THE INTENSITY DISTRIBUTION WITHIN THE NITROGEN SPECTRUM FROM CANAL RAYS AND NEGATIVE GLOW, WITH REFERENCE TO THE AURORAL LUMINESCENCE

BY

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§ 1. INTRODUCTION

The fact that the nitrogen bands and particularly those of the negative group appear with great intensity in the auroral luminescence even at the upper limit of the longest auroral streamers (1, 2), is of great importance and value for the study of the physics of the upper atmosphere. From the intensity distribution within a rotational series of lines we can determine an upper limit for the temperature at various altitudes within the auroral region (ionosphere) (2). The validity of this method has been verified by laboratory experiments (2, 3).

The influence of the excitation process on the "band temperature" and the deviation of this temperature from that of the not excited gas molecules has been the subject of theoretical and experimental investigations by Vegard and collaborators (3, 4).

It was shown that when N_2 molecules are excited by swift electrons at low pressure, the excitation process has a comparatively small influence on the intensity distribution within a rotational series, and, in that case, the measured apparent "band temperature" is not much greater than the temperature, which would exist at the same place without excitation.

Excitation with canal rays, however, produced a considerable increase in the average rotational energy, and the "band temperature" was found to be about 80—100° higher than that of the gas surrounding the canal ray beam.

The results of a large number of measurements gave an ionospheric "band temperature" of about ÷ 45° C or 228° K (5). If the auroral luminescence is excited by swift electrons, the true temperature of the not luminous atmosphere would not be much lower than the directly measured "band temperature". If, however, the aurorae were mainly excited by positive rays, we should according to our laboratory experiments (3) expect the "band temperature" to be about 80° to 100° higher than the temperature of the unexcited gas.

This would bring the ionospheric temperature down to about ÷ 130° C, a value which is probably too low. These considerations suggest that the auroral luminescence is mainly excited by electron rays, in agreement with results derived from the intensity distribution of light along the auroral streamers (6) and the type of the auroral spectrum.

While the intensity distribution within a rotational band keeps fairly constant in the auroral luminescence, the relative intensity of the various vibrational bands belonging to a certain group of nitrogen bands is subject to considerable fluctuations. Also the relative intensities of the band groups (1st and 2nd positive, Vegard-Kaplan bands and the neg. group) are subject to great variations which have been dealt with in previous papers (7, 8).

The present paper, however, deals with the variation in relative intensity of vibrational bands belonging to the negative nitrogen group.

When the intensity distribution within the auroral spectrum of the negative nitrogen bands are measured from spectrograms of very long exposures, we get a kind of average intensity distribution which is not essentially changed from time to time. Auroral spectrograms taken from different auroral types, however, may show very considerable differences with regard to the intensity distribution including also the negative bands.

Variations of the relative intensities of the negative bands in aurorae have been dealt with in papers by Vegard and collaborators (7, 8, 9).

Very pronounced deviations from the average intensity distribution have been observed by Lord Rayleigh (10) and more recently by Størmer (11). In these cases the bands corresponding to higher vibrational quant numbers (v) showed exceptionally great intensity.

Table I.

Wave length	v′—v″	Relative Intensity of blue Rays (Störmer)	Average relative Intensity (Vegard)
4708........	0—2	100	100
4652........	1—3	97	59
4596........	2—4	85	44
4551........	3—5	70	26
4278........	0—1	100	100
4236........	1—2	59	24
4200........	2—3	35	8

Table I gives the relative intensities of bands of the two sequences $\triangle v = 1$ and $\triangle v = 2$. The third column contains the intensities found by Störmer from a spectrogram of blue rays at a great altitude that appeared Sept 15. 1938. The average distribution found by Vegard is given in the last column.

The low temperature which has been found to exist in the auroral region shows that these changes of relative intensities of vibrational bands within the negative group cannot be due to temperature variations.

At low gas temperatures the intensity distribution of the vibrational bands within a band system will first of all be governed by the Franck-Condon principle and be further influenced by the excitation process. Moreover the physical conditions under which emission takes place may influence the relative probability for transitions from a given vibrational level of the upper electronic state reaching the various vibrational levels of the lower electronic state. This means that for a series (v_0—v), for which the vibrational quantnumber v_0 of the upper electronic state is constant, the relative intensity of the bands may show variations.

Such variations have been found for the negative nitrogen bands appearing in the aurorae (7).

It may now be a matter of interest to find out how far —and under what condition—similar variations in the intensity distribution of the negative nitrogen bands can be obtained from artificial light sources produced in the laboratory.

Experimental investigations in this direction were planned by one of us (Vegard) in 1934 as a continuation of the work referred to regarding the influence of the excitation process on the rotational "band temperature".

The actual experiments to be dealt with in this paper were made in 1938—39 and finished just before the war.

Among the conditions which may possibly account for the variability shown by the intensity distribution of the negative nitrogen bands we may mention:

1. Change of properties of the exciting rays.
   Electric rays of different carrier (electrons, atomic or molecular ions) may be expected to give different intensity-distributions, which for a given carrier may vary with the ray-velocity.
2. The luminescence may be produced indirectly by transfer of energy from excited particles in some metastable state (collisions of the second kind). It might therefore be of interest to investigate the intensity distribution in the discharge through nitrogen mixed with a gas which has metastable states of sufficiently high energy to excite the negative bands. We might e. g. study discharges through a mixture of N_2 and He.

In accordance with these considerations we have compared spectra from the negative glow, where the excitation is mainly due to rapidly moving electrons, with those obtained from canal rays of nitrogen. We have further studied the intensity distribution of negative bands at different velocities of the canal rays, and in the luminescence from discharges produced in mixtures of nitrogen and helium.

Already more than 30 years ago one of us (12,13) made comparisons between the auroral spectrum and spectograms obtained from the neg-glow and canal rays of nitrogen. It was then pointed out that the spectra excited in nitrogen by electron rays and by positive rays, showed typical differences which might indicate the type of electric rays responsible for the excitation of the auroral luminescence in individual cases.

At that time, however, no quantitative determinations of relative intensities were made.

The results of experimental studies of the intensity distribution of the negative bands, corresponding to various excitation processes, have more recently been published by Smyth and Arnott (14) and by Duffendack, Revans and Roy (15). Their results will be dealt with later in this paper.

§ 2. EXPERIMENTAL PROCEDURE

a) Discharge Arrangement.

The discharge arrangement is indicated in fig. 1. During discharge a current of gas (either N_2 or a mixture of N_2 and He) is made to pass through the canal ray tube A—B. The diffusion pump D is kept going and the strength of the gas

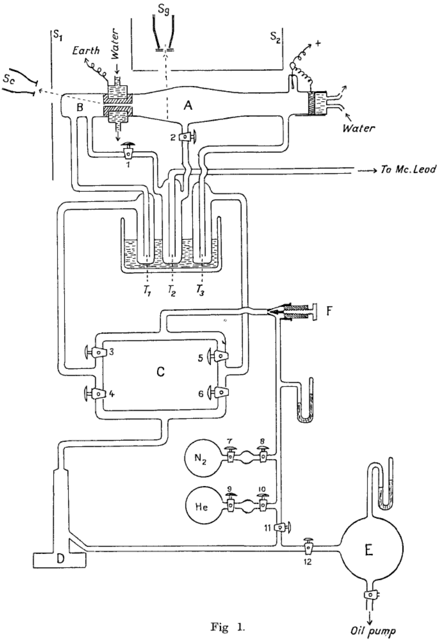

Fig 1.

current is regulated by the needle valve F so as to obtain the proper pressure and discharge potential in (A). The pressures in (A) and (B) can be measured by connecting them in turn to a McLeod gauge by means of the taps (1) and (2).

The direction of the gas-current through the tube can be reversed by the proper manipulation of the taps (3), (4), (5) and (6). All tubes from the discharge tube pass through the traps T_1, T_2, T_3, which can be immersed in liquid air to prevent mercury and other vapours from entering the discharge tube.

The cathode as well as the anode plate opposite to it, were cooled by water currents.

b. *The Spectrograms and their Treatment.*

Spectrograms were taken with a glass-spectrograph, which combined fairly high light power with a suitable dispersion. The position of the collimator by the exposure of canal rays and negative glow are indicated by S_c and S_g. (Fig. 1.) The screens (S_1) and (S_2) prevented unwanted light from entering the spectrograph.

For the determination of relative intensities of the bands an intensity scale was photographed on the same plate as that containing the spectrograms to be measured. In order to determine the true relative intensity of bands with different wavelength we took spectrograms of a light source giving a continuous spectrum of known intensity distribution.

The procedure followed by the intensity determinations was essentially the same as that described by one of us in previous papers (2, 7). Registrams of the spectra were obtained by means of a Moll registering photometer.

§ 3. SPECTRA FROM CANAL-RAYS AND THE NEGATIVE GLOW

A considerable number of spectrograms were taken on Agfa isochrom plates both from canal rays and from the negative glow. One spectrogram of each type is reproduced on the plate, No I_a taken from the negative glow. No I_b from canal rays. The discharge voltage was 14000 volts, pressure 0,04 mmHg, and current 4,0 M.A. The spectrum of the negative glow being excited by swift cathode rays is dominated by the negative bands, and, in addition, it only shows a few faint bands of the 2nd positive group and a few very faint N II lines. The latter may originate from the canal ray bushel usually appearing in front of the cathode.

Also the canal ray spectrum shows intensive negative bands, but, in addition, bands of the 2nd positive group and a number of atomic N-lines — mostly originating from N^+— appear quite strong.

Comparing the negative nitrogen bands on the two types of spectrograms, we notice *that within the same sequence, bands of high vibrational quant number are stronger in the case of canal rays.* This is also confirmed by the intensity measurement, the results of which are given in table II.

Table II.

Δv	v″—v′		I Canal rays	I Neg. glow
0	0—0	3914	2500	2500
	1—I	3884	500	150
1	0—1	4278	1000	1500
	1—2	4236	280	200
	2—3	4200	120	70
2	0—2	4708	140	300
	1—3	4652	70	100
	2—4	4600	55	35
3	0—3	5228	24	45
	1—4	5149	18	25
	2—5	5076	16	9

In order to obtain the weaker bands, the strongest belonging to the vibrational series (o—v″) will be somewhat over exposed, so their relative intensities may be less accurately determined than those of the somewhat weaker bands.

The results are illustrated in the diagram fig. 2. Here the relative intensities for the three sequences Δ v = 0,1 and 2 are put up for canal rays, neg. glow and the average intensities of aurorae as found by Vegard.

The bands of the series (o—v″) and (1—v″) and also the bands of each sequence are connected by lines. For the principal series (o—v″) the intensity decreases rapidly with increase of v″, but the

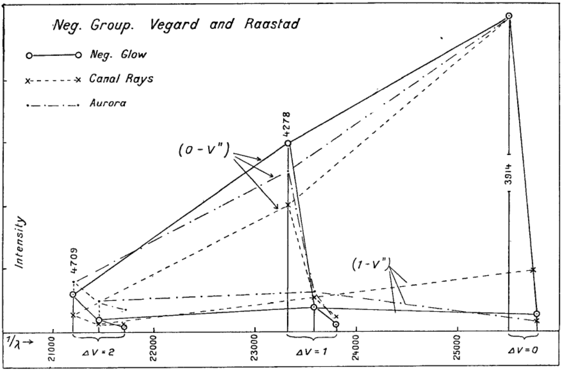

Fig. 2.

rate of decrease is greater for canal rays than for the neg. glow. The effect seems to be too great to be accounted for by errors, and, if so, it means that in the case of canal rays the probability of a transition from the upper zero-level to a lower level with vibrational quant number v″, decreases more rapidly with increase of v″ for canal rays than it does for electrons.

The relative intensities within the three principal sequences ($\Delta v = 0, 1, 2$) are more clearly shown in fig. 3. Here the strongest band of each sequence is put equal to 10. Comparing the curves on fig. 2 and 3 representing the average relative intensities of the auroral bands with those of canal rays and the neg. glow, we notice that the auroral intensities for the two sequences

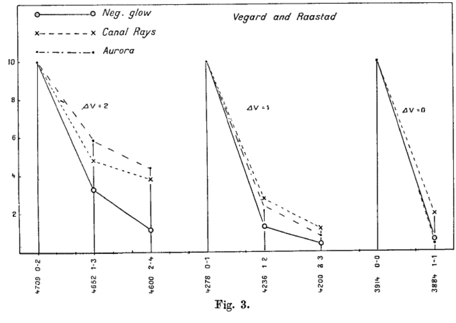

Fig. 3.

$\Delta v = 1$ and 2 agree best with the canal ray curves. In the case of the sequence $\Delta v = 0$, the auroral intensities agree perfectly well with those of the neg. glow, while the relative intensity of the (1—1) bands in the case of canal rays, is about three times greater than that of the aurorae.

§ 4. THE ATOMIC LINES IN THE CANAL RAY SPECTRUM

The wave length of the atomic nitrogen lines which appear in the canal ray spectra (cfr. Ib on the plate) have been measured and identified. The results are given in table III.

Table III.

Atomic Nitrogen Lines in Canal Ray Spectrum.

λ Obs.	Interpretation	λ in Aurorae
5699	5710,8 5686 5679 5676 NII	5677 NII
5005	5007,3 5005,1 5002,7 5001,5 5001,1 NII	Probably 5006,7 OIII, Nebulium
4640	4643,1 NII 4641,9 NIII 4640,4 NIII	Masked by the neg. band 4652
4628	4630,6 NII	4633 NII
4528	4530,0 4529,4 NII	4535 ε (3—15)
4431	4432,7 NII	4434 NII
4240	4241,8 NII	Masked by neg. band 4236
4175	4176,2 NII	4176 NII. ε (3—14)
4041	4043,5 4041,3 4039,0 NII	4042 NII
3960	3955,9 NII	3957 NII

As the somewhat broad band heads were used as lines of reference, the accuracy of the wave-length measurements is not so high as it might have been by means of sharp standard lines.

All the lines measured can be referred to the NII-spectrum originating from the N^+ ion. In the case of the line 4640 also NIII lines from N^{++} may come into consideration. To each of the two lines 5699 and 5005 corresponds a group of NII lines falling so close together that they could not be separated by the spectrograph used.

In the last column are put up the auroral lines which might possibly be identical with the NII lines from the canal ray spectrum.

In th auroral spectrum we either find a corresponding line or one falling close to a strong band.

With regard to the group of NII lines between 5001 and 5007 Å we have often observed and measured auroral lines in this interval. The wave-length differs in individual cases quite considerably, and the difference is so great that it is not likely due to errors.

The values given in previous publications are collected in table IV.

Table IV.

Obs.	Interpretation given	Remark
4998,0	N	Paper No. 2, 1932
5002,6	NII (5002,7)	» » 16, 1933
5001 . . .	NII	» » 17, 1933
5003	NII	» » 18, 1938
5006,8[1]........	OIII, Nebul	» » 19, 1941
5006,7[1]........	OIII, »	» » 20, 1944

[1] Error less than 1 Å unit.

The values given in the two last publications from 1941 and 44 are derived from spectrograms of considerable dispersion, and giving a weak but sharp line. As these values are derived from 9 such spectrograms the error is probably not greater than 0,2 Å and the identification with the OIII nebulium line is well founded.

On account of the great variability of the auroral spectrum it is quite likely that also lines of the NII group (5001—5007) may appear.

§ 5. VARIATIONS OF INTENSITY DISTRIBUTION OF THE NEGATIVE BANDS BY CHANGE OF THE ENERGY OF THE EXCITING ELECTRIC RAYS

a. Excitation by Electrons.

Spectrograms from the negative glow for a pressure 0,04 mm Hg and discharge potential 14000 volts, were compared with spectrograms from the negative glow at a pressure 0,5 and potential 3500 volts. The spectra showed considerable differences with regard to the intensity distribution of the neg. bands.

The results are given in table V.

The increase of electron velocity and descrease of pressure have the effect of producing a relative enhancement of the bands of higher vibrational quant numbers.

Table V.

	v'—v''	Intensities	
		p = 0,04 mm, V = 14000	p = 0,5 mm, V = 3500
	0—0	2500	2500
Δv = 1	0—1	1500	1325
	1—2	200	130
	2—3	70	24
	3—4	45	9
Δv = 2	0—2	300	275
	1—3	100	70
	2—4	35	16
	3—5	30	12
	4—6	27	8

b. Influence of Canal Ray Energy.

In order to study the influence of the canal ray energy on the intensity distribution of the negative bands, we have taken a series of canal ray spectrograms corresponding to discharge potentials varying from 8500 to 26000 volts. We took 6 such series. The relative band intensities were measured for each of these series.

The object of these experiments was to find out whether the relative intensity of the bands within a sequence varies with the energy of the canal rays which is measured by the discharge potential V. Our measurements have been carried out for the two sequences v'' — v' = Δv = 1, and 2.

For a given sequence the relative intensity of a band is a function of v' and V. We measure for a given tension V_0, the relative intensities corresponding to v' = 0, 1, 2 etc., for a given sequence and get:

$$I(0)_{V_0},\ I(1)_{V_0},\ I(2)_{V_0}$$

Then spectrograms of the same bands are taken at a tension V_1, and we get the intensities

$$I(0)_{V_1},\ I(1)_{V_1},\ I(2)_{V_1}$$

Then for two bands corresponding to v' = 0 and v' = v'$_1$ we form the proposition:

$$\left(\frac{I(0)}{I(v'_1)}\right)_{V_0} : \left(\frac{I(0)}{I(v'_1)}\right)_{V_1} = D(v'_1, V_1) \quad \ldots (1)$$

In the case of the sequences Δv = 1 we have only considered the ratio $\left(\frac{I(0)}{I(1)}\right)$ of the two bands (0—1) and (1—2) as a function of V.

For the sequense Δv = 2 we have found the two ratios $\left(\frac{I(0)}{I(1)}\right)$ and $\left(\frac{I(0)}{I(2)}\right)$ as function of the tension. From the equation (1) we see that $V_1 = V_0$ gives $D(v_1', V_0) = 1$. V_0 is put equal to 8500 volts which is the smallest potential used.

The values found for D as a function of V for each of the 6 series of spectrograms are in good agreement, and in table VI we only give the mean values for the two sequences measured.

Table VI.

Potential V In Volts	Sequence Δv = 1	Sequence Δv = 2	
	D (1, V)	D (1, V)	D (2, V)
8500	1 000	1 000	1 000
12400	0,966	0,975	1,021
14000	0,998	0,990	1,044
18200	0,883	0,862	0,896
22000	0,874	0,834	0,892
26000	0,815	0,768	0,795

We see from the table that *the ratio D decreases with the increase of canal ray energy.* Taking into account the expression for D (eq. 1) *this means that an increase of the canal ray energy will produce an increase of the relative intensity of the bands of higher vibrational quant number within a sequence.*

The influence of the canal ray energy on the intensity distribution of bands within the two sequences is illustrated in fig. 4. To facilitate the understanding of the diagrams the double rations (D) have been given explicitly in terms of the vibrational quant numbers v′ and v″.

§ 6. INTENSITY DISTRIBUTION WITHIN THE NEG. GROUP IN NITROGEN-HELIUM MIXTURES

Spectra were first taken of the negative glow from a discharge through pure N_2. The potential was 3500 volts pressure 0,5 mm Hg.

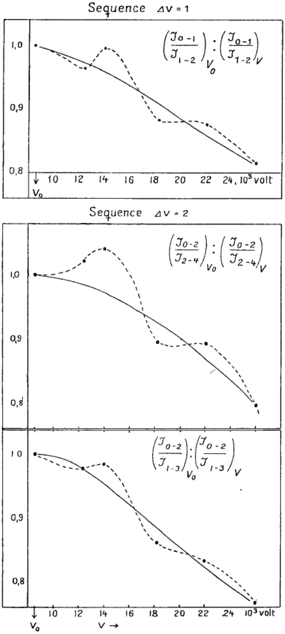

Fig. 4.

Then similar spectrograms were taken at the same tension and total pressure from a mixture of 10 % N_2 and 90 % He. In both cases we used the red sensitive Agfa Isopan ISS plates.

One of the spectrograms from pure N_2 and one from the ($N_2 + He$) mixture are reproduced on the plate No II a and II b.

The results of our intensity measurements of the neg. bands are given in table VII and illustrated in fig. 5.

In the discharge, where most of the gas consists of He, the neg. nitrogen bands from N_2^+ ions which require an exitation energy of about 19,6 e. Volts, will be mainly excited by collisions of the second kind between N_2-molecules and He-atoms in one of the metastable states.

Then the results of table VII and fig. 5 show that excitation by He-atoms in a metastale state produces a relative enhancement of the bands of high vibrational quant numbers v′ when compared with that obtained by excitation with swift electrons. The distribution produced by He-collissions is similar to that produced by canal rays.

Table VII.

	Ω'—Ω''	(Å)	I ($N_2 + He$)	I (N_2)
Δv = 0	0—0..	3914	2500	2500
	1—1..	3884	490	285
Δv = 1	0—1..	4278	1120	1325
	1—2..	4236	210	130
	2—3..	4199	60	24
	3—4..	4167	30	10
Δv = 2	0—2..	4709	250	275
	1—3..	4652	95	70
	2—4..	4600	30	15
	3—5..	4554	25	12
	4—6..	4516	20	8

§ 7. COMPARISON WITH RESULTS FOUND BY OTHER INVESTIGATIONS

Smyth and Arnott (14) have compared the intencity distribution of the neg. N_2-bands produced by canal rays, with that produced by

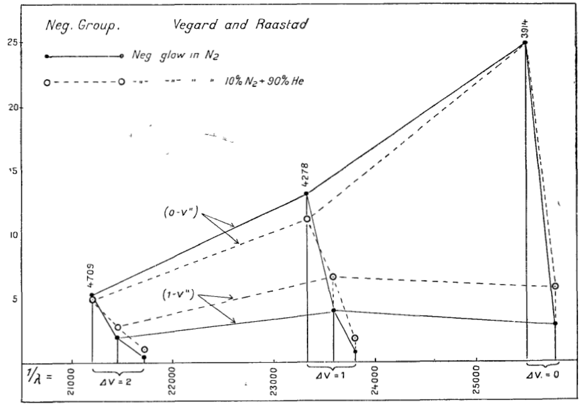

Fig. 5.

electrons of 700 e. volt energy. Duffendack, Revans and Roy (15) have compared the intensity distribution of the luminescence from a low voltage arc in one case formed in pure N_2 and in another in a mixture of N_2 and He. Their results are illustrated by the diagrams fig. 6 and fig. 7, constructed in the same way as fig. 2 and 5.

Their intensity distributions differ from ours with regard to the relative intensities found for the bands of the vibrational series (0—v″) and (1—v″). We found a more rapid diminution of intensities with increasing v″.

In the papers referred to (14, 15) it is not stated that the relative intensities they give of bands of different wave-length mean relative energies. Even if they have not determined relative energies by means of light sources of known energy distribution, the energy changes which are obtained under different conditions of excitation can still be estimated, and we see that their spectra which are excited by electrons, canal rays and by collisions with He-atoms in the metastable states, show very pronounced differences of the same type as those found by our measurements.

The excitation produced by canal-rays or collisions with excited He-atoms, *has the effect of increasing very considerably the relative intensity of bands of the greater vibrational quant-numbers* (v′) *of the upper electronic state, when compared with the intensity distribution produced by electrons.*

§ 8. APPLICATIONS TO THE AURORAL LUMINESCENCE

Returning to table I showing the peculiar intensity distribution of the negative bands within the sequences Δv = 1 and 2 of the auroral spectrogram obtained by Störmer, the question arises: Can the excitation experiments dealt with in this paper help us in explaining the low rate of decrease with increase of v′ of the auroral bands of the two sequences?

Størmer's spectrogram corresponds to very high auroral rays situated in an altitude interval between 400 and 650 km, where the gas density is so extremely small that collisions of the second kind between neutral N_2-molecules and some

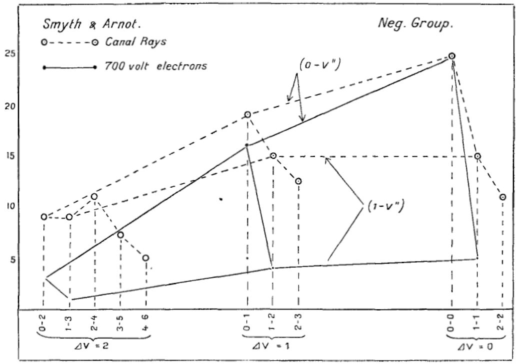
Smyth & Arnot.
Neg. Group.
o- - - - -o Canal Rays
•———• 700 volt electrons
(0-v")
(1-v")
25
20
15
10
5
0-2
1-3
2-4
3-5
4-6
0-1
1-2
2-3
0-0
1-1
2-2
ΔV = 2
ΔV = 1
ΔV = 0

Fig. 6.

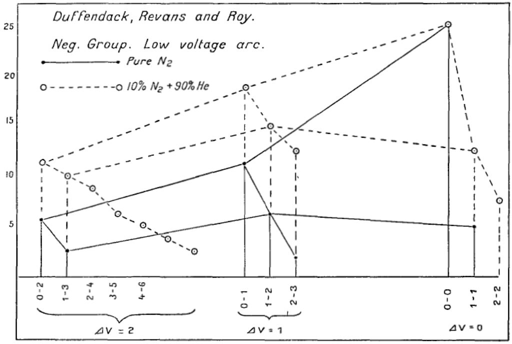
Duffendack, Revans and Roy.
Neg. Group. Low voltage arc.
•———• Pure N2
o- - - - - - - -o 10% N2 + 90% He
25
20
15
10
5
0-2
1-3
2-4
3-5
4-6
0-1
1-2
2-3
0-0
1-1
2-2
ΔV = 2
ΔV = 1
ΔV = 0

Fig. 7.

other molecules or atoms in a metastable state can hardly come into consideration.

On the other hand, it is quite likely that the canal ray effect will give us the true explanation of the intensification in the auroral luminescence of bands of high vibrational quant-number (v′) of the upper electronic level.

In the experiments the canal ray effect was produced by singly ionised nitrogen atoms. It is, however, to be expected that also positive rays of other ions will produce similar effects.

According to Vegard's (21) theory of the solar corona, the bundles of solar electric rays which produce aurorae and prominent types of magnetic disturbances, consist of electrons neutralised by positive ions—particularly protons and other ions of great specific charge (24). In order that electron rays shall penetrate down to an altitude of say 80—100 km an energy of the order of 10—20 KeV will be sufficient. If the energy of the accompanying positive ions is of the same order of magnitude—or probably smaller—the solar positive ions will be absorbed in the very highest strata of the auroral region, where they excite auroral luminescence.

In accordance with this view regarding the constitution of the solar electric ray bundles, Vegard found in 1939 (22, 23) that the hydrogen lines occasionally appeared in the auroral spectrum, but, as a rule, were absent, thus indicating that showers of hydrogen entered into the atmosphere.

This result has been confirmed by a number of spectrograms taken with spectrographs of considerable dispersion. In some cases it was found that the $H\beta$-line was displaced towards shorter waves through Doppler effect, showing that hydrogen atoms were mowing into the atmosphere with velocities of the order of 200—300 Km/sek.

The study of the intensity variations of the sodium lines in aurora, night sky and twilight, indicates that sodium ions, too, occasionally enter the atmosphere. We must therefore expect that a great part of the auroral luminescence at very high altitudes is occasionally excited by positive rays and that they will produce negative bands with an intensity distribution different from that produced by electrons, and characterised by the enhancement of the bands of high vibrational quant-numbers (v′) and give a spectral type like that of table I observed by Störmer and collaborators from bluish rays at altitudes above say 400 km.

Thus this spectral type gives new evidence of the correctness of Vegard's view regarding the solar corona and the solar electric ray-bundles.

SUMMARY

1. It is pointed out that the intensity distribution within a rotational series from negative nitrogen auroral bands gives a means of determining an upper limit for the temperature in the auroral region and that this intensity distribution and the resultant temperature keeps fairly constant.
2. On the other hand, the relative intensities of vibrational bands, e.g. within the neg. group, may vary considerably. Thus a spectrogram obtained by Störmer from bluish rays at altitudes between 400 and 650 km shows an extraordinary intensity distribution of vibrational bands of the neg. group. Within a sequence, the bands of higher vibrational quantnumbers are considerably enhanced.
3. The temperature measurements show that this peculiar intensity distribution of vibrational bands cannot be due to change of temperature, but must result from changes in the excitation proess.
4. In order to find a possible explanation of these variability effects, we have investigated the intensity distribution of bands within the neg. nitrogen group under different conditions of excitation.
5. The intensity distribution of neg. bands has been determined for the neg. glow (cathode ray excitation) and canal rays for different discharge potentials) or different energies of the exciting rays). Further spectra from the neg. glow of a discharge from pure N_2 have been compared with spectra taken by the same tension and total pressure from a mixture of 10 % N_2 and 90 % He.
6. Compared with the spectrograms of the negative glow, we found that within a given sequence the intensity of the bands of higher vibrational quant-number are considerably increased in

canal rays, with increasing ray velocity and in *He*-mixtures. As far as a comparison is possible, our results agree with those of Smyth and Arnott and by Duffendack, Revans and Roy.

7. The peculiar intensity distribution sometimes found from the aurorae at high altitudes is explained by means of the observed canal ray effect. Such an effect is to be expected from the fact found by Vegard, that hydrogen occasionally enters the atmosphere. According to the constitution of the bundles of electric solar rays which follows from Vegard's theory of the solar corona, the bundles consist of a mixture of electrons and positive ions. While the electrons get down to say 90—100 km, the positive rays will be absorbed very high up in the ionosphere, and there they produce an intensity distribution of the type shown by Störmer's spectrograms from aurorae at altitudes above 400 km.
8. A number of NII lines appearing in the canal ray spectrum, are probably present in the auroral luminescence.

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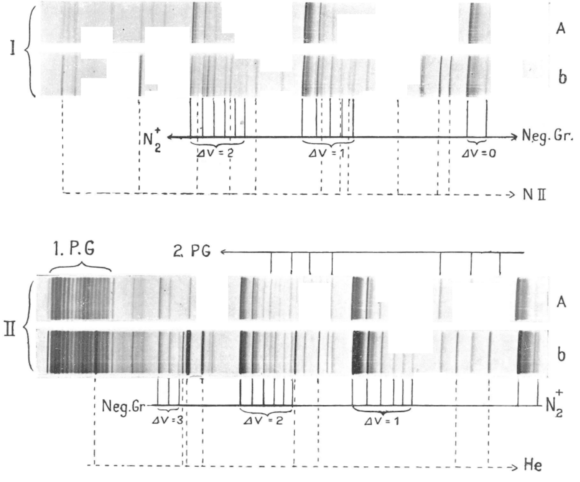
PLATE

I : Discharge Pot. 14000 volt, Pressure 0,04 mm Hg

A : Neg. Glow, b : Canal Rays

II : Discharge Pot. 3500 volt, Pressure 0,5 mm Hg

A : Pure N_2. b : 10% N_2 + 90% He



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