1\frac{1}{2}}$ — ${}^2P_{1\frac{1}{2}}$
3-	340.516	293672	7	$s^2p^3\ {}^2D^o_{1\frac{1}{2}}$ — $({}^1D)3d\ {}^2D_{2\frac{1}{2}}$
3	339.953	294158	6	${}^2D^o_{\frac{1}{2}}$ — ${}^2D_{1\frac{1}{2}}$
3	339.463	294583	6	${}^2D^o_{1\frac{1}{2}}$ — ${}^2D_{1\frac{1}{2}}$
*3	316.947	315510	7	$s^2p^3\ {}^2D^o_{1\frac{1}{2}}$ — $({}^1S)3d\ {}^2D_{1\frac{1}{2}}$
*0	316.389	316067	7	${}^2D^o_{\frac{1}{2}}$ — ${}^2D_{1\frac{1}{2}}$
1	251.465	397670		$s^2p^3\ {}^2P^o_{\frac{1}{2}}$ — $({}^3P)4s\ {}^2P_{\frac{1}{2}}$
3	250.269	399570	7	${}^2P^o_{1\frac{1}{2}}$ — ${}^2P_{1\frac{1}{2}}$
R4	240.724	415414		$s^2p^3\ {}^2P^o_{1\frac{1}{2}}$ — $({}^3P)4s\ {}^2P_{\frac{1}{2}}$
4	239.527	417476		${}^2P^o_{2\frac{1}{2}}$ — ${}^2P_{1\frac{1}{2}}$
5	232.537	430039		$s^2p^3\ {}^2D^o_{2\frac{1}{2}}$ — $({}^3P)4s\ {}^2D_{2\frac{1}{2}}$
4	232.275	430524		${}^2D^o_{1\frac{1}{2}}$ — ${}^2D_{1\frac{1}{2}}$
3	230.501	433838	6	$s^2p^3\ {}^2P^o_{1\frac{1}{2}}$ — $({}^3P)4s\ {}^4P_{\frac{1}{2}}$
5	229.743	433838	6	${}^2P^o_{1\frac{1}{2}}$ — ${}^4P_{1\frac{1}{2}}$
6	228.634	437380	6	${}^2P^o_{1\frac{1}{2}}$ — ${}^4P_{2\frac{1}{2}}$

Highly Ionized Potassium and Calcium Spectra. Part IV.

K VIII — Ca IX

The lines sp^3P — $p^2\ {}^3P$ of K VIII spectrum were analyzed by Whitford[1] using Ekefors' data. In the present work, the lines of same nature are obtained in the calcium spectrum. In addition to this, two principle singlets are also recognized by the application of irregular doublet law. The analyzed lines are

1. Phys. Rev. 46, 791 (1934).

	K VIII	Ca IX
sp $^1P^\circ_1$ — sd $^1D_2$	*106577.2(2)	*120707.2(2)
sp $^3P^\circ_2$ — p^2 $^3P_1$	174583.8(1)	*194364.2(1)
sp $^3P^\circ_1$ — p^2 $^3P_0$	175598.8(2)	*195286.9(2)
sp $^3P^\circ_2$ — p^2 $^3P_2$	176955.5(3)	*197564.8(4)
sp $^3P^\circ_1$ — p^2 $^3P_1$	177159.5(6)	
sp $^3P^\circ_0$ — p^2 $^3P_1$	178064.6(3)	*198704.0(2)
sp $^3P^\circ_1$ — p^2 $^3P_2$	179523.9(1)	*200808.9(3)
s^2 $^1S_0$ — sp ^1P	*192540.2(5)	*214487.8(6)

The following table shows the irregular doublet law:

		s^2 $^1S_0$—sp $^1P^\circ_1$	sp $^1P^\circ_1$ —sd $^1D_2$	sp $^3P^\circ_2$ —p^2 $^3P_2$
Mg	I [2]	35051.4	11352	35961.5
		24798	14277	20727
Al	II [2]	59849.7	25629	56688.4
		23035	13700	20300
Si	III [3]	82885.0	29329.9	76988
		22304	13621	20048
P	IV [3]	105189.0	52950.7	97036
		21960		19951
S	V [3]	127149		116987
		21800		19947
Cl	VI [4]	148949	4×13405	136934
A	VII	2×21796		2×20010
K	VIII	192540.2	106577.2	176955
		22053	14137	20609
Ca	IX	214487.8	120707.2	197564.8

2. Ann. d. Phys. 12, 4, p. 509 (1932).
3. Phys. Rev. 39, 8 (1932).
4. Bacher & Goudsmit. Atomic Energy States.

No intercombinations have been found, so the singlets and triplets are listed in the following separate tables:

Singlets	K VIII	Ca X
$s^2\ ^1S_0$	0	0
$sp\ ^1P_1^\circ$	192540.2	214487.8
$sd\ ^1D_2$	299117.4	335195.0

Triplets	K VIII	Ca IX
$sp\ ^3P_0^\circ$	0	0
	905	1139
$^3P_1^\circ$	905	1139
	2572	3200
$^3P_2^\circ$	3477	4339
$p^2\ ^3P_0$	176504	196426.1
	1561	2278.7
$^3P_1$	178066	198704.2
	2366	3244.1
$^3P_2$	180431	201948.1

Highly Ionized Potassium and Calcium Spectra. Part V. K IX — Ca X

On the basis of Ekefors list, Whitford[1] first attemped an analysis of K IX spectrum. He classified (3) 157158.6 and (5) 160921.1 as due to the transitions 3s ^2S — 3p ^2P. Very recently Edlén[2] in Upsala has given a rather complete analysis of Na I like spectra from K IX to Cu VIX. In the Edlén's work the transitions 3d-4f, 3p-4s for K IX and 3s-3p, 3p-3d, 3d-4f, 3p-4s for Ca X have been identified. The present work is supplementary to Edlén's, and gives the identification of eight additional lines for K IX and six additional lines for Ca X. Table I gives the analyzed lines.

Table I. The analyzed lines.

	K IX		Ca X	
$3s\,^2S_{\frac{1}{2}} - 3p\,^2P^\circ_{\frac{1}{2}}$	*636.300	157158.6 (3d)	*574.007	174213.9 (3)
$^2S_{\frac{1}{2}} - {}^2P^\circ_{1\frac{1}{2}}$	*621.422	160921.2 (5d)	———	———
$4f\,^2F^\circ_{3\frac{1}{2}} - 5g\,^2G_{4\frac{1}{2}}$	545.232	183048.2 (1)	———	———
$^2F_{2\frac{1}{2}} - {}^2G_{3\frac{1}{2}}$	544.855	183535.1 (1)	———	———
$p\,^2P^\circ_{1\frac{1}{2}} - 5s\,^2S_{\frac{1}{2}}$	453.882	220321.6 (0)	371.902	268888 (2)
$^2P^\circ_{\frac{1}{2}} - {}^2S_{\frac{1}{2}}$	451.078	221691.1 (1)	———	———
$3p\,^2P^\circ_{1\frac{1}{2}} - 3d\,^2D_{2\frac{1}{2}}$	———	———	*419.778	238221 (3)
$4d\,^2D_{2\frac{1}{2}} - 5f\,^2F^\circ$	439.047	227766.0 (3+)	355.692	281142.1 (R1)
$^2D_{1\frac{1}{2}} - {}^2F^\circ$	438.647	227973.8 (2d)	355.351	281411.9 (R1)
$3d\,^2D_{2\frac{1}{2}} - 4p\,^2P^\circ_{1\frac{1}{2}}$	259.609	385195 (2)	———	———
$^2D_{1\frac{1}{2}} - {}^2P^\circ_{1\frac{1}{2}}$	258.873	386290 (3−)	205.391	486876 (2)
$3d\,^2D_2 - 4f\,^2F^\circ_{3\frac{1}{2}}$	*205.862	485762 (2)	*167.034	598681 (1+)
$^2D_{1\frac{1}{2}} - {}^2F^\circ_{2\frac{1}{2}}$	*205.772	485975 (2−)	*166.945	5990000 (1)
$3p\,^2P^\circ_{1\frac{1}{2}} - 4s\,^2S_{\frac{1}{2}}$	*185.883	537973 (2)	*153.012	653544 (0+)
$^2P^\circ_{\frac{1}{2}} - {}^2S_{\frac{1}{2}}$	*184.587	541750 (0)	*151.832	658623 (0)

1. F. Whitford Phys. Rev. **46**, 793 (1934).
2. Edlen, Zeits. f. Phys. **100**, 621 (1936).

In the following table, it can be shown that the 4 series of combinations, namely 4f-5g, 3d-4p, 5s-4p, and 4d-5f, satisfy Moseley's law.

		$3f^2F_{3\frac{1}{2}}-5gG_{4\frac{1}{2}}$		$3d^2D_{2\frac{1}{2}}-4p^2P_{1\frac{1}{2}}$		$5s^2S_{\frac{1}{2}}-5p^2P_{1\frac{1}{2}}$		$4d^2D-5f^2F$	
		$\sqrt{\nu}$	$\Delta(\nu)\frac{1}{2}$	$\sqrt{\nu}$	$\Delta(\nu)\frac{1}{2}$	$\sqrt{\nu}$	$\Delta(\nu)\frac{1}{2}$	$\sqrt{\nu}$	$\Delta(\nu)\frac{1}{2}$
Na	I			33.16		54.11		50.10	
					62.54		66.05		51.77
Mg	II			95.71		110.16		101.87	
					70.89		53.85		53.34
Al	III	164.98		166.60		164.01		155.21	
			44.09		74.34		52.76		53.86
Si	IV	209.07		240.94		216.77		209.07	
			40.11		75.67		51.91		53.76
P	V	249.18(?)		316.61		268.69		262.80	
			49.91		76.06				
S	VI	299.09		392.67					
Cl	VII						4×50.17		4×53.64
			3×43.06		3×76.28				
A	VIII								
X	IX	428.26		621.52		469.38		477.25	
					76.24		49.12		52.97
Ca	X			697.76		518.58		530.22	
					72.85				
Sc	XI			770.61					2×49.36
					74.50				
Ti	XII			845.11				628.94	
					74.69				51.06
V	XIII			919.80				680.00	
					74.94				51.29
Cr	XIV			996.74				731.29	
									51.74
Mn	XV							783.03	
									50.99
Fe	XVI							834.02	
									50.78
Co	XVII							884.80	

All the term values are given with respect to $3s^2S_{\frac{1}{2}}$. The $4s^2S$, and $3p^2P$ are obtained directly from the related lines. The $4p^2P$, $3d^2D$, and $5g^2G$ are calculated from the assumed values of the $4f^2F$. The $4f^2F$ terms are given by Edlén in his isoelectronic sequences analysis for assume value of effective number. The term value of $4d^2D_2$ can be calculated if we assumed $n^* = 3.9133$ for Ca X, and 3.9119 for K XI. $5f^2F$ being not resolved and taken as single. The absolute value of $3s^2S$ for K IX is 1417810, and for Ca X is 1704040 with respect to $2p^6\ {}^1S_0$.

Table III. The Term Values.

	K IX		Ca X	
$3s^2S_{\frac{1}{2}}$	0		0	
$4s^2S_{\frac{1}{2}}$	698901		832841	
$5s^2S_{\frac{1}{2}}$	981535		11732278	
$3p^2P_{\frac{1}{2}}$	157159	(3762)	174213.9	(5079)
$^2P_{1\frac{1}{2}}$	160921		179293	
$4p^2P_{\frac{1}{2}}$	759850	(1358)	904390	
$^2P_{1\frac{1}{2}}$	761208		———	
$3d^2D_{1\frac{1}{2}}$	374918	(263)	417115	(399)
$^2D_{2\frac{1}{2}}$	374655		417514	
$4d^2D_{1\frac{1}{2}}$	837172	(208)	986670	(270)
$^2D_{2\frac{1}{2}}$	837380		986940	
$4f^2F_{2\frac{1}{2}}$	860630	(50)	1016115	(80)
$^2F_{3\frac{1}{2}}$	860680		1016195	
$5f^2F$	1065146		1268082	
$5g^2G_{3\frac{1}{2}}$	1044165.1	(−76.9)		
$^2G_{4\frac{1}{2}}$	1044088.2			