WAVE-LENGTH STANDARDS IN THE EXTREME ULTRA-VIOLET SPECTRA 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_{III} 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 preceding article[1] by Dr. Millikan and one of the authors 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

[1] Bowen and Millikan, Phil. Mag. **48**, 259 (1924).

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 the 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

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				

TABLE I (Continued)

Int.	λ I. A. Vac.	ν	Accuracy	Int.	λ I. A. Vac.	ν	Accuracy.
			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				

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 .04A.

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

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'
$\Delta\nu$			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'
$\Delta\nu$	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'
$\Delta\nu$			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'
$\Delta\nu$	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	

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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