WAVE-LENGTH STANDARDS IN THE EXTREME ULTRA-VIOLET SPECTRA OF CARBON, NITROGEN, OXYGEN AND ALUMINUM.

and

THE SPECTRUM OF SULPHUR, SII.

by

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WAVE-LENGTH STANDARDS IN THE EXTREME ULTRA-VIOLET SPECTRUM OF CARBON, NITROGEN, OXYGEN AND ALUMINUM.

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Abstract.

Wave-length determinations.-- The wave-lengths of lines in the extreme ultra-violet spectra of carbon, nitrogen, oxygen and aluminum have been determined with an accuracy of .01 to .04A by direct comparison with iron standards.

pp' groups in carbon C_{111} and nitrogen N_{IV}-- pp' Groups of carbon C_{III} and nitrogen N_{IV} have been completely resolved into six components and the ratio P_1P_2/P_2P_3 found to be 2.47 and 2.33 respectively.

1. Determination of Wave-lengths.

In a pevious article[1] by Dr. Millikan and Dr. I. S. Bowen wave-length standards in oxygen and nitrogen were published. For these earlier determinations the strong aluminum lines between 1850A and 2000A served as primary standards. In the course of subsequent studies it has become increasingly evident that the wave-lengths of these aluminum lines were inconsistent with themselves, one of the doublet separations being in error by as much as .17A. The present paper presents an attempt to eliminate this source of error by bringing high orders of strong lines in the extreme ultra-violet into direct comparison with first order iron lines. This standardization has also been carried to carbon and aluminum as well as to the nitrogen and oxygen reported in the earlier article, thus providing a set of standards completely covering the range from 600A to 2000A.

For this purpose the spectrum of a vacuum spark between one aluminum and one iron electrode was photographed in various regions between 3000A and 6000A. As has been noted previously such a spark brings out the carbon and oxygen lines strongly in addition to those of aluminum and iron.

In the determination of wave-lengths the first step was the calculation of approximate values on the assumption of a linear relationship between the position on the plate and the wave-length. Using these approximate values all iron lines appearing on the plate were identified and the difference between their true and approximate wave-lengths determined. Plotting these deviations against the wave-length gave a curve which could be used in correcting the approximate wave-lengths of all other lines on the plate. In general this correction did not exceed one angstrom.

The various values of the wave-lengths of the oxygen, carbon, and aluminum lines were weighted as to order, sharpness of the line, and nearness to iron standards, and then averaged. As a further check on their mutual consistency and on the doublet separations the values thus determined were compared with the data obtained from a number of high order plates that had been taken for other purposes. Some slight adjustments were made to correct a few discrepancies brought to light by this comparison, but in no case was this adjustment greater than the indicated possible error in the wave-length (see below).

The best of the plates compared was that of a spectrum of a vacuum spark between aluminum electrodes containing sodium nitrate. The wave-lengths of the lines on this plate had previously been determined by means of a large number of first order oxygen lines occurring on it. The comparison with our carbon, oxygen, and aluminum standards indicated a systematic error of about .04A in this previous determination. After correcting for this small error the data from this plate were used for the determination of the nitrogen standards.

A test of accuracy of the fine structure separations can be obtained by comparison of related series lines and pp' groups. Thus, an error of about .01A in any one of the four lines involved would account for the difference between the doublet separations of 1854A and 1379A, and errors of from .006A to .009A would account for all discrepancies in the pp' groups at 685A, 922A and 1175A. It is also possible to check the absolute values of certain lines. Thus, the frequency of the 1935A line and the difference in the frequencies of the lines at 1605A and 1379A can be calculated from series relationships. In both of these cases the error does not exceed .003A.

The intensities and final wave-lengths are given in the first two columns of table I. A letter A in the fourth column indicates that the line can probably be depended upon to .01A, B indicates .02A, and C .03A or C4A.

2. The pp' Groups in Carbon C_{III} and Nitrogen N_{IV}.

Among the lines studied in the above work were the pp' groups of carbon C_{III} and Nitrogen N_{IV} which were here for the first time completely resolved into their six components as shown in table II. This enables us to determine the ratios of the separations of P_1P_2 and P_2P_3 which are given in table III together with all previous determinations in related elements. It is at once seen that in going to elements of higher atomic number this ratio approaches the value 2 called for by Landé's interval rule.

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1. Bowen and Millikan, Phil.Mag. 48, p.259 (1924)

TABLE I

Int.	λ I. A. Vac.	ν	Accuracy	Int.	λ I. A. Vac.	ν	Accuracy
Carbon							
5	977.031	102350.9	B	2	1247.391	80167.3	C
1	1009.863	99023.3	B	5	1334.541	74932.1	B
1	1010.095	99000.6	B	5	1335.703	74866.9	B
1	1010.383	98972.4	B				
				5	1548.189	64591.6	A
2	1036.339	96493.5	A	4	1550.774	64483.9	A
2	1037.018	96430.3	A				
				2	1560.257	64092.0	B
3	1174.922	85112.0	A	3	1560.660	64075.5	B
3	1175.261	85087.5	A	3	1561.378	64046.0	B
2	1175.577	85064.6	A				
4	1175.711	85054.9	A	4	1931.027	51785.9	B
3	1175.988	85034.9	B				
3	1176.359	85008.1	A				
Nitrogen							
3	685.000	145985.4	A	4	989.802	101030.3	B
3	685.517	145875.3	A	4	991.570	100850.2	B
4	685.822	145810.4	A				
3	686.346	145699.1	A	5	1083.956	92254.7	B
				5	1084.529	92205.9	B
3	763.348	131001.8	C	3	1085.497	92123.7	C
3	764.358	130828.7	C	6	1085.688	92107.5	C
3	765.158	130692.0	C				
				2	1134.180	88169.4	B
1	771.542	129610.6	B	3	1134.420	88150.8	B
2	771.914	129548.1	B	3	1134.987	88106.7	B
2	772.398	129466.9	C				
1	772.938	129376.5	C	3	1199.533	83365.8	B
				2	1200.200	83319.4	B
3	915.595	109218.6	B	1	1200.681	83286.1	C
4	915.986	109172.0	B				
4	916.690	109088.1	B	0	1740.315	57460.9	C
				3	1742.740	57380.9	B
2	921.978	108462.5	B	3	1745.260	57298.1	B
2	922.512	108399.7	B	2	1747.855	57213.0	B
1	923.037	108338.0	B				
3	923.211	108317.6	B				
2	923.658	108265.2	B				
2	924.264	108194.2	B				
Oxygen							
2	599.600	166777.9	B	2	796.665	125523.3	B
2	702.329	142383.4	A	4	832.754	120083.5	A
2	702.813	142285.4	A	3	832.924	120059.0	A
2	702.905	142266.7	A	4	833.327	120000.9	A
3	703.850	142075.7	A	4	833.739	119941.6	A
				5	834.459	119838.1	A
3	718.522	139174.6	B	3	835.099	119746.3	A
				5	835.288	119719.2	A
1	779.824	128234.1	B				
2	787.716	126949.3	B				
2	790.205	126549.4	B				
Aluminum							
2	1352.857	73917.6	A	4	1760.101	56814.9	A
				4	1761.973	56754.6	A
4	1379.675	72480.8	B	5	1763.939	56691.3	A
4	1384.140	72247.0	B	4	1765.814	56631.1	A
				4	1767.730	56569.7	A
7	1605.764	62275.7	B				
7	1611.858	62040.2	B	10	1854.715	53916.6	B
				10	1862.775	53683.4	B
6	1670.802	59851.5	C				
				6	1935.881	51656.1	B
4	1719.455	58158.0	A				
5	1721.273	58096.5	A	4	1990.534	50237.8	B
5	1724.982	57971.6	A				

Table II

pp′ Groups in two-valence-electron atoms

Carbon C_{III}

		p_1		p_2		p_3	
Int.	:			(3)			
λ	:			1175.988			
ν	:			85034.9			p_3'
Δ ν	:			29.7			
Int.	:	(3)		(2)		(3)	
λ	:	1176.359		1175.577		1175.261	
ν	:	85008.1	56.5	85064.6	22.9	85087.5	p_2'
Δ ν	:	46.8		47.4			
Int.	:	(4)		(3)			
λ	:	1175.711		1174.922			
ν	:	85054.9	57.1	85112.0			p_1'

Nitrogen N_{IV}

		p_1		p_2		p_3	
Int.	:			(2)			
λ	:			923.658			
ν	:			108265.2			p_3'
Δ ν	:			72.8			
Int.	:	(2)		(1)		(2)	
λ	:	924.264		923.037		922.512	
ν	:	108194.2	143.8	108338.0	61.7	108399.7	p_2'
Δ ν	:	123.4		124.5			
Int.	:	(3)		(2)			
λ	:	923.211		921.978			
ν	:	108317.6	144.9	108462.5			p_1'

Table III

Ratio of the triplet separations p_1p_2/p_2p_3

	$2p$	$3p$
Be_I	3.57	
B_{II}		
C_{III}	2.47	2.33
N_{IV}	2.33	
O_V	2.27	

THE SPECTRUM OF SULPHER, SII.

By S. B. Ingram.

Abstract.

One hundred and eighty-three lines are classified in the spectrum of SII. Thirty-three terms of the quartet system and thirty-six of the doublet system are determined and correlated with the electron configurationsby means of the Hund theory. The ionization potential of the SII ion is fixed at 23.3±.1 volts.

Experimental Work.

The sulphur spectrum was obtained by passing a condensed discharge through H_2S gas. At higher pressures the Balmer series predominated but as the pressure was reduced towards the limiting value at which a discharge could sustain itself the hydrogen linesbecame relatively weak and the sulphur spectrum came out with great intensity. When the self induction of the discharge circuit was reduced to a minimum the lines of SII, III, IV and V appeared strongly on the plates. Insertion of sufficient self induction into the circuit to reduce the frequency of oscillation, and hence the instantaneous value of the current, to about one-tenth its former value completely suppressed all of these except the SII lines. The visible and ordinary ultra-violet regions were photographed by means of a 7 meter concave grating in a Rowland mounting. In the ultra-violet these observations were supplemented by a plate taken on a Hilger quartz spectrograph E2. In the extreme ultra-violet a vacuum spectograph with a grating of 1 meter radius was used. The exactness with which the data fit the series relationships gives a check on the accuracy of the measurements. The probable errors, estimated in this way are: for the measurements on the large grating about .02A, on the quartz spectrograph about .3A, and on the vacuum spectrograph about .03A. Some of the weaker lines have been taken from old data appearing in Kayser's Handbuch der Spectroscopie. The probable error in these measurements appears to be about .2A.

Predicted Terms.

The spectrum of sulphur II should be similar to that of oxygen II containing a doublet and quartet system. Table I gives a summary of the predictions of the Hund theory. The notation used is standard excepting for the introduction of primes on the letter referring to the orbit of the excited electron. Unprimed terms are based on the ^3P state of the SIII ion, singly primed terms on the ^1D state and doubly primed terms on the ^1S state. Those terms which have been observed are italicized in the table.

Term Values.

Two members of both of the series of terms ms^4P and ms^2P, m = 4, 5, have been detected, thus making possible the determination of the term values and of the ionisation potential. In fixing the terms $4s^4P$, and $4s^2P$, an increase of effective quantum number of 1.02 between the terms 4P and 5P has been assumed. This assumption is arbitrary except insofar as it is justified by analogy with the terms of OII and of other light elements. The term values calculated on this assumption are about 700 cm^{-1} less than those determined by an ordinary Rydberg formula. The combination of the $4s^4P$ term with the low ^4S term in the extreme ultra-violet fixes the ground term of the SII ion at 188824.5 cm^{-1} giving an ionization potential of 23.3 ± .1 volts. The complete list of term values is given in Table II. Since no intercombinations between the doublet and quartet systems have been detected the term values given in the two systems bear no absolute relationship to each other.

Description of Table III.

Table III gives a complete list of all the lines which have been classified in SII. In the first column is given the intensity of each line on a scale running from 0 to 10. Since the photographs were taken on different spectrographs the intensities are not in all cases comparable. The intensities of lines measured on the large grating spectrograph are prefixed by the letter R, the intensities of those taken from Kayser's tables are prefixed by K, and of those measured on the quartz spectrograph by Q. In general lines marked K are weaker than 0 lines on the R scale and those marked Q are weaker than either the K or R lines. Lines below 2000A are measured on the vacuum spectrograph. The second column of the table gives the wavelengths, the third the wave numbers, and the fourth and fifth the series designation in the quartet and doublet systems respectively.

No intercombinations between the doublet and quartet systems have been identified. The reason is doubtless that the data available in the present work did not include accurate measurements on the weaker lines among which such intercombinations are to be expected. Table IV gives a list of the only unclassified lines which can be definitely ascribed to SII. The group of lines in the region of 4200A probably involves the high $^2(S\ P\ D\ F\ G)$ terms of the $s^2p^2.4d$ configuration but it has not been possible to resolve them into multiplets. One line requires special mention, 4162.64, one of the strongest lines in the spectrum. It is without question the leading line of the multiplet $4p\,^4D-4d\,^4F$ and probably masks the line $4p'\,^2F_4-4d'\,^2G_5$ which should also be a strong line very close to this position. This line has been used to fix both the $4d\,^4F_5$ and $4d'\,^2G_5$ levels. The assumption of this value of the $^2G_5$ level gives an inverted G term of separation 1.90 cm^{-1}, a very reasonable value since in OII this term is inverted and has a separation of 1.2 cm^{-1}.

No terms from the configuration $s^2p^2.4f$ have been detected. Both the quartet and doublet terms based on the ^3P state of SIII should be hydrogen-like and hence have term values in the neighborhood of 27000. The doublet terms based on the ^1D term of SIII should lie at about 15000. The combination of these terms with the terms of the $s^2p^2.4d$ configuration will give faint lines in the red or infra-red whereas the combinations with the observed terms of the $s^2p^2.3d$ configuration will give faint lines in the ultraviolet near 2000A where they might easily be missed.

Strong doublet lines in the extreme ultra-violet should arise from combinations between the low ^2D and ^2P terms and the doublet terms of the $s^2p^2.4s$ and $s^2p^2.3d$ configurations. These lines have been identified. The low terms should also combine strongly with the ^2P, ^2D and ^2S terms of the sp^4 configuration. An inverted ^2P term of separation 445 cm^{-1} at 82000 cm^{-1} which combines with the $s^2p^2.4p$ doublet terms is doubtless the ^2P term of this group. Another ^2P term near 48000 and an unclassified term, x, at 55147.9 give strong lines in the extreme ultra-violet in combination with the low doublet terms.

One component P_2, of the $s^2p^2.3d\ ^2P$ term could be definitely fixed by combinations with the $s^2p^2.4p$ terms and with a^2P_2. The lines given by the P_1 member are doubtless too weak to be detected.

I am indebted to Dr. I. S. Bowen for the identification of two important multiplets in the extreme ultra-violet, $a^4S_2-b^4P_{321}$ and $a^4S_2-b^4P_{321}$ which were taken from unpublished data of his.

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TABLE I.

Predicted terms of SII.

Electron configuration	Prefix	Terms	Prefix	Terms	Prefix	Terms
s^2p^3	a	$^4\underline{S}$				
	a	$^2\underline{D}$ $^2\underline{P}$				
sp^4	b	$^4\underline{P}$				
	b	$^2\underline{P}$ ^2D ^2S				
SIII ion s^2p^2		^3P		^1D		^1S
SII $s^2p^2.ms$	ms	$^4\underline{P}$				
	ms	$^2\underline{P}$	ms'	$^2\underline{D}$	ms"	^2S
$s^2p^2.mp$	mp	$^4\underline{S}$ $^4\underline{P}$ $^4\underline{D}$				
	mp	^2S $^2\underline{P}$ $^2\underline{D}$	mp'	$^2\underline{P}$ $^2\underline{D}$ $^2\underline{F}$	mp"	^2P
$s^2p^2.md$	md	$^4\underline{P}$ $^4\underline{D}$ $^4\underline{F}$				
	md	$^2\underline{P}$ $^2\underline{D}$ $^2\underline{F}$	md'	^2S ^2P ^2D ^2F $^2\underline{G}$	md"	^2D
$s^2p^2.mf$	mf	^4D ^4F ^4G				
	mf	^2D ^2F ^2G	mf'	^2P ^2D ^2F ^2G ^2H	mf"	^2F

TABLE II.

Term values

		s^2p^3			
a^4S_2	188824.5	a^2P_2	163934.5	a^2D_3	173623.9
		a^2P1	163983.1	a^2D2	173655.4
		sp^4			
b^4P_3	109429.7	b^2P_2	82908.36		
b^4P_2	109066.6	b^2P_1	82463.28		
b^4P_1	108856.5				
Terms based on SIII ^3P				Terms based on SIII ^1D	
		$s^2p^2.4s$			
$4s^4P_3$	78556.17	$4s^2P_2$	75045.88	$4s'^2D_3$	66977.31
$4s^4P_2$	78993.17	$4s^2P_1$	75570.00	$4s'^2D_2$	66978.87
$4s^4P_1$	79264.00				
		$s^2p^2.5s$			
$5s^4P_3$	37828.16	$5s^2P_2$	36596.42		
$5s^4P_2$	38293.29	$5s^2P_1$	37123.21		
$5s^4P_1$	38566.02				
		$s^2p^2.4p$			
$4p^4S_2$	57795.79			$4p'^2P_2$	44883.79
				$4p'^2P_1$	45018.43
$4p^4P_3$	58690.48	$4p^2P_2$	55107.43		
$4p^4P_2$	58966.43	$4p^2P_1$	55238.70	$4p'^2D_3$	47798.45
$4p^4P_1$	59036.81			$4p'^2D_2$	47757.24
$4p^4D_4$	60225.45	$4p^2D_3$	57320.17	$4p'^2F_4$	48188.00
$4p^4D_3$	60591.48	$4p^2D_2$	57866.26	$4p'^2F_3$	48277.33
$4p^4D_2$	60848.28				
$4p^4D_1$	60999.51				

$s^2p^2.3d$

$3d\,^4F_5$	78058.19	$3d\,^2P_2$	78360.37		
$3d\,^4F_4$	78316.02				
$3d\,^4F_3$	78511.37	$3d\,^2D_3$	69212.27		
$3d\,^4F_2$	78647.67	$3d\,^2D_2$	69265.17		
		$3d\,^2F_4$	73221.76		
		$3d\,^2F_3$	73703.11		

$s^2p^2.4d$

$4d\,^4P_3$	33005.80			$4d'\,^2G_5$	24171.53
$4d\,^4P_2$	32795.14			$4d'\,^2G_4$	24169.63
$4d\,^4P_1$	32676.09				
$4d\,^4D_4$	35410.80	$4d\,^2D_3$	29679.53		
$4d\,^4D_3$	35541.51	$4d\,^2D_2$	29841.18		
$4d\,^4D_2$	35622.66				
$4d\,^4D_1$	35670.67				
$4d\,^4F_5$	36208.98	$4d\,^2F_4$	31903.37		
$4d\,^4F_4$	36519.60	$4d\,^2F_3$	32385.52		
$4d\,^4F_3$	36729.90				
$4d\,^4F_2$	36864.80				

Terms combining with $a\,^2D$, $a\,^2P$, of s^2p^3 configuration.

$^2P_2$	48491.6
$^2P_1$	48661.7
^2x	55147.9

TABLE III.

Classified lines of SII.

Int.	I.A.Air		Quartets	Doublets.
R 1	5819.22	17179.68		$4sP_2 - 4pD_2$
R 3	5664.73	17648.21	$3dF_2 - 4pD_1$	
R 4	5659.95	17663.11	$3dF_3 - 4pD_2$	
R 6	5646.98	17703.68		$4sP_1 - 4pD_2$
K 2	5645.70	17707.68	$4sP_3 - 4pD_2$	
R 5	5640.32	17724.58	$3dF_4 - 4pD_3$	
R 8	5639.96	17725.71		$4sP_2 - 4pD_3$
R 1	5616.63	17799.34	$3dF_2 - 4pD_2$	
R 6	5606.11	17832.74	$3dF_5 - 4pD_4$	
R 1	5578.85	17919.88	$3dF_3 - 4pD_3$	
R 4	5564.94	17964.67	$4sP_3 - 4pD_3$	
K 1	5558.91	17984.14		$4pP_2 - 5sP_1$
R 1	5556.01	17993.54	$4sP_2 - 4pD_1$	
K 3	5536.76	18056.12	$3dF_2 - 4pD_3$	
R 1	5526.22	18090.54	$3dF_4 - 4pD_4$	
K 3	5518.76	18115.00		$4pP_1 - 5sP_1$
R 5	5509.67	18144.88	$4sP_2 - 4pD_2$	
R 5	5473.59	18264.49	$4sP_1 - 4pD_1$	
R10	5453.81	18330.72	$4sP_3 - 4pD_4$	
R 9	5432.77	18401.71	$4sP_2 - 4pD_3$	
R 5	5428.64	18415.72	$4sP_1 - 4pD_2$	
K 3	5400.83	18510.54		$4pP_2 - 5sP_2$
R 5	5345.67	18701.54		$4s\,{}'D_2 - 4p\,{}'F_3$
R 7	5320.70	18789.31		$4s\,{}'D_3 - 4p\,{}'F_4$
R 4	5212.61	19178.92		$4s\,{}'D_3 - 4p\,{}'D_3$
K 2	5201.35	19220.45		$4s\,{}'D_3 - 4p\,{}'D_2$

Int.	I.A.Air		Quartets		Doublets
R 2	5201.00	19221.73			$4s'D_2-4p'D_2$
K 1	5125.78	19503.82	$4pS_2-5sP_2$?		
R 2	5103.30	19589.72	$4sP_3-4pP_2$		
R 0	5047.28	19807.14			$4sP_2-4pP_1$
R 5	5032.41	19865.67	$4sP_3-4pP_3$		
R 3	5014.03	19938.49			$4sP_2-4pP_2$
R 4	5009.54	19956.36	$4sP_2-4pP_1$		
R 1	5006.71	19967.64	$4pS_2-5sP_3$		
R 3	4991.94	20026.72	$4sP_2-4pP_2$		
R 0	4942.47	20227.17	$4sP_1-4pP_1$		
R 5	4925.32	20297.60	$4sP_1-4pP_2$		
R 4	4924.08	20302.71	$4sP_2-4pP_3$		
R 2	4917.15	20331.33			$4sP_1-4pP_1$
R 0	4901.30	20397.07	$4pP_3-5sP_2$		
R 0	4900.47	20400.53	$4pP_2-5sP_1$		
R 1	4885.62	20462.53			$4sP_1-4pP_2$
R 0	4835.81	20673.30	$4pP_2-5sP_2$		
R 3	4824.03	20723.79			$4pD_3-5sP_2$
R 2	4819.55	20743.05	$4pP_1-5sP_2$	(Blend)	$4pD_2-5sP_1$
R 9	4815.52	20760.41	$4sP_3-4pS_2$		
R 3	4791.97	20862.43	$4pP_3-5sP_3$		
R 2	4763.34	20987.82			$3dD_2-4p'F_3$
R 3	4755.07	21024.32			$3dD_3-4p'F_4$
R 0	4729.45	21138.21	$4pP_2-5sP_3$		
R 7	4716.25	21197.37	$4sP_2-4pS_2$		
R 0	4700.19	21269.80			$4pD_2-5sP_2$
R 4	4668.59	21413.77			$3dD_3-4p'D_3$
R 5	4656.75	21468.21	$4sP_1-4pS_2$		
R 3	4648.14	21507.98			$3dD_2-4p'D_2$

Int.	I.A. Air		Quartets	Doublets
R 5	4552.37	21960.44		$4s'D_2-4p'P_1$
R 6	4524.96	22093.46		$4s'D_3-4p'P_2$
R 2	4524.65	22094.98		$4d'D_2-4p'P_2$
K 1	4508.93	22172.03	$4pP_1-4dF_2$?	
K 1	4492.32	22254.01	$4pS_2-4dD_3$	
R 3	4486.63	22282.21	$4pD_2-5sP_1$	
R 6	4483.42	22298.16	$4pD_3-5sP_2$	
R 7	4463.58	22397.28	$4pD_4-5sP_3$	
R 4	4456.39	22433.41	$4pD_1-5sP_1$	
R 3	4432.37	22554.98	$4pD_2-5sP_2$	
R 2	4431.00	22561.95		$3dP_2-4p'D_3$
K 2	4402.64	22707.28	$4pD_1-5sP_2$	
R 3	4391.81	22763.28	$4pD_3-5sP_3$	
R 1	4333.84	23067.76	$4pP_3-4dD_2$	
R 4	4318.64	23148.95	$4pP_3-4dD_3$	
R 6	4294.39	23279.67	$4pP_3-4dD_4$	
R 1	4291.43	23295.72	$4pP_2-4dD_1$	
R 4	4282.60	23343.75	$4pP_2-4dD_2$	
R 4	4278.51	23366.07	$4pP_1-4dD_1$	
R 5	4269.72	23414.17	$4pP_1-4dD_2$	
R 6	4267.76	23424.93	$4pP_2-4dD_3$	
R 4	4230.94	23628.78		$4p'D_3-4d'G_4$
R 4	4217.19	23705.82	$4pD_4-4dF_4$	
R 4	4189.68	23861.59	$4pD_3-4dF_3$	
R 5	4168.37	23983.46	$4pD_2-4dF_2$	
R 10	4162.64	24016.47	$4pD_4-4dF_5$ (Blend)	$4p'F_4-4d'G_5$
R 2	4162.29	24018.49		$4p'F_4-4d'G_4$
R 10	4153.05	24071.92	$4pD_3-4dF_4$	
R 5	4146.90	24107.62		$4p'F_3-4d'G_4$

Int.	I.A.Air		Quartets	Doublets
R 8	4145.05	24118.38	$4pD_2-4dF_3$	
R 8	4142.24	24134.74	$4pD_1-4dF_2$	
R 2	4050.08	24683.92	$4pD_4-4dD_3$	
R 6	4032.77	24789.87	$4pS_2-4dP_3$	
R 7	4028.74	24814.67	$4pD_4-4dD_4$	
R 1	4009.35	24934.67		$4pD_3-4dF_3$
R 1	4007.77	24944.50		$3dF_4-4p'F_3$
R 2	4003.87	24968.80	$4pD_3-4dD_2$	
R 5	3998.74	25000.84	$4pS_2-4dP_2$	
R 6	3993.49	25033.70		$3dF_4-4p'F_4$
R 5	3990.90	25049.96	$4pD_3-4dD_3$	
R 4	3979.81	25119.75	$4pS_2-4dP_1$	
K 3	3970.67	25177.58	$4pD_2-4dD_1$	
K 2	3963.09	25225.72	$4pD_2-4dD_2$	
R 0	3950.39	25306.82	$4pD_2-4dD_3$	
R 2	3946.94	25328.94	$4pD_1-4dD_1$	
K 1	3944.91	25342.00		$3dP_2-4p'P_1$
K 1	3939.75	25375.20	$4pD_1-4dD_2$	
R 7	3933.25	25416.80		$4pD_3-4dF_4$
R 3	3932.29	25423.30		$3dF_4-4p'D_3$
R 5	3931.90	25425.82		$3dF_3-4p'F_3$
R 1	3931.50	25428.41		$4pP_2-4dD_3$
R 0	3924.07	25476.56		$3dP_2-4p'P_2$
R 6	3923.43	25480.71		$4pD_2-4dF_3$
K 1	3918.16	25514.99		$3dF_3-4p'F_4$
R 1	3906.95	25588.19		bP_2-4pD_3
R 5	3892.28	25684.63	$4pP_3-4dP_3$	
R 4	3860.64	25895.13	$4pP_3-4dP_2$	

Int.	I.A.Air		Quartets	Doublets
R 0	3859.21	25904.72		$3dF_3-4p'D_3$
R 2	3853.08	25945.93		$3dF_3-4p'D_2$
R 3	3850.91	25960.55	$4pP_2-4dP_3$	
R 1	3809.65	26241.70	$4pP_1-4dP_2$	
R 1	3802.61	26290.29	$4pP_2-4dP_1$	
Q 1	3734.8	26767.9		$4sP_2-4p'F_3$
R 1	3672.11	27224.58		bP_1-4pP_1
R 4	3669.03	27247.43		$4sP_2-4p'D_3$
K 1	3663.36	27289.58		$4sP_2-4p'D_2$
K 1	3654.52	27355.63		bP_1-4pP_2
R 1	3638.17	27478.54		$4pD_3-4dD_2$
R 4	3616.90	27640.13		$4pD_3-4dD_3$
Q 5	3613.1	27669.4		bP_2-4pP_1
R 3	3595.98	27800.93		bP_2-4pP_2
R 3	3594.45	27812.76		$4sP_1-4p'D_2$
R 3	3567.16	28025.53		$4pD_2-4dD_2$
Q 3	3329.3	30027.6		$4sP_2-4p'P_1$
R 1	3314.47	30162.09		$4sP_2-4p'P_2$
Q 4	3272.3	30550.8		$4sP_1-4p'P_1$
Q 3	3257.9	30685.5		$4sP_1-4p'P_2$
Q 2	3015.7	33150.3		$4pD_3-4d'G_4$
Q 1	2886.9	34628.9		$bP_2-4p'F_3$
Q 3	2670.0	37442.4		$bP_1-4p'P_1$
Q 1	2660.3	37578.8		$bP_1-4p'P_2$
Q 1	2638.1	37894.6		$bP_2-4p'P_1$
Q 2	2629.1	38024.7		$bP_2-4p'P_2$

Int.	I.A.Vac		Quartets	Doublets
5	1259.53	79394.8	aS_2-bP_3	
5	1253.79	79757.9	aS_2-bP_2	
3	1250.50	79968.0	aS_2-bP_1	
3	1234.14	81028.0		aP_2-bP_2
0	1233.36	81079.3		aP_1-bP_2
4	1227.45	81469.9		aP_2-bP_1
1	1226.70	81519.5		aP_1-bP_1
2	1131.65	88366.5		aP_2-4sP_1
2	1131.05	88413.1		aP_1-4sP_1
1	1125.00	88888.6		aP_2-4sP_2
1	1124.39	88937.3		aP_1-4sP_2
3	1102.32	90717.7		aD_3-bP_2
2	1096.57	91193.2		aD_2-bP_1
4	1031.34	96961.3		$aP_2-4s'D_{3,2}$
1	1030.87	97004.9		$aP_1-4s'D_2$
2	1019.53	98084.7		aD_2-4sP_1
2	1014.42	98578.0		aD_3-4sP_2
0	1014.09	98610.2		aD_2-4sP_2
2	1000.48	99952.3		aD_2-3dF_3
2	996.00	100401.9		aD_3-3dF_4
0	968.37	103265.9		aD_3-3dP_2
1	957.88	104397.5		(aD_3-3dD_3 (aD_2-3dD_2
3	937.69	106644.8		$aD_3-4s'D_{3,2}$
3	937.41	106676.6		$aD_2-4s'D_{3,2}$
1	919.24	108785.8		aP_2-x
3	918.82	108835.0		aP_1-x
3	912.74	109560.7	aS_2-4sP_1	
3	910.49	109830.3	aS_2-4sP_2	

Int.	I.A.Vac.		Quartets	Doublets
3	906.87	110269.0	aS_2-$4sP_3$	
1	867.50	115273.7		aP_2-P_1
1	867.15	115320.5		aP_1-P_1
1	866.23	115443.3		aP_2-P_2
0	865.87	115491.1		aP_1-P_2
2	843.82	118508.5		aD_2-x
0	800.04	124993.9		aD_2-P_1
0	799.14	125134.6		aD_3-P_2
0	798.92	125168.8		aD_2-P_2
0	707.86	141271.0		aD_2-$4dF_3$
0	705.62	141720.1		aD_3-$4dF_4$
0	694.71	143944.9		aD_3-$4dD_3$
1	641.81	155810.0	aS_2-$4dP_3$	
0	640.93	156023.7	aS_2-$4dP_2$	
0	640.41	156149.9	aS_2-$4dP_1$	

TABLE IV.

Unclassified lines of SII.

Int.	I.A.Air	
1	5142.33	19441.04
2	5027.19	19886.30
0	5011.61	19948.12
2	4779.09	20918.65
3	4561.87	21914.71
4	4549.56	21974.01
6	4464.44	22392.96
2	4431.00	22561.96
5	4340.29	23033.48
2	4259.15	23472.28
3	4257.39	23481.98
1	4193.50	23839.73
2	4185.90	23883.02
6	4174.25	23949.67
4	4173.97	23951.28
2	3860.11	25898.68
4	3831.37	26092.95
3	3783.13	26425.66
1	3678.11	27180.17
2	3385.79	29526.76
1	3371.87	29648.65
1	3368.07	29682.10
0	3356.40	29785.30