RESULTS FROM AURORAL SPECTROGRAMS OBTAINED AT TROMSØ DURING THE WINTER 1950/51

BY

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1. Introductory Remarks.

In some papers recently published (1, 2, 3, 4) results were given of an auroral spectrogram obtained with a new spectrograph, which was particularly designed for the spectral analysis of the auroral luminescence, and which combined the great light-power $F:1{,}2$ of the camera lens with a considerable dispersion as indicated in table I.

Table I.

Wavelength in Å	Scale value A/mm
4000	41,1
4500	66,4
5000	99,3
5500	138,4
6000	186,3
6500	240,0

The collimator and the camera lens had a diameter of 178 mm, and the two prims had corresponding dimensions.

The spectrogram referred to was taken at Oslo during the night Feb. 23—24, 1950, on a Kodak 103a T plate, for which the sensitivity towards long waves stops at about 6300 Å.

Through this single spectrogram the number of observed auroral lines and bands in the wavelength interval (6300—3880) was increased from about 112 to 370. A complete table giving the observed lines and bands as well as their interpretation is given in paper (4).

In the summer 1950 the new spectrograph was taken to the Auroral Observatory at Tromsø. It was mounted inside a well insulated wooden box, which could be turned round a vertical axis. In front of the slit a plane mirror was put forming an angle 45° with the collimator axis. This mirror was placed in a tube which could be turned round a horizontal axis. By means of a condensor lens with its focus on the slit, light from any part of the sky could be sent through the slit.

The box was provided with proper devices for a very accurate automatic regulation of the temperature of the spectrograph.

2. Plan of the Work and Spectrograms Obtained.

The plan adopted for our work during the winter 1950/51 was mainly the following:

1. To investigate the auroral luminescence in the red part, by using properly selected pancromatic plates.
2. To obtain spectrograms in the infra-red region.
3. To obtain strongly exposed spectrograms from which a great number of the weak lines could be accurately measured so as to check the wavelength values previously obtained from the Oslo spectrogram taken Feb. 23—24, 1950.
4. To continue the study of the appearance of the Hydrogen lines (5, 6) and their doppler displacement which was discovered in 1941 (cfr. papers 3, 7, 8, 9, 10, 11).
5. To measure the ionospheric temperature from the intensity distribution of the R-branches of the negative nitrogen bands.

6. In order to measure the relative intensity of the auroral lines, intensity scales consisting of spectrograms from a light source of known spectral intensity distributions should be taken preferably on the same plate as the auroral spectrogram.

For the study of the more or less rapid variations of the spectral intensity distribution another spectrograph was last summer, 1951, installed at the Tromsø Observatory. It was made at the same firm by dr. J. Cojan and had the much higher light power $F:0{,}65$ of the camera lens, but only about half the dispersion. Details will be found in a paper by Cojan (12).

During the winter season 1950/51 we obtained with the first new spectrograph five sucsessful spectrograms. The following three spectrograms were taken on "pancromatic plates" (Kodak 103 a—E), and they are reproduced on Pl, I No. 1a, 2 and 3. For the sake of comparison a reproduction of the Oslo spectrogram, taken Feb. 23 on Kodak 103 a—T is also given on the Plate I (No. 4).

Two spectrograms were taken on infra-red sensitive Kodak I N plates (sensitized with NH_3). Reproductions of these spectrograms together with corresponding photometer curves are given on plate II.

The comparison spectrum was taken from an Argon lamp containing some hydrogen. More details regarding the exposure of each of these spectrograms are given in the "explanation of the plates" at the end of this paper.

In order to illustrate the band systems, which appear in the region of long waves, we have on plate III given greatly enlarged reproductions on which the classification of auroral bands and lines appearing in red and infra-red has been indicated. On plate III spectrograms No. 1 and 2 are the red parts of the spectrograms 1a and 2 of Pl. I, and spectrogram 3 is the infra red part of spectrogram 2a on plate II.

The magnification of the spectrograms on the three plates is indicated by a line corresponding to a given length on the negative.

3. Wavelength Measurements and Identifications.

The wavelength values of bands and lines in the infra red were determined from the two spectrograms 1a and 2a on plate II, and most bands in the red and yellow part were determined from spectrograms 1a and 2 on plate I. The red part of spectrogram (3) on plate I was too heavily exposed for accurate measurements. A reproduction of the red part copied with weak light and short exposure is shown on the upper half of the spectrogram No. 3. As will be seen, this heavily exposed spectrogram contains a great number of the weak lines very distinctly, including also the H_β-line with doppler displacement. The somewhat strong lines and bands are greatly over-exposed.

In order to detect and measure the very weakest lines or bands, we have adopted the procedure used in the case of the Oslo spectrogram and which is described in paper (4). In this case the wavelength values are found from a photometer curve of great magnification.

In this way the spectrogram pl. I No. 3 gives an important check of the appearance and the wavelengths of the weakest lines and bands we measured from the Oslo spectrogram from Feb. 23, 1950.

The results of our wavelength measurements are collected in table 2. In the last column giving the interpretation of the lines and bands the following abbreviations are used:

Atomic Lines

OI and NI: Lines from neutral O and N atoms.
OII and NII: Lines from atoms of O and N having lost 1 electron.
OIII and NIII: Lines from atoms of O and N having lost 2 electrons.
NaI D: Yellow sodium line.
H_α, H_β and H_γ: Lines from the Balmerseries of Hydrogen.

In order not to complicate the printing too much we have not given the term symbols for the atomic lines. For most of them, these symbols can be found in paper (4). On the other hand we have given the wavelength of the atomic line (or group of lines) with which an auroral line has been identified. The two first figures of the wavelength value are dropped.

Molecular Bands.

N_2 1.P : First positive group from neutral N_2
N_2 2.P : Second » » » » N_2
N_2V.K.: Vegard-Kaplan bands » » N_2
N_2G.K.: Goldstein-Kaplan » » » N_2
N_2^+ 1N : First negative group from ionized N_2 mol.
N_2^+ 2N : Second » » » » N_2 »
O_2 S.R.: Schuman-Runge bands from neutral O_2.
NO_β : β-bands from Nitrogen monoxyd (NO).

The vibrational quant numbers of the upper and lower electronic state are given in brackets after the band symbols.

Measured relative intensities (I) for some of the lines and bands are given in the first two columns of the table 2. The column (a) contains the intensities earlier measured, and may be said to correspond to the previously measured wavelength values given in the third column. In column (b) are put up relative intensities measured from the Tromsø spectrograms given on plates I and II.

In the wavelength interval 8850 to 6700 the intensity values derived from the spectrograms on. pl. II, are adjusted relative to the N_2^+ 1N-band 4709, the intensity of which is put equal to 7,8, which again is the mean intensity of this band earlier found, when the intensity of the green auroral line (5577) is put equal to 100.

In a similar way the intensities found from spectrogram 1a pl. I, in the interval 6688—3997, are adjusted relative to the N_2^+ 1N-band 4649, the intensity of which is put equal to 4.6.

On the spectrogram Pl. I No. 3 most lines were to heavily exposed for photometric intensity measurements.

Table 2.

Spectral Lines and Bands in the Auroral Luminescence.

I		Wavelength		Interpretation
a	b	Previously measured	From present Spectrograms	
	21		8850	$N_2$1P (1—0) (11—12)
			38	$N_2$1P (1—0) (11—12)
4		8774		$N_2$1P (2—1)
10		14	8711	$N_2$1P (2—1) NI (04, 11, 19)
32	48	8684		$N_2$1P (2—1) NI (81, 84, 86)
10		65	8672	$N_2$1P (2—1)
			56	$N_2$1P (2—1) NI(56), O_2^+(0—1)
10	32	23	27,5	$N_2$1P (2—1)O_2^+1N(4—3), NI(29)
			8552,1	O_2^+1N(4—3)
	10		39,5	$N_2$1P(3—2)
		8525		$N_2$1P(3—2)O_2^+1N(0—5)
3		8469		
17	23	47	8447,4	OI(46.8, 46.4)
3		36		NII(39)
(3)	12	8344	8352	N_2^+2N(3—2)
(2)	9.7	8291	8300	N_2^+2N(3—2)$N_2$1P(4—3)
4	7.8	16	8218,1	NI(16.5, 21.8), $N_2$1P(14—15) (5—4), OI(22)
4		8182	8187	NI(83.9)
			53,7	
4	22	8093	06,5	N_2^+2N(2—1)
4	29	64	8059	N_2^+2N(2—1), $N_2$1P(6—5)
4	11	7993	7995,5	OI(95,1),
8		14	13,8	
16	61	7879	7879,4	N_2^+2N(1—0), O_2^+1N(0—4)
11		54		$N_2$1P(7—6)
	41		33,0	N_2^+2N(1—0)
5		20		

I		Wavelength		Interpretation
a	b	Previously measured	From present Spectrograms	
30	32	7774	7774,0	OI(76, 74, 72)
		46	48,1	$N_2$1P(2—0) (8—7), N_2V.K(7—23)
15		30	35,3	$N_2$1P(2—0) (8—7), N_2^+2N(6—4)
15	44	17		$N_2$1P(2—0) (8—7)
15		7688	7697,8	N_2^+2N(6—4)
4	11	25	21,6	$N_2$1P(3—1)
12	30	7580	7582,5	NI(87)
			00,6	N_2^+2N(5—3), $N_2$1P(4—2)
4	22	7482	7486	OI(81), N_2IP(10—9) (4—2)
4		50	63,6	N_2^+2N(5—3), $N_2$1P(4—2)
			7399,0	$N_2$1P(5—3), NI(97,5)
	10	7385	82,5	$N_2$1P(5—3)
	10.5	68	70,5	$N_2$1P(5–3) NI(66)
			60,0	$N_2$1P(11—10) (19—20), NI(51, 4)
	10.3		45,6	$N_2$1P(11—10) (19—20), NI(47, 7), O_2^+1N(0—3)
		39	41,7	$N_2$1P(11—10) (19—20)
	8.5		7284,5	$N_2$1P(6—4) N_2^+2N(4—2)
			78,8	$N_2$1P(6—4) (16—16)
	9.5	7264	71,4	$N_2$1P(6—4) (16—16)
	9.2	48	46,9	N_2^+2N(4—2)
			32,4	$N_2$1P(12—11)
		7094	7098,8	$N_2$1P(12—11)
	13		84,1	N_2^+2N(3—1)
		68	77,2	$N_2$1P(8—6)
	13		48,6	N_2^+2N(3—1)
	10.3		6895,5	N_2^+2N(2—0) OII(95.3)
		60	63,5	$N_2$1P(10—8)
	14	6849	58,3	N_2^+2N)2—0), $_2$1P(3—0), O_2^+IN(0—2), NII(57.6)
			42,5	N_2V.K.(7—22), $N_2$1P(3—0)
			34,1	N_2V.K.(3—19) O_2^+IN(0—2)
3		6784	6787,4	$N_2$1P(4—1) (16—15)
	13		80,8	$N_2$1P(4—1) (16—15), O_2^+IN(0—2)
		54	48,5	$N_2$1P(4—1)
			42,9	$N_2$1P(4—1), NI(41, 3)
			04,7	$N_2$1P(5—2), NI(06.2)
5		6693	6693,5	$N_2$1P(5—2)
	12		87,2	$N_2$1P(5—2)
		79	74,5	$N_2$1P(12—10) (17—16), OII(78,2)
		69	65,9	OII(66,9), NI(66,8)
			55,2	NI(53.4, 56.6), OI(53.8), N_2^+2N(6—3)
			49,0	NI(46,5), $N_2$1P(6—2)
			30,0	NII(30,5)
3		22	21,7	$N_2$1P(6—3), NI(22,5), N_2^+2N(6—3)
	11		16,8	$N_2$1P(6—3)
		05	08.0	$N_2$1P(6—3), NII(10,6)
		6592	6592,6	N1$_2$P(6—3)
			83,3	NII(83,4), $2p^2$ ($^3P_2$—$^1D_2$)
		63	62,5	H_α (showing Doppler displacement
			58,5	
			54,5	NII(54,7) →
	5.5		51,7	NII$2p^2$($^3P_1$—$^1D_2$) $N_1$1P(7—4)
6,5	8.3	43	40,8	NI(44,2) →
		26	27,7	NI(28,4)
		12	12,2	NI(10,3) } $N_2$1P(7—4)
			05,5	NI(06), NII(04,9)

I		Wavelength		Interpretation
a	b	Previously measured	From present Spectrograms	
			6480,2	NII(82), N_2^+2N(5—2), $N_2$1P(8—5)
5.0	4.1	6467	66,5	$N_2$1P(8—5), O_2^+1N(0—1)
		54	53,9	N_2(8—5), OI(53.6, 54.5)
		41	37,9	NI(37,3), $N_2$1P(8—5), N_2^+2N(5—2)
			33,2	NI(28,0)
	1.2		17,0	NI(17,1), O_2^+1N(0—1), $N_2$1P(9—6)
	2.6	6398	6391,0	NI(93,6), O_2^+1N(0—1), $N_2$1P(9—6)
			79,8	NI(78,0), O_2^+1N(0—1), $N_2$1P(9—6)
1—200		6363	63,2	OI2p^4($^3P_1$—$^1D_2$), $N_2$1P(9—6)
			20,7	NI(21,7), $N_2$1P(10—7), O_2S.R(6—31)
			18	$N_2$1P(10—7)
3—600		6300,0	6300,3	OI2p^4($^3P_2$—$^1D_2$), N_2^+2N(4—1)
	1.2		6272,4	NI(72,8), N_2^+2N(4—1), O_2S.R(2—28)
		6267	64,0	OI(64.4, 66.9)
		52		$N_2$1P(11—8), N_2V.K.(4—19)
			43,8	NI(43,2)
		40	39,6	NI(37,5), $N_2$1P(11—8)
		22	23	NI(24), O_2S.R.(5—30)
	0.5	6185	6183,5	$N_2$1P(12—9) (4—0)
		76	6173	$N_2$1P(12—9), O_2S.R.(1—27), NII(73,4)
	1.5	55	55,6	$N_2$1P(4—0), OI(56.0, 56.8)
	1.6	39	37,5	N_2^+2N(3—0), NII(36,9)
		27	27,0	$N_2$1P(5—1), N_2VK(7—21), O_2SR(4—29)
		19		O_2S.R.(7—31)
4.0		09,5	08,7	$N_2$1P(5—1), N_2^+2N(3—0), OI(06,3)
		6093		$N_2$1P(5—1)
		78		N_2V.K.(3—18), O_2S.R.(0—26), NI(75,7)
		71		$N_2$1P(6—2)
	1.2		6067,3	$N_2$1P(6—2), NI(69,0)
		62	59,6	$N_1$1P(6—2), NI(61,9)
	1.7	46	44,3	OI(46.2, 46.5), NI(44,8)
		(34)		
		25	23,3	O_2^+1N(0—0), O_2S.R.(3—28)
10	2.8	11,08	11,2	$N_2$1P(7—3),NI(8.4, 12.0)
		00	02,0	O_2^+1N(0—0), NI(5999.6), N_2^+2N(7—3)
		5992	5989,0	$N_2$1P(7—3), O_2^+1N(0—0), NI(87,5)
		76	75,5	O_2^+1N(1—1) (0—0), NI(72,1), N_1^+2N(7—3)
		69		NI(72,66)
	2.0	58	58,0	NI(58,8), NII(60,9), $N_2$1P(8—4)
		50	51,0	NI(51,1), NII(52,4), $N_2$1P(8—4)
		40		NII(40.3, 41.7), NI(41,9)
	1.1	30	34	NII(31,8), NI(31,2)
		25	28,4	NII(27,8), NI(27,5), O_2^+1N(2—2)
	1.1	04	02,6	$N_2$1P(9—5), NI(05,07)
5	1.7	5892,3	5892,0	Na.D_1, D_2,$N_2$1P(9—5)
	1.1	78	77,7	$N_2$1P(9—5), O_2^+(3—3)
13		65,6		N_2^+1N(0—4), NI(63)
		52	53,0	$N_2$1P(10—6), NI(54)
	0.6	42		$N_2$1P(10—6), NI(41), O_2^+1N(4—4)
		30	31,8	$N_2$1P(10—6), NI(29.6, 34.8), N_2^+2N(6—2)
			09,0	$N_2$1P(11—7), NI(16), N_2^+2N(6—2)
		01		$N_2$1P(11—7), NI(03)
		5790		NI(90,4)
		86		$N_2$1P(11—7)
		80		NI(81,7), N_2V.K.(5—19)

I		Wavelength		Interpretation.
a	b	Previously measured	From present Spectrograms	
		71	5770,7	NI(68.6, 72.8)
		66		NI(64,5), NII(67,4), O_2S.R.(11—32)
		53,5	53,8	NI(52,7), $N_2$1P(12—8), N_2^+1N(1—5), NII2p^2($^1D_2$—$^1S_0$)
		45		NI(47,3), NII(47,3), $N_2$1P(12—8), O_2S.R.(0—25)
		32	30	NII(30,7), OI(31,1), $N_2$1P(12—8)
			25,6	NI(28,3), OI(20.6), $N_2$1P(12—8)
		10	10,5	NI(10,7), NII(10,8)
		5688	5684,5	NII(86,2), N_2^+2N(5—1)
5.5	1.1	79,5	79,4	NII(79,6) (76), O_2^+1N(1—13)
1.3		67	65,5	NII(66,6), N_2^+2N(5—1), N_2^+1N(3—7)
		58		$N_2$1P(14—10), N_2^+2N(2—6), O_2S.R.(8—30)
		30	30	O_2^+1N(1—0), $N_2$1P(5—0)
1.9		22,2	20,6	O_2^+1N(1—0), $N_2$1P(5—0), NI(23) (18), N_2V.K(4—18)
	1.2	16		O_2^+1N(1—0), $N_2$1P(15—11), NI(16,5) O_2S.R(5—28)
		12	13,5	O_2^+1N(1—0), $N_2$1P(5—0), NI(11,3)
		03	01	O_2^+1N(1—0), N_2V.K.(0—15)NI(04,4) (00,5)
		5595		O_2^+1N(2—1), $N_2$1P(6—1) (15—11)
100		5577,35	5577,35	OI($^1D_2$—$^1S_0$)
0.22			66,5	O_2^+1N(3—2), $N_2$1P(16—12), NII(65,3)
			58,5	$N_2$1P(7—2)
		5554		$N_2$1P(7—2), OI(54,9)
			50	$N_2$1P(7—2), NII(52,0)
		43		$N_2$1P(7—2), NII(43,5), N_2^+2N(4—0)
0.47		37	39,5	O_2^+1N(4—3)
		31		N_2V.K.(7—20), NI(30,0), NII(30,3)
			21	O_2^+1N(5—4), NI(24)
		17	16,3	$N_2$1P(8—3), NI(19,4)
		13	10	OI(12,7)
		5497	5496,0	NI(96,6), NII(95,7), $N_2$1P(8—3), O_2^+2N(0—12)
		92	92,0	OI(92,8)
		88	87,0	OI(86,6), N_2^+1N(4—8)
		78	76	NII(78,1), $N_2$1P(9—4)
0.2		67		N_2V.K.(3—17)
		62	61,5	NII(62,5), $N_2$1P(9—4)
		57		NII(54,3)
		52		NII(52,1)
		42	43,5	$N_2$1P(10—5). O_2^+2N(0—12)
0.5		36	38,6	OI(35.2, 35.8, 36.8), O_2S.R(0—24)
		34		$N_2$1P(10—5)
		26		O_2S.R(3—26)
		21	22,5	$N_2$1P(10—5)
		17	18,0	NI(19,3)
		12	11,0	OI(10,8)
		05	05,5	$N_2$1P(11—6)
			01,0	NI(01,2)
		5392		NI(5392,7)
		90	91	$N_2$1P(11—6)
		75		$N_2$1P(12—7), N_2V.K(6—19), N_2^+1N(6—10)
		69	68	NI(67.3, 71.0)
		60		NI(60,1)
0.22		58		NI(56,8)
		50		NII(51,2)
		46		NI(44,2)
		42		NI(40,3), NII(40,2)

I		Wavelength		Interpretation.
a	b	Previously measured	From present Spectrograms	
0.37		34	34,5	NI(34,3), N_2^+2N(7—2), $N_2$1P(13—8)
		30	30,5	OI(29.0, 29.6, 30.7), NI(28,8)
		19		$N_2$1P(13—8), NII(21,0)
		15		NI(5315,2), NII(13,4)
			01,0	N_2^+2N(7—2), $N_2$1P(14—9)
		5297	5296,0	O_2^+1N(2—0), OI(99,0)
		92		O_2^+1N(2—0), NI(92,8)
		82	80,5	NI(81,2), O_2^+1N(2—0), $N_2$1P(14—9)
		72	75	O_2^+1N(3—1) (2—0), OI(75,1), $N_2$1P(15—10)
		(64)		O_2S.R.(9—29)
0.37		57		O_2^+1N(4—2), $N_2$1P(15—10)
	2.0	56	55,4	NO$_\beta$(3—18)
		50		O_2^+1N(5—3), O_2S.R(4—26)
		42	43	O_2^+1N(6—4), O_2S.R(1—24)
		5234		O_2^+1N(7—5), N_2V.K(5—18)
1.2	2.4	27	5228,7	N_2^+1N(0—3)
2.5		5199	5199,5	NI2p^3($^4S_{3/2}$—$^2D_{5/2,3/2}$), 3p^{2}S—5d$^2P_{3/2,1/2}$), NII(5199,5)
		93	89	NI(87.1, 89 3, 91.7), N_2^+2N(6—1), NII(90,4)
		80	81	NI(79.6, 80.9, 82,5), NII(79.5, 80.3)
		77		NII(75,9), $N_2$1P(18—14)
		73		NII(73,4)
		66	67,5	NI(65,8) (68,0), NII(68,2), N_2^+2N(6—1)
		54	52	NI(56) $N_2$1P(19—14), O_2S.R(3—25)
0.38		48	48,2	N_2^+1N(1—4), NI(48,7)
		40		NI(40,8)
		32	32,5	OI(30,5)NI(30)
		25	24	
		14	13,5	
		09	08,0	
		05		NII(04,5)
		5093		N_2V.K.(4—17)
		78		N_2^+1N(2—5), O_2S.R.(11—29), N_2G.K.(0—12)
		67		NI(68), O_2S.R.(2—24)
		53	53,5	$N_2$1P(11—5), NI(51.6, 54.7)
0.15		48	46,5	OI(47,7), $N_2$1P(11—5), O_2S.R.(7—27)
0.19		43		NII(45,1)
		32		N_2V.K.(7—19), $N_2$1P(11—5)
		29		$N_2$1P(12—6)
		19	18,5	OI(18.8, 19.3, 20.1)
		14		NII(12.0, 16.4), N_2^+1N(3—6)
2.8		11	10,5	NII(10.6, 11.2)
		06,7	07	OIII(06,9)?
		05	04,4	NII(05,1)
	2.4	03	02,4	NII(02,7)
2.8		01,4		NII(01,5, 01.1)
		4999	4998,5	NII(97,2), N_2^+1N(4—1)
		94	96	NII(94,4)
		90		NII(91.2, 87.4)
		80	82	OI(79,6)
			77	O_2S.R.(1—23)
0.16		74	72,5	$N_2$1P(4—11)
0.27		67,5	67,9	OI(68,8) (67,9) (67,4)
0.24		62	61,5	N_2V.K(3—16)
			57	N_2^+1N(4—7)
			55	OII(55,7)

I		Wavelength		Interpretation.
a	b	Previously measured	From present Spectrograms	
		42		OII(43,41)
0.35		34,5	35	NI(35,0)
		28		O_2S.R.(10—28)
		23		OII(24,5)
0.14		17	17,5	$N_2$2P(1—7)
0.18		15		NI(14,9)
		13		NO_β(3—17)
			09,0	NII(10,3)
		07		OII(06,8)
			05,0	O_2S.R.(3—24)
0,27		4895,5	4896,5	NII(95,2), N_2V.K(6—18). N_2^+2N(7—2)
		91		OII(90,9), NO_β(3—17)
		87	85,0	NI(86,3), O_2S.R(0—22)
0.16		83	82,7	NI(81,8), N_2^+2N(8—2), N_2^+1N(6—9)
0.14		80		
			74,5	OII(72)
0.15		67		NI(68,9)
0.15		65	64,5	OII(64,9)
0.48		62	61,7	H_β, with Doppler-shift OII(60,9), NII(60,4),
0.15		57	57,0	OII(56,8)
			46,5	NI(47,4)
0.39		38	38,0	NI(37,8)
		35	35,9	N_2V.K(2—15), O_2S.R.(11—28)
			16.5	O_2S.R.(2—23)
		14	13,5	$N_2$2P(2—8), O_2S.R.(9—27)
		12		NII(10,3), NO_β(2—16)
0.18		02,5		OI(01.8, 02.2, 03.0), NII(03.3)
0.14		4799	4798,5	
		92	92.0	NII(93,7), NO_β(2—16)
		87	87,5	NII(88,1)
		81	83,0	NII(81,2)
			78,0	NII(79,7)
0.22		72	68	NII(72.5, 72.9, 73.8), N_2V.K.(5—17)
		(58)	54,2	NI(53,1), OII(52,7)
0.12		50	51,5	NI(50,3), OII(51,3)
0.09		24	24,0	$N_2$2P(3—9), O_2S.R(6—25)
			20	NII(18.4, 21.6), O_2^+2N(0—10)
7.8	7.8	09	09	N_2^+1N(0—2)
0.23		4686		NI(85,7)
0.35		77,5	4677,1	OII(77.0, 76.2), NII, (77.9, 75.0)
0.15		73	71,5	OI(73.7, 72.8), OII(73.8), O_2S.R(3—23)
0.14		70		NI(69,8)
			68	$N_2$2P(0—5)
0.35		61,6	61,5	OII(61,7), NI(60,0), N_2^+2N(6—0)
5.0	4.6	51,5	51,2	N_2^+1N(1—3). NI(51), OII(50,9)
			50	OII(49,1), N_2V.K(4—16), N_2^+2N(6—0)
		42,6	41,7	OII(41,8), NII(43,1)
		39	38,5	OII(38,9)
0.37		31,5	31,3	OII(30,6), O_2S.R(11—27)
0.11		21,5	22,5	OII(21,3), NII(21,4)
		14		OII(13,9), NII(13,7)
		10	09,0	OII(10,1)(9,4) NII(09,4)
0.15		8		NII(07,2), O_2S.R(7—25)
			02,0	NII(01,5), OII(02,1)

I		Wavelength		Interpretation.
a	b	Previously measured	From present Spectrograms	
0.41	0.5	00,8	00,1	N_2^+1N(2—4)
0.25		4596,5	4597.0	OII(96,1)
0.54		91	91,5	OII(90,9), NO_β(3—16)
		89	90,0	OI(89.0, 89.9)
			81,0	O_2S.R(2—22)
0.29		73,5	73,2	$N_2$2P(1—6), NO_β(3—16)
		70	70	
		63	67	NII(64,8)
0.3	0.7	53	53,3	N_2^+1N(3—5), NI(53.4, 54,2)
		52		NII(52,5)
			4547,0	N_2^+2N(9—2)
0.61	0.7	4533	32,6	N_2V.K(3—15)
		30,5	31,0	N_2^+2N(9—2), NII(30,4)
0.16		15,1	15,2	N_2^+1N(4—6)
		11	10	O_2S.R(6—24)
		07	06,7	NII(07,6)
		4498	4498,3	NI(97.5, 99.1)
			95,5	NI(94,7)
0.19		91		$N_2$2P(2—7), N_1(92,4), OII(91.2, 89.5)
0,12		88,6	88,0	OII(87.7, 88.2), NII(88.2)
0.08	0.6	85	84,2	NI(85,1), N_2^+1N(5—7)
		83	82,2	OII(82,9), NO_β(2—15)
		77	75,7	OII(76.1, 77.9), NII(77.3)
		72	70,7	OII(69,4)
0.18		68	67,5	OII(67,8)
0.15		66		OII(66,3)
0.14		65	65,5	OII(65,5), NII(65,5)
		52	50,8	OII(52,4)
		49	48,7	NII(47,0)
			45,2	N_2G.K.(0—10)
0.15		42	40,5	NII(42,0),N_2G.K.(0—10), O_2S.R(11—26)
0.53	0.8	33	32,8	NII(31.8, 32.7, 33.5), N_2G.K.(0—10)
0.13		29	28,8	NII(28,0)
0.19		27,3	27,6	NII(27,2)
		24	24,0	N_2V.K(2—14)
		22	23,2	O_2S.R(5—23)
0.76	1.3	17	16,5	OII(17,0), $N_2$2P(3—8)
0.82		15	15,1	OII(14,9)
			11,5	
0.10		04,5	07,0	OII(06,0), O_2S.R.(7—24)
			02,7	
			01,1	
			4397,0	OII(96,0), O_2^+2N(0—9)
0.19		4380	82,7	N_2V.K(5—16)
0.15		79	79,0	OII(78,4)
1.24	1.8	77	77,9	OII(78,0)
		75	75,0	NII(75), O_2S.R(2—21)
		68,3	68,3	OI(68,3), OII(66.9, 69.3)
		58,3		OII(58.5, 57.3), NI(58.3)
0.32	1.0	52	51,0	OII(51,3)
0.18		50	48,9	OII(49,4)
0.12		48		OII(47,4)
		45	46,6	OII(45.6) (44.3)
0.49	1.6	43	43,0	$N_2$2P(0—4), OII(43.4, 42.8)
		42		OII(42,0)

I		Wavelength		Interpretation.
a	b	Previously measured	From present Spectrograms	
0.23		41		H_γ with Doppler shift
		39	39,2	OII(40,3)
		37	36,9	OII(36,9), NI(36,5)
		34,5	34,5	OII(34,2)
		30	32,0	OII(31.8, 31.4)
			29,4	OII(28.6, 27.8)
			26,3	OII(25,8) (27,5)
		25	23,1	NI(24,9)
0.3—1.6		4322	4321,2	NI(22,0)
		19,3	19,5	OII(19,9)
		17,8	17,9	OII(17.7, 17.2), NI(17,7)
		13,5		OII(13,4), NI(13,1)
		09,0		OII(09,0)
		05	06,5	NI(05,5)
			04,2	OII(03,8)
		4294		OII(94,7)
			4292	OII(92,1)
		88	88,8	OII(88,8) NO_β(3—15)
			86,2	OII(85,6)
		85	84,7	NI(84,9)
24.4		78	78	N_2^+1N(0—1), N_2V.K.(4—15), OII(76.6, 77.4)
0.9		41,3	41,4	NII(41,8)
5.9	(16)	36	36,3	N_2^+1N(1—2), NII(36.9, 37.0)
		31		NI(30,4), OI(33,3)
		29		NI(29,6)
0.12		26,5		NII(27,8), O_2S.R(5—22)
		24		NI(24,7)
0.15		23		NI(23,0), OI(22,8)
		21		NI(20,8)
0.10		19		N_2V.K.(0—12)
		17,5		OI(17,1)
0.10		15,5	15,8	NI(15,9), NO_β(2—14)
0.10		14		NI(14,7), O_2S.R.(0—19)
0.17		11,5	11,7	NI(13,0)
0.09		08	08,2	NI(09,1)
			06,1	NI(06,3)
0.10		05	05,1	NI(05,7)
0.8—2	(2.2)	4199,4	4199,5	N_2^+1N(2—3), $N_2$2P(2—6), NO_β(2—14)
0.15		96	95,5	OII(96.3, 96.7)
0.15		93	94,0	OI(92,5), NI(93,5)
0.23		89	89,8	OII(89,8)
		88		NI(87)
0.10		85	85,2	OII(85,5)
		80,5	80,5	NI(80,0), NII(79,7)
1.4		76,5	76,0	NII(76,2)
0.18		74,5	74,0	NII(73.5, 73.7), N_2^+1N(3—4)
0.12		71,0	71,6	NII(71,6), N_2V.K.(3—14)
		68,5	68,5	OII(69,3)
0.15		67,5		
		66	65,4	NI(66,6)
		64		NI(64,8)
		60		NII(60,8)
		56,5		OII(56,5)
		53,5		OII(53,3)
		52		NI(51,5)

I		Wavelength		Interpretation.
a	b	Previously measured	From present Spectrograms	
		49	48,8	
		45	45,9	NI(45,8), N(45,8), N_2V.K.(6—16) (45,7)
			42,7	OII(42.0, 42.1, 42.3), N_2^+1N(4—5)
0.17		41	40,9	OII(40,7), $N_2$2P(3—7)
		40	40,2	
		38,5	39,0	
		4137,1	4136,7	NI(37,6)
		34	32,1	OII(32,8), NO_β(1—13), NII(33,7)
		31	28,2	OII(29,3), NI(29,2), NO_β(1—13)
		25	24,4	NII(24,1)
1.6		20,5	21,4	OII(21.5, 20.6, 20.3)
		19	18,8	OII(19,2)
		14,5		NI(14,0), OII(13,8), NO_β(1—13), O_2^+2N(0—8)
		12		OII(12,0)
		11	11,0	OII(10,8)
		09,5	09,9	OII(10,2), NI(10,0), NII(10,0)
		06,5		OII(07.1, 06.0, 08.8)
			05,6	OII(05.0, 04.7)
			03,0	OII(03,3), NI(02,2)
0.08		4100,0	4100,0	$N_2$2P(7—11), NI(99,9) (01,7)
		4097,5	4097,6	OII(97.2, 97,3)
		95,5	95,0	OII(94.2, 94.7, 95.6, 96.2, 96.5), O_2S.R(1—19)
0.14		94		$N_2$2P(4—8), OII(94,2)
			92,8	OII(92,9)
		89	89,6	OII(89,3)
		86	86,7	OII(87,1),
		85,5		NII(85,1)
			84,3	OII(84,7) (83,9)
0.17		82	82,8	NII(82,9), O_2^+2N(0—8)
		79,2	79,3	OII(78,9)
0.50		76	76,2	OII(75,9)
0.43		73		NII(73,1)
0.44		72	72,2	OII(72,2), N_2V.K.(2—13)
0.36		71	70,8	OII(69.9, 69.6)
		66	67,1	
			64,7	O_2S.R.(3—20)
		61		OII(61.0, 60.6)
1.5->3.4	6.7	58,5	58,3	$N_2$2P(0—3)
		57		NII(57,0)
			53,6	OII(54,1) (54,6)
			52,6	
			51,7	
			48,1	OII(48,2)
0.40		47	47,0	OII(46,2)
0.35		45,5	45,0	OII(45,0), NII(44,8), O_2S.R(5—21)
0.33		43,2	43,1	NII(43,5)
0.48		41	41,2	NII(41,3), OII(41,3), NO_β(0—12)
		36,6		NI(37,4)
0.28		35,8	34,9	OII(35,1), NII(35,1)
		33	33,1	OII(33,2), NI(33,6)
		30	29,5	NO_β(0—12)
0.30		26	26,2	OII(26,4), NII(26,1)
0.20		24	23,4	OII(24,0)
		11	10,8	NI(11,0)
		09	08,4	

I		Wavelength		Interpretation
a	b	Previously measured	From present Spetcrograms	
			05,8	
		01		NI(01.0, 01.7)
2.1→3.7	7.6	3997,5	3997,2	$N_2$2P(1—4)
0.70		3995	3994,9	NI(94,9), NII(95,0)
		92,5	92,3	
		91,5		
		89	89,1	
		(86,5)	87,5	O_2S.R(2—19)
		85,5		OII(85,5)
		82,5		OII(82,7)
		81		
		79		
			77,9	N_2V.K.(1—12)
		73,5	73,2	OII(73,2)
		68,5		NI(70,0)
		61		NO_β(2—13)
		55		OI(54.7. 54.6), NII(55.9), NI(57.0)
		54		OI(53.1, 53.0), OII(54.4)
		49		NO_β(2—13)
		47	47,4	N_2V.K.(4—14), OI(47.6, 47.5, 47.3)
		45		OII(45,0)
1.1		42	41,9	$N_2$2P(2—5)
		41,5		N_2V.K.(7—16)
		30,5		
		18,5		OII(19,3), NII(19,0)
47.4		3914	3914	N_2^+1N(0—0), O_2S.*R*.(1—18)
		3887,8		N_2V.K.(0—11), O_2S.R.(3—19)
		86		
3.2		84	3884,0	N_2^+1N(1—1)
		83		OII(82,4) (83,2)
		80,5		NO_β(1—12)

4. Discussion of Results.

The spectrograms on plate II and No. 1a and 2 on pl. I have greatly increased our knowledge regarding the spectrum of the auroral luminescence particularly in the red and infra red region in the interval 6250—8850.

Apart from the red OI doublet (6300, 6364) the auroral luminescence in this interval is usually dominated by the three following band systems:

The first positive group of nitrogen (N_2 1P)
» second negative » » » (N_2^+ 2N)
» first negative » » oxygen (O_2^+ 1N)

Further a number of lines from neutral and ionized atoms of oxygen and nitrogen appear very distinctly on our Tromsø spectrograms. In some cases H_α may appear with a dominating intensity. The appearance and position of the auroral bands and lines in this interval of long waves are illustrated by means of the greatly enlarged spectrograms on plate III.

We notice the remarkable fact, that the heavily exposed spectrogram No. 1, pl. III, shows no trace of the H_α line, while it appears on the much weaker spectrogram 2, for which the collimator was directed towards magnetic zenith.

Recently A. B. Meinel has obtained at the Yerkes observatory some interesting auroral spectrograms in the the long wave region, particularly in the infra red. Partly on account of the considerable dispersion he was able to show that in addition to bands of the first positive group of nitrogen, also bands from the system here denoted by N_2^+ 2N appeared in the infra red auroral luminescence (13, 14).

From his wavelength table as well as from the reproductions of his spectrograms it appears that his results as far as they go are in good agreement with those obtained in our country and especially with those derived from the present auroral spectrograms for the long wave region.

A comparison shows that Meinel's table contains two very weak (N_2 1P) bands 6962 and 7149 and the weak NI line 8243, which are not found on our spectrograms.

On the other hand, in the wavelength interval of Meinel (6300—8900) our table contains about 40 bands and lines not previously observed.

From the spectrograms of Pl. III (and from the table 2) we see that our spectrograms show a greater number of the Meinel bands (N_2^+ ($A^2\Pi$ — $X^2\Sigma$) as well as of the (N_2 1P) and (O_2^+ 1N) bands. Our spectrograms also indicate the appearance of a greater number of atomic lines in this interval than found by Meinel.

Comparing the spectrogram Pl. I No. 3 from Tromsø and that from Oslo, treated in a previous paper (4) we find for the intervall 6300 to 3880, that all stronger lines and bands appear on both. This also holds for most of the weak lines and therefore these ought to be real.

The fact that some of the very weakest lines are only observed on one of the two spectrograms, does not mean that these lines are not real. We have to take into account the great variability of the spectral composition of the auroral luminescence and that the lines we obtain on a spectrogram greatly depend on the way in which the sensitivity of the plate varies with the wavelength, the width of the slit, sharpness of the lines and the degree of exposure.

From the way in which they are detected and measured, and on account of their close coincidence with known lines, we have good reason to believe, that also most of these lines, which only appear on one of the two spectrograms, are present in the auroral luminescence. The question as to their reality, however, calls for further observations and discussion.

Diagrams of the term values of the neutral and singly ionized atoms of O and N are given in paper (4), where the atomic transitions corresponding to observed auroral lines are indicated.

These transitions also include those corresponding to the metastable ground states of the neutral and singly ionised atoms.

In the case of O II the forbidden line (^2D—^2P) (7330) may be masked by the strong bands appearing in this region. *The doublet OII* ($^4S_{3/2}$—$^2D_{3/2,\,5/2}$) *(3729, 3726) coincides in a satisfactory way with the observed auroral line 3728,4.*

One of the forbidden NI lines (^2D—^2P) lies in the infra red, *the line NI* (^4S — ^2P) *(3466) appears in the auroral spectrum. With regard to the doublet NI* ($^4S_{3/2}$ — $^2D_{5/2,\,3/2}$) *(5201, 5198) it is not separated, but coincides in a satisfactory way with the auroral line 5199,5.*

This line and the band N_2^+ 1N (0—3) (5227) as well as a O_2^+ 1N sequence, will on spectrograms of small dispersion, take the form of a broad diffuse line, called "the second green line". The maximum gave usually a wavelength of about 5220—5230. "The second green line" has been observed on spectrograms of about the same small dispersion by Slipher and Sommer (15), Gøtz (16), Dufay (17) and Barbier (18) at lower latitudes, and they found a wavelength which fitted well with the NI-doublet.

This suggested, that at high latitudes "the second green line" was dominated ny the N_2^+ and O_2^+ bands (19). This would mean that *the relative intensity of the forbidden NI-line (5199) decreased towards higher latitudes.* This variability effect is in fact clearly shown by comparing the Tromsø spectrogram pl. I, No. 1 and 3, with the Oslo spectrogram pl. I, No. 4.

On the Oslo spectrogram the line 5199 is more than twice as strong as the band head 5227. On the Tromsø spectrogram pl. I, 1a, the band heads 5227 (N_2^+ *1N*) **(0—3)** *and 5257* (O_2^+ *1N*) *(4—2) appear quite distinctly, while the line 5199 is absent. On spectrograms pl. I, No. 3. the line 5199 appears, but is weaker than the band head 5227.*

We have previously found (20, 21) that the forbidden OI lines (5577), (6300 and 6364) are greatly enhanced relative to the negative nitrogen bands, when we pass towards lower latitudes (6,19). A similar latitude effect is now also found for the forbidden NI-doublet (5201, 5198). The question as to whether also the forbidden NI-line 3466 and possibly the forbidden lines of OII and NII show similar enhancement towards lower latitudes has not yet been investigated.

The forbidden NII-line 5755 ($^1D_2$—$^1S_0$) and the doublet 6583, 6547, NII ($^3P_{2,1}$—$^1D_2$) are likely to be more or less masked by nitrogen bands, but we have occationally registered lines, which coincide with these forbidden lines as nearly as could be expected, when the dispersion and the quality of the spectrograms are taken into account. On the Tromsø spectrogram (pl. I No. 3), however, we have measured the lines 5754, 6583 and 6551, and everything considered these lines give a satisfactory coincidence with the forbidden NII-lines.

The ultra violet region, which is not covered by the present spectrograms, has been previously analysed by means of quartz spectrographs. The results are given in previous papers (cfr. paper 4).

5. Auroral Hydrogen Lines and their Doppler Displacement.

In a paper (20) recently published, Vegard gives some historical facts regarding the detection of auroral hydrogen lines, their variability, their doppler displacement and their bearing on the theory of aurora and magnetic disturbances. For the sake of convenience we recall to mind some points from this paper:

a. Spectrograms obtained at Oslo in 1939 with spectrograms of fairly small dispersion showed on the same spectrogram both H_α and H_β. Intensity measurements showed that H_α was about 4 times stronger than the negative nitrogen band 4278 and H_β was about twice as strong as the band 4708 (6). From this occasional occurence of Hydrogen lines it was concluded that "hygrogen showers" (or proton radiation from the sun) occasionally entered into the earth's atmosphere (5,6).

b. A spectrogram obtained in the spring 1940 at the Auroral Observatory, Tromsø with a spectrograph (B) of much greater dispersion showed a fairly sharp H_β-line exactly coinciding with the H_β-line of the comparison spectrum.

c. Some spectrograms obtained at Tromsø with the big (B)-spectrograph during the years 1940 and 1941 showed a very diffuse and broadened H_β-line[1]) particularly displaced in the direction of short waves, *while on the same spectrograms the other lines of similar intensity came out very sharp.* After careful consideration this broadening and displacement of H_β was interpreted as Doppler effect of hydrogen atoms (protons) entering the atmosphere. We were observing a "Hydrogen shower".

The Doppler displacement of H_β — from two of the Tromsø spectrograms from 1941, were shown by means of photometer curves of the broadened and displaced H_β-lines, as well as of the undisplaced H_β-line of the comparison spectrum. The auroral Doppler H_β-band is seen to be several times broader than an undisplaced H_β-line of the same intensity and on the same spectrogram. The maximum displacement is further much greater towards shorter waves (cfr. paper 20.)

d. The Auroral H-lines were thus identified and their dopppler displacement detected before Gartlein's work (21) on the auroral hydrogen lines, and about nine years before Meinel observed the H_α-dopplershift on August 18. and 19., 1950.

Meinel is thus mistaken when in his paper "Doppler-shifted auroral Hydrogen emission" (22) states, that Vegard was unable to measure any Doppler shift for the broadened hydrogen lines. Meinel only refers to Vegard's note in C. R. 1950 (1) on the spectrogram obtained at Oslo Feb. 1950, where the Doppler displacement of H_β- was mentioned, without giving any exact results, based on photometer-curves. The final treatment was first given in paper (4). Meinel does not seem to have known Vegard's results from 1939—41 summarized in paper (20).

e. The Hydrogen showers and the Doppler displacement of the auroral hydrogen lines, came as a confirmation of Vegard's theory of the constitution of the solar ray bundles which produce the auroral and most magnetic disturbances. According to Vegard (24, 25) the ray bundles consist of electrons electro-statically neutralized by positive ions of great specific charge, preferably protons.

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[1]) The plates were not sensitive to red (H_α)

The current density (i) of the bundle composed of protons and electrons will be:

$$i = en\,(V_e - V_p) \qquad (1)$$

V_e and V_p are the velocities of electrons and protons, n is the number of electrons and protons per unit volume of the bundle. The bundle although electro-statically neutral is magnetically active, and will be deviated in the earth's magnetic field in a similar way as that found by Birkeland and Størmer for electrons moving in the earth's field without taking into account the electrostatic repulsion.

The essential properties of the aurora are accounted for if we assume V_p smaller than V_e. The number of protons ν_p relative to that of the electrons ν_e entering the atmosphere in unit time is

$$\nu_p/\nu_e = V_p/V_e \qquad (2)$$

This means that the great changes in the relative intensity of the H-lines in the auroral spectrum in the various aurorae is due to change of proton velocity relative to that of the electrons. The greater the proton velocity, the greater is the effective magnetic stiffnes of the bundle, the greater the distance of the aurorae from the magnetic axis point and the greater is the relative intensity of the H-line in the auroral spectrum. Thus we should expect the relative intensity of the H-lines to increase towards lower latitudes. In fact as far as our present observational material goes the relative intensity of the H-lines is on an average greater at Oslo than at Tromsø.

f. In paper (20) is shown that the protons will be absorbed in the higher part of the auroral streamers, and the lower part down to the lower limit is due to the more penetrating electron rays. *In the upper atmosphere the electron rays can be neutralized by atmospheric positive ions, and the protons of solar bundles are no longer wanted for neutralization, and they will be absorbed independent of the electron rays.*

On the Tromsø spectrograms treated in this paper H_β appears quite strong and with doppler effect on spectrogram pl. I No. 3 and H_α on spectrogram pl. I no. 2.

In the case of the first of these spectrograms the exposure lasted from 17. 1. to 9. 2. 1951 with an effective exposure time of 6½ hours. Now at Tromsø the aurora usually appears strong near the zenith and therefore the auroral light comes from directions with a small magnetic zenith-distance. Consequently we should have the greatest Doppler shift towards shorter waves. This is also shown by the photometer curve of H_β (fig. 1) and the smooth curve (fig. 2).

Photm Curve from Spectr. 17-1 - 9 2-1951, Tromso

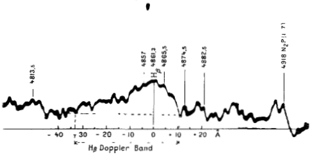

Fig. 1.

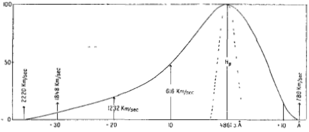

Fig. 2.

From the maximum Doppler displacement we find the maximum velocity towards the observer to be 2220 km/sec. or 2. 22. 10^8 cm/sec. The physical explanation of the velocities away from the observer is given in paper (4). It is partly due to the fact that the protons will move in screw lines round the magnetic lines of force, partly due to deviations through collisions of the protons with atmospheric atoms. The maximum velocities derived from Vegard's earlier determinations from spectrograms obtained at Tromsø 1941 and from Oslo Feb. 1950 are given in paper (20).

In dealing with the intensity variations of the H-lines in the auroral spectra, we must remember that the H-lines are emitted from neutralized protons. Thus we must expect that, when the protons enter the atmosphere, the emission increases as the neutralisation sets in, and reaches a maximum, after which the relative intensity of the hydrogen ray emission gradually decreases on account of absorption.

We must also take into account that the probability of neutralisation and light emission decreases with increasing velocity.

Investigations by Vegard of the Doppler effect of canal rays (26) have shown *that the light emitted from the moving H-atoms decreases with increase of velocity and seems to vanish when the velocity exceeds about 5×10^8 cm/sec.* As far our present observations go regarding the maximum Doppler displacement of auroral H-lines, the maximum velocities do not exceed about $3{,}5 \times 10^8$ to 4×10^8 cm/sec, which is indeed near to the limit, where the light emission of hydrogen rays stops. As long as the relative intensity of auroral H-lines is weak, the proton velocity is small and probably not greater than the velocity derived from the maximum Doppler displacements we get in the direction towards magnetic zenith.

How far the protons, when they enter into the atmosphere, can have velocities too great for light emission, will have to be a subject for further investigation.

In the case of spectrogram pl. I No. 2, the instrument was directed towards magnetic zenith. The hydrogen emission is very weak. Although the nitrogen band 4708 is quite strong, no trace of H_β is to be seen. A weak H_α-line, however, appears in an interval between two N_2 1P bands. It seems to be displaced towards shorter waves, but the Doppler band is partly masked by a N_2 1P band.

6. The Ionospheric Temperature measured from the Negative Nitrogen Bands.

The following four negative nitrogen bands have a suitable density for photometric determination of the intensity distribution within the R-branch, which is the basis of the measurements of ionospheric temperature:

Band	3914	on spectrogram	pl.	I	No.	1a
»	4278	»	»	II	»	1a
»	4278	»	»	II	»	2a
»	4278	»	»	I	»	2

On these bands the rotational components are distinctly separated.

The procedure to be followed by the temperature measurements have been described in previous papers (27, 28). Having determined how the relative intensity (I) of the components of the R-branch vary with the rotational quant number (K) these quantities according to the theory are connected by the following equation:

$$\log_{10} (I_K/K) = -\varkappa_1 (K + 1) K \qquad (3a)$$

where

$$\varkappa_1 = \frac{h^2 \log_{10} \varepsilon}{8\pi^2 k T_\varkappa J} \qquad (3b)$$

$T_\varkappa$ is the absolute temperature of the emitting N_2^+ ions, the moment of inertia (J) of the N_2^+ ion in the upper electronic state is equal to $13{,}4 \times 10^{-40}$ (gr. cm²) h and k are Plank's and Boltzmann's constants. These quantities inserted into equation (3b) give

$$T_\varkappa = \frac{1.2855}{\varkappa_1} \qquad (4)$$

We can also determine the temperature (T_m) from the quant number (K_m) of the component of maximum intensity by means of the equation.

$$T_m = 2{,}96\, K_m (2\, K_m + 1) \qquad (5)$$

If the intensity distribution within the R-branch follows Maxwell's law we should have:

$T_\varkappa = T_m =$ the absolute temperature T of the light emitting N_2^+ ions.

The value of K_m is found directly from the maximum of the intensity curve (I_k, K) and $\varkappa_1$ is found by plotting the value of $\log_{10} (I_k/K)$ as a function of $(K + 1) K$ which should be a straight line, the slope of which gives us $\varkappa_1$.

For our four bands (I_k — K) curves are given in fig. 3 and the straight lines ($\log_{10} (I_k/K)$ — $(K + 1) K$ in fig. 4. The results are collected in table (3).

The unusual low temperature found from spectrogram pl. II No. 2a is no doubt due to the fact that the exposure of the R-branch is too weak for accurate photometric intensity measurements.

The mean ionospheric temperature $T_{ion.}$ derived from the three other spectrograms is then found to be: 217° Kelvin or — 56° C.

Table 3.

Spectrogram	Band	T_m	$T_\varkappa$	$T_{ion} = \frac{T_\varkappa + T_m}{2}$
Pl. I No. 1a	3914	202° K	227° K	214.5° K = — 58.5° C
» II » 1a	4278	206° »	247° »	226.5° » = — 46.5° »
» II » 2a	4278	186° »	189° »	187.5° » = — 85.5° »
» I » 2	4278	202° »	218° »	210.0° » = — 63.5° »
			Mean T_{ion}	209.6° K = — 63.4° C

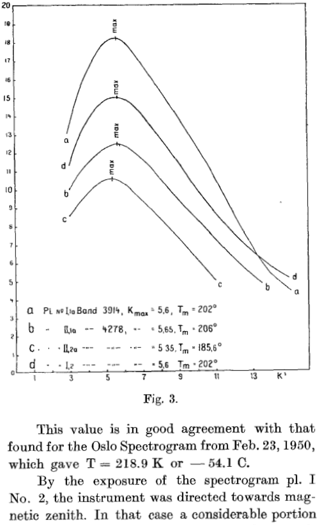

Fig. 3.

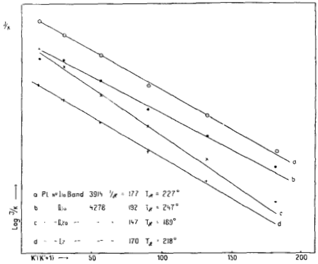

Fig 4.

This value is in good agreement with that found for the Oslo Spectrogram from Feb. 23, 1950, which gave T = 218.9 K or — 54.1 C.

By the exposure of the spectrogram pl. I No. 2, the instrument was directed towards magnetic zenith. In that case a considerable portion of the light will come from high altitude towards the top of the auroral rays and streamers. The measurements, however, give no indication of any deviation from the Maxwell distribution, which corresponds to a constant temperature. The observed points on the curve $\log_{10}(I_k/K)$ — $K(K+1)$ fall on a straight line and there is no indication of an increase in temperature with increasing altitude.

In conclusion we wish to thank Mr. Steinar Berger for able assistance in connection with the observations at Tromsø. Further, our most sincere thanks are due to Mr. Anders Omholt and Mr. Endre Lillethun for invaluable assistance in various ways in connection with the treatment of the observations understaken at Oslo.

We are also indepted to the Norwegian Scientific Research Council for financial support of the auroral investigations at Oslo an d Tromsø

Physical Institute, University of Oslo, April, 1952.

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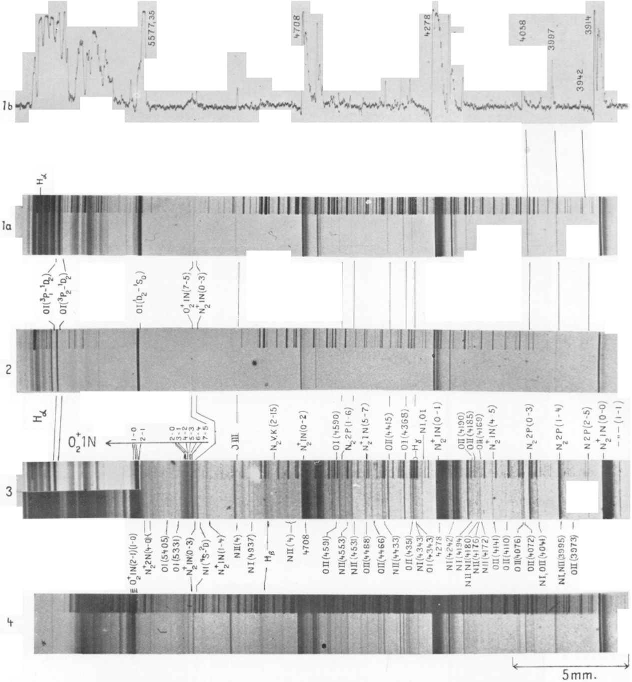
Pl. I.



Spectrograms No. 1, 2 and 3 were taken at the Auroral Observatory, Tromsø, during the winter 1950/51. Spectrogram No. 4 taken at Oslo Feb. 1950

No. 1a. Exposure on Kodak 103 a E from 10. 11.—13. 12. 1950. Total exposure 5 hours.

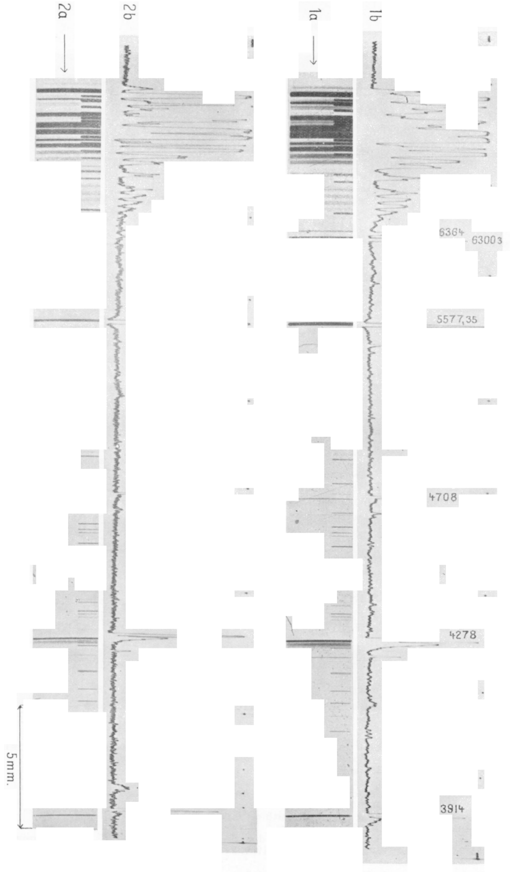
No 1b Registram of spectrogram 1a.

No. 2. Spectrogram taken towards magnetic zenith on Kodak 103 a E sensitized with NH_3. Exposure from 3. 4.—5. 4. 51, total $1\frac{1}{4}$ hour.

No. 3. Spectrogram taken partly near the zenith on Kodak 103 a E, sensitied with NH_3. Exposure 17. 1.—9. 2. 51. Total $6\frac{1}{2}$ hours.

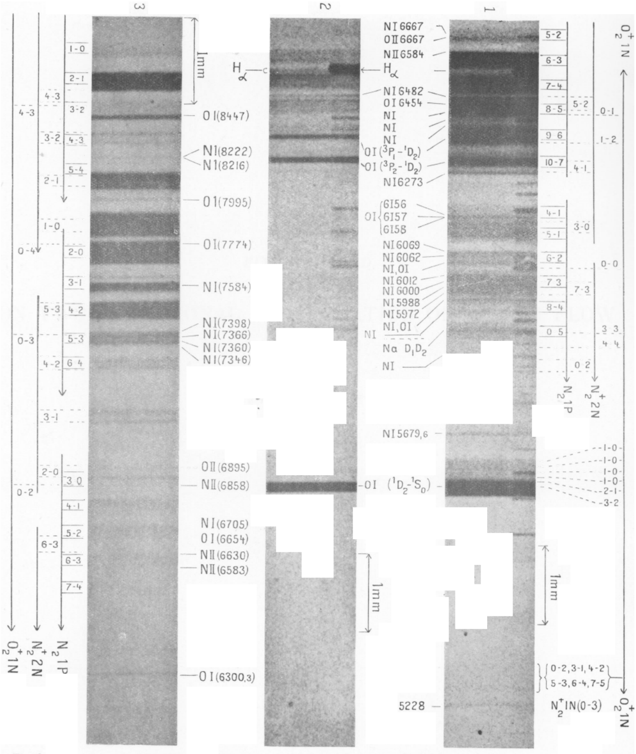
No. 4. Spectrogram taken at Oslo in a fixed direction on Kodak 103 a T. The exposure lasted from 19.35 23.2. to 05.30 in the morning 24. 2 1950.

Pl. II.



Spectrograms taken at Tromsø on infra-red sensitive Kodak I N plates sensitized with NH_3
No. 1a. Exposure 4. 1.—12.1. 1951, total 6½ hours.
No. 1b. Registram of spectrogram 1a.
No. 2a. Exposure 3 hours on Jan. 16th, 51.
No 2b. Registram of spectrogram 2a.

Pl. III.



The long wave part of spectrograms No. 1a and 2 on Pl. I and No. 2a on Pl. II in greater enlargement with indication of some of the most conspicuous lines and band systems appearing in the long wave region.

No. 1. Spectrogram taken 10. 11.—13. 12. 1950 on Kodak 103 a E
No. 2. » » 3. 4.— 5. 4. 1951 » » 103 a E.
No 3. » « 16. 1. 1951 » » I. N.