CONTINUED INVESTIGATIONS ON THE TEMPERATURE OF THE UPPER ATMOSPHERE DETERMINED BY MEANS OF BANDS APPEARING IN THE AURORAL SPECTRUM

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(Manuscript received 15th February 1935).

1. Aim and purpose.

More than ten years ago one of us suggested that the nitrogen bands appearing in the auroral spectrum would give us means of determining the temperature in the auroral region — which means from say 70 km. and upwards as far as the auroral luminescence appear with sufficient brightness for spectographic observations.

During the years 1923—1926 a number of auroral spectrograms were obtained with a large glass spectrograph, and on some of these spectrograms the negative nitrogen band 4278 appeared with a good definition and a suitable density for photometric measurements. An intensity scale was photographed on each of the plates.

The problem of determining the temperature from the intensity distribution within the R-branch of the negative nitrogen bands as well as the results obtained from the spectrograms referred to, were dealt with by one of us in two previous papers (1,2). As referred to in these papers an "absolute" determination of the temperature by means of the intensity distribution within the R-branch, can be made when we have spectrograms of the bands taken with so large dispersion, that the individual rotational components of the R-branch appear separated.

The dispersion of the spectrograph used in the region of the band 4278 (27 Å/mm) was just too small to give separation, and the R-branch had the appearance of a continuous band. It was, however, pointed out that the intensity distribution and the development of this continuous band must vary in a definite way with temperature, and suitable methods for the determination of the temperature from continuous R-bands were worked out and applied to the auroral spectrograms to be treated.

The methods adopted for continuous bands are naturally closely related to those to be applied in the case, when the components are separated.

The intensity distribution of the components of a branch is determined by the distribution of rotational energy of the molecules in the excited state, which forms the upper electronic and vibrational level for the formation of the bands in question.

As pointed out by one of us in previous papers (1, 2, 3) the distribution of rotational energy in the excited state may differ from that which the molecules possess before excitation, or the one, which corresponds to the temperature of the gas. How far the distribution of the rotational energy of the excited molecules will differ from that of the surrounding gas will depend on the type of excitation process.

If the light is produced from thermal excitation, or if the temperature or pressure is so high that the average time between successive collisions of a molecule is small compared with the average time which the molecule remains in the excited state, then the molecules in this state will have a Maxwellian distribution of rotational energy determined in the wellknown way, from the temperature of the gas. If, however, the light is produced by some sort of electric rays (or rays of high frequency) shooting into a gas of fairly low temperature and pressure, the distribution of rotational energy may be considerably effected by the excitation process, and the apparent band temperature may differ from that of the surrounding gas.

These questions have been treated by one of us in the previous papers mentioned, and particularly in a recent paper (3), which also gives the results of a number of laboratory experiments. The object of these experiments may be shortly stated as follows:

The apparent band temperature was determined from light sources produced by shooting electric rays (cathode rays and canal rays) into a chamber containing nitrogen of low pressure, and it was compared with the temperature of the surrounding gas (vessel). The ray chamber had either room temperature or that of liquid air. It was found that the influence of the cathode ray excitation on the distribution of rotational energy was smaller than the possible error of the experiments, while the canal rays had a considerable effect, corresponding to an increase of say 80°—90° C. in the apparent band temperature.

In dealing with the problem of determining the temperature from band spectra, we have to proceed in the following way:

We measure the intensity distribution of the components within the band branch selected, and we compare it with the theoretical expression corresponding to a Maxwellian distribution of rotational energy. If the observations approximately obey the theoretical law, the intensity distribution of the band define an "apparent band temperature," which characterize the distribution of rotational energy in the excited state. This apparent band-temperature, however, may be different from (as a rule larger than) the true temperature of the excited gas. The apparent band temperature will give us an upper limit to the temperature of the surrounding unexcited gas and it will be a matter for special considerations to find out to what extent, under the conditions present, the apparent band temperature may be higher than that of the gas.

In the case of the R-branch of the negative nitrogen bands, the intensity distribution is given by the relation:

$$\log \text{nat}\ (I_K/K) = -\varkappa K\ (K+1) \qquad (1\,a)$$

I_K is the intensity of the component for which the rotational quant number of the initial state is K.

$$\varkappa = \frac{h^2}{8\pi^2 JkT} \qquad (2\,a)$$

h is Plancks constant, J the moment of inertia corresponding to the upper level $= 13{,}4\ 10^{-40}$ and k is Boltzmanns constant.

When we use ordinary logaritms equation (1a) takes the form:

$$\log_{10}\ (I_K/K) = -\varkappa' K\ (K+1) \qquad (1\,b)$$

where:

$$\varkappa' = \varkappa \log_{10} e = 0{,}43429\ \varkappa \qquad (2\,b)$$

We measure I_K and if the curve $\log\ (I_K/K) - K\ (K+1)$ is nearly a straight line, the slope of this line gives us the constant $\varkappa'$ from which the temperature is found by the relation:

$$T = \frac{1{,}2855}{\varkappa'} \qquad (3)$$

We can also find the temperature by determining the quant number of the strongest component. From the condition that in equation (1 a) I_K shall be a maximum, we find:

$$\varkappa\ K_m\ (2\ K_m + 1) = 1 \qquad (4\,a)$$

$$T_m = 2{,}96\ K_m\ (2\ K_m + 1) \qquad (4\,b)$$

It is to be noticed that the value (K_m) which satisfies equation (4a) needs not be a whole number, but (K_m) may be any positive quantity.

When the rotational components of the R-branch are not separated, we adopt the following procedure. If we have a comparison spectrum with known lines near the R-branch, we find the position on the photometer curve of a selected number of R-components of known rotational quant number. For each value of K we measure the corresponding intensity I_K.

Just as in the case of separated components we get a number of intensities I_K and corresponding quant numbers K. Either we draw the curve $[\log\ (I_K/K) - K(K+1)]$, and determine $\varkappa'$, which by equation (3) gives us the temperature T, or we plot (I_K) as a function of K and find the value K_m, which corresponds to the point of maximum of the curve $(I_K - K)$. From K_m the temperature is determined by means of equation (4 b).

It is perhaps more convenient to proceed in such a way that we first select a number of suitable points and corresponding intensities on the photometer curve. Then by means of some comparison line, we determine the corresponding K-values. In this case (K) must be regarded as a quantity which varies continuously. Within the error of measurements both procedures should give the same temperature.

When the auroral spectrograms to be dealt with in the present paper were taken, a glass plate with an intensity scale (a Zeiss-Stufenfilter) was placed in front of the slit. An ordinary comparison spectrum therefore could not be taken and we have to use the head of the P-branch as a comparison line.

Although the wavelength of this head has been determined with considerable accuracy from spectrograms, which were taken with the same spectrograph, still this value may contain some error, which will produce a corresponding systematic error in the temperature measurement. With the fairly large dispersion used, this error should be very small.

We have also to consider the fact, that in the case that the components do not appear separated, the photographic effect of one component will partly cover that of its neighbours. If the components were equidistant, this overlapping would tend to give a too high value of the apparent band temperature as measured from the $\varkappa$-curve.

In fact the components of the R-branch are not equidistant, but the interval increases somewhat with increasing quant number. The photographic overlapping therefore is most marked for small quant numbers, and consequently it should produce a diminution of the measured band temperature.

As already shown by one of us in a previous paper (1,2), the band temperature obtained by means of the method here given, will not differ much from the true temperature of the excited molecules. This was shown by comparing with results obtained from spectra of the same band (4278) corresponding to luminiscence produced by cathode rays in nitrogen of known temperature. Similar investigations have been undertaken during the last two years by Vegard and his collaborators Ringdal and Benedicks, and the results were discribed in a paper recently published (4).

They used a quártz spectrograph which at the band 3914 had a dispersion of 68 A/mm. Experiments were undertaken at room temperature and at that of liquid air. The apparent band temperature was first determined in the way described by means of the curves (log $(I_K K) - K(K+1)$). Then the intensity distribution was corrected for overlapping due to the variation in the interval between successive components.

The "true" intensity $I'(K)$ was derived from the measured intensity $I(K)$ by means of the simple relation:

$$I'(K) = I(K)\, d(K) \tag{5}$$

where $d(K)$ is the interval between successive components corresponding to the quant number (K). The correction for overlapping according to formula (5) amounts to about 19 per cent of the absolute temperature.

It was found, however, that the intensity distribution corrected for this type of overlapping effect gave too large temperatures, while the uncorrected distribution gave nearly the true temperature of the source. This means that the various sources of error happen to cancel each other approximately, and within the error of our measurements, we therefore obtain the right band temperature by simply measuring the temperature from the R-branch, as if the components were separated.

When we remember that the errors due to overlapping and to uncertainty regarding the position of the P-head diminish when the dispersion increases, we should obtain a fairly correct temperature from the auroral bands by treating them as if the individual components were separated; for the dispersion of the auroral band 4278 is more than twice that of the bands measured by Vegard, Ringdal and Benedicks.

In order to state more definitely the accuracy with which the auroral band temperature is measured, we intend to take spectra of the 4278 band from sources of known temperature with the spectrograph used at Tromsö.

2. The Spectrograms.

The spectrograph used was described by one of us in previous papers [cfr. paper 1, plate IV, Fig. 1 or the papers (5) and (6)].

In addition to the intensity scale obtained by means of the Zeiss "Stufenfilter" put in front of the slit, another scale was photographed on the same plate by taking a series of spectra from a constant light source with exposures varying in the proportion 1 : 2 : 4 : 8.

During 1933 and the spring 1934 the following four successfull spectrograms were taken:

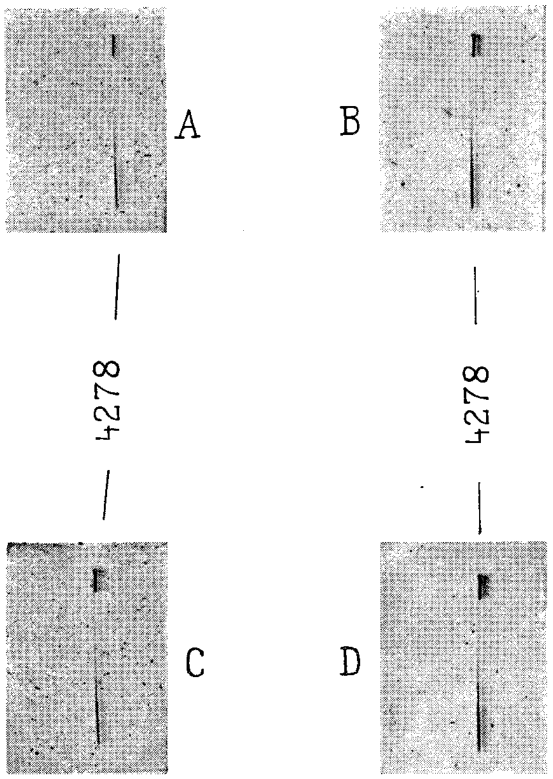

Fig. 1 a.

Spectrogram A.

Exposed on Ilford Double *x*-press plate from $^{15}/_{2}$—$^{20}/_{2}$ 1933. Effective exposure 6 hours with northlight.

Spectrogram B.

Exposed on Ilford Double *x*-press plate from $^{21}/_{2}$—$^{26}/_{2}$ 1933. Effective time of exposure 18—19 hours.

Spectrogram C.

Exposed on Ilford Double *x*-press from $^{17}/_{3}$—$^{7}/_{4}$ 1933. Effective time of exposure 9 hours.

Spectrogram D.

Exposed on Ilford Double *x*-press from $^{3}/_{3}$ to $^{23}/_{3}$ 1934. Effective time of exposure 21 hours.

The same slit aperture was used by all spectrograms. In all cases the band 3914 was too faint to be measured and only the band 4278 is suitable for temperature measurements. Photographic reproductions of this band as it was obtained on the four spectrograms are shown in fig. 1 a. The corresponding photometer curves are given in Fig. 1 b.

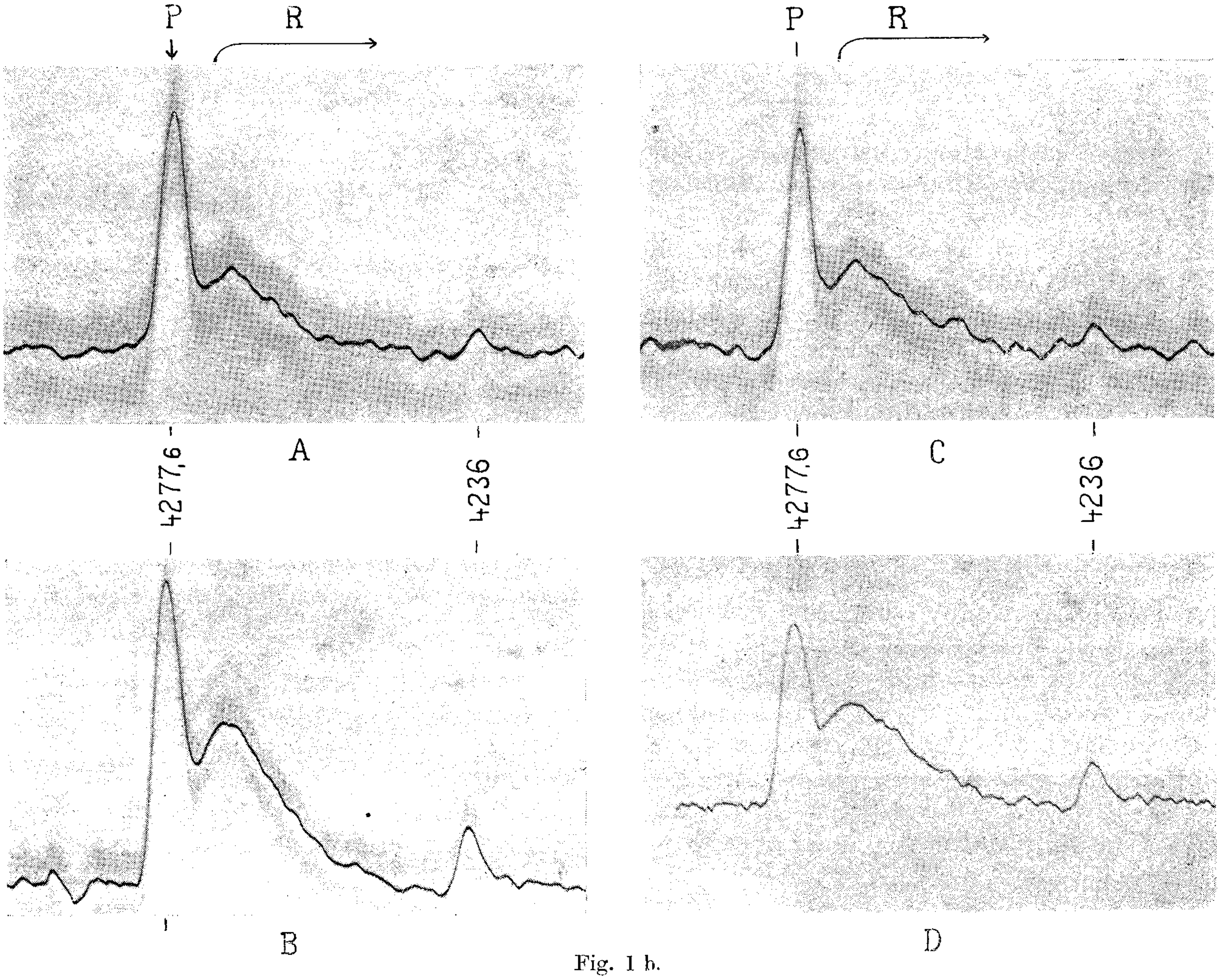

Fig. 1 b.

Table 1.

Spectrum A.

K	I	I'	$K(K+1)$	log I/K	log I'/K
3,80	19,4	19,4	18,2	1,71	1,71
5,05	21,7	22,3	30,6	1,63	1,645
7,20	19,9	23,3	59,0	1,44	1,51
9,20	16,2	19,7	93,8	1,24	1,33
10,95	12,2	17,1	130,9	1,05	1,195
12,60	8,2	12,2	171,4	0,81	0,985
14,15	5,0	7,9	214,4	0,55	0,75
$K_m = 5,5$	$K'_m = 6,5$		$T_1 = 195°$		
$T_m = 195°$	$T'_m = 267°$		$T_2 = 229°$	$T' = 266$	

Table 3.

Spectrum C.

K	I	I'	$K(K+1]$	log I/K	log I'/K
3,20	37,8	34,7	13,4	1,07	1,035
4,90	43,7	44,7	28,9	0,95	0,96
7,00	37,8	43,2	56,0	0,73	0,79
9,00	30,6	39,3	90,0	0,53	0,64
10,80	24,3	33,3	127,4	0,35	0,49
12,50	17,1	25,8	168,8	0,14	0,315
13,30	13,8	21,6	190,2	0,02	0,21
$K_m = 5,1$	$K'_m = 6,1$		$T_1 = 171°$		
$T_m = 169°$	$T'_m = 238°$		$T_2 = 246°$		$T' = 290°$

Table 2.

Spectrum B.

K	I	I'	$K(K+1)$	log I/K	log I'/K
3,00	39,0	35,5	12,0	2,11	2,07
4,90	45,0	45,7	28,9	1,96	1,97
6,70	44,0	51,3	51,6	1,82	1,88
7,60	40,0	47,9	65,4	1,72	1,80
8,50	35,0	44,7	80,7	1,62	1,72
10,00	28,0	38,0	110,0	1,45	1,58
11,05	24,0	33,9	133,2	1,34	1,49
12,40	19,0	28,8	166,2	1,19	1,37
13,70	13,5	21,4	201,4	0,99	1,19
15,10	9,0	15,1	243,1	0,78	1,00
$K_m = 5,45$	$K'_m = 6,5$		$T_1 = 192°$		
$T_m = 192°$	$T'_m = 267°$		$T_2 = 240°$		$T' = 284°$

Table 4.

Spectrum D.

K	I	I'	$K(K+1)$	log I/K	log I'/K
2,90	109	99,3	11,3	1,575	1,53
4,80	119	123	27,8	1,40	1,41
6,50	110	121	48,8	1,23	1,27
9,00	89,0	114	90,0	1,00	1,105
11,00	70,0	98,0	132,0	0,805	0,95
11,90	58,3	85,1	153,5	0,69	0,855
13,10	47,9	72,8	184,7	0,56	0,745
14,15	40,3	63,9	214,4	0,455	0,655
15,30	31,6	52,5	249,4	0,315	0,535
16,70	22,9	41,5	295,6	0,15	0,395
$K_m = 4,83$	$K'_m = 5,8$		$T_1 = 157°$	$T'_1 = 190°$	
$T_m = 152°$	$T'_m = 216°$		$T_2 = 271°$	$T'_2 = 359°$	
			$T_3 = 328°$		

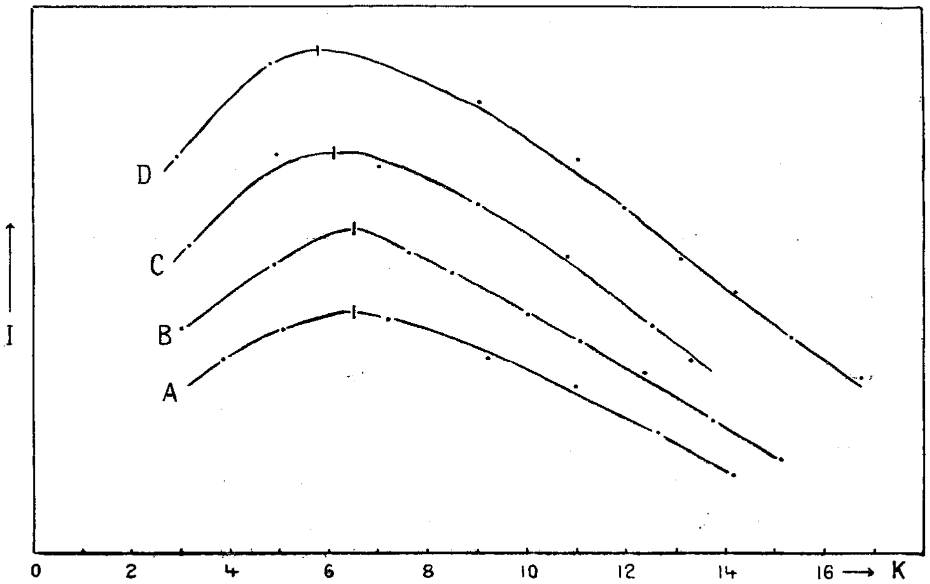

Fig. 2.

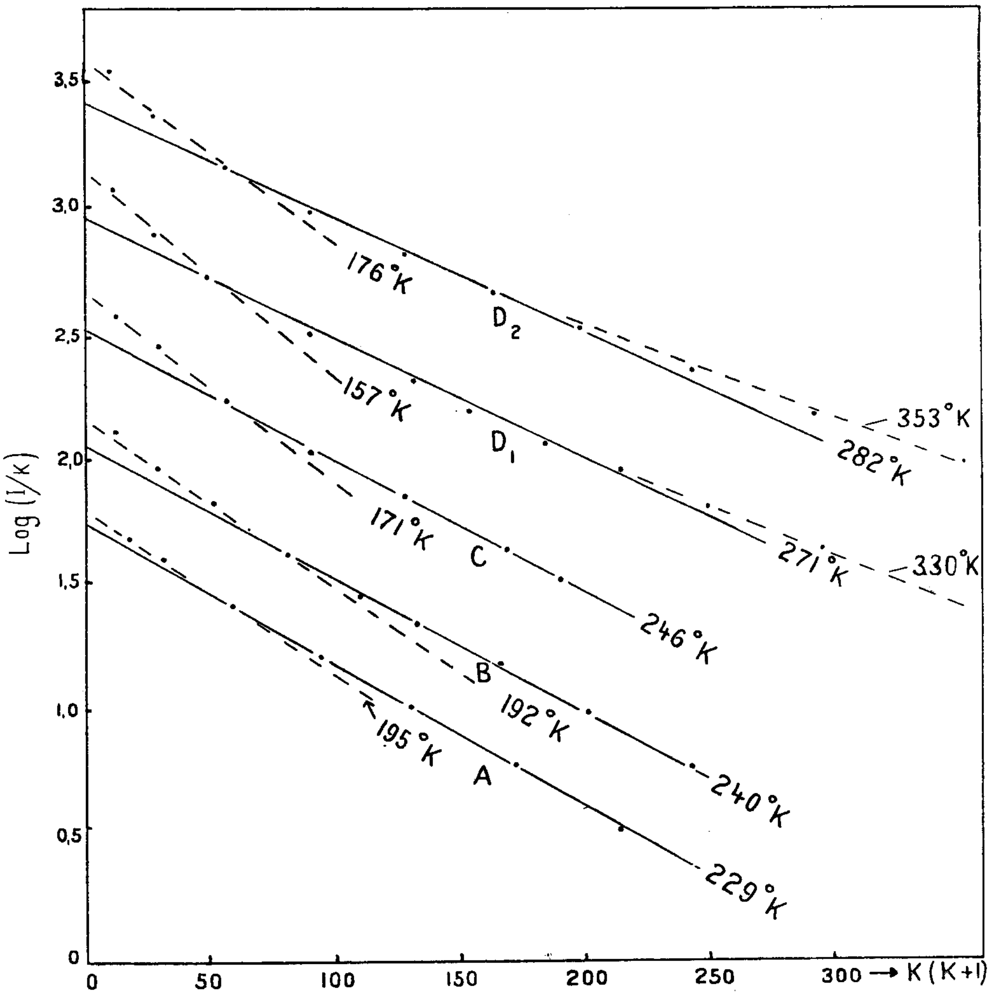

Fig. 3.

3. Results of the temperature measurements.

By means of photometer curves of our intensity scale, curves were constructed giving the relation between photometer deflection and intensity or rather log I.

On the *R*-branch of the photometer curves a number of points were selected and the corresponding K values found in the way described. For each selected point we further determine the intensity I (from the photographic intensity curve) and we calculate log (I/K) and $K\ (K + 1)$. The resulting values for each plate are given in the tables 1, 2, 3 and 4 for the four plates respectively. The intensity I as a function of (K), as given in the tables, are represented by the curves Fig. 2.

In order that the curves may appear well separated, the intensity scale has been varied from one curve to another. From these curves we determine the quant number K_m for which the intensity (I) has a maximum, and the temperature T_m is found from equation (4_b). The value of K_m and T_m are given at the bottom of each table.

By means of the values of $K\ (K + 1)$ and log (I/K) of the table we construct the $\varkappa'$-curves Fig. 3. These curves are not exactly straight lines, but they seem to consist of two, and in one case of three, straight lined parts giving $\varkappa'$-values $\varkappa'_1$, $\varkappa'_2$ and $\varkappa'_3$ and corresponding temperatures T_1, T_2 and T_3. These values are given at the bottom of each table.

In order to find an upper limit for the effect of photographic overlapping, we further determined an intensity (I') from equation (5).

For the 4278 band we have:

$$d(K) = d_0 + \alpha K \tag{6}$$

where $d_0 = 0{,}725\ \text{Å}$, $\alpha = 0{,}0615\ \text{Å}$. Knowing $d\ (K)$ we calculate $I'\ (K)$ and log (I'/K) for any value

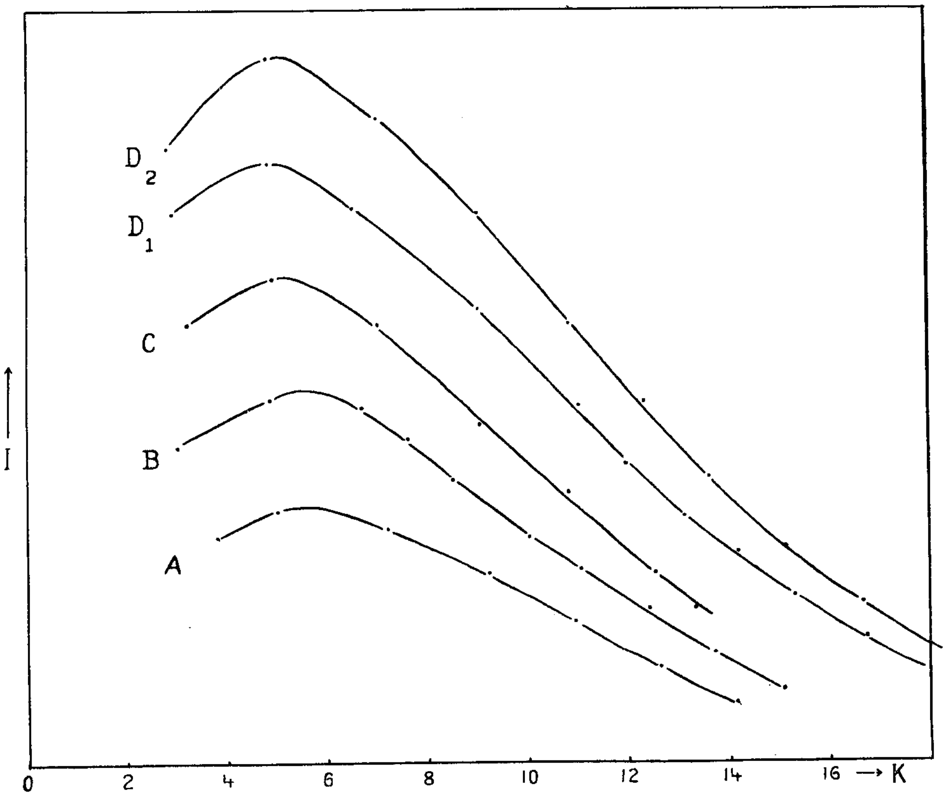
D2
D1
C
B
A
I
0
2
4
6
8
10
12
14
16 → K

Fig. 4.

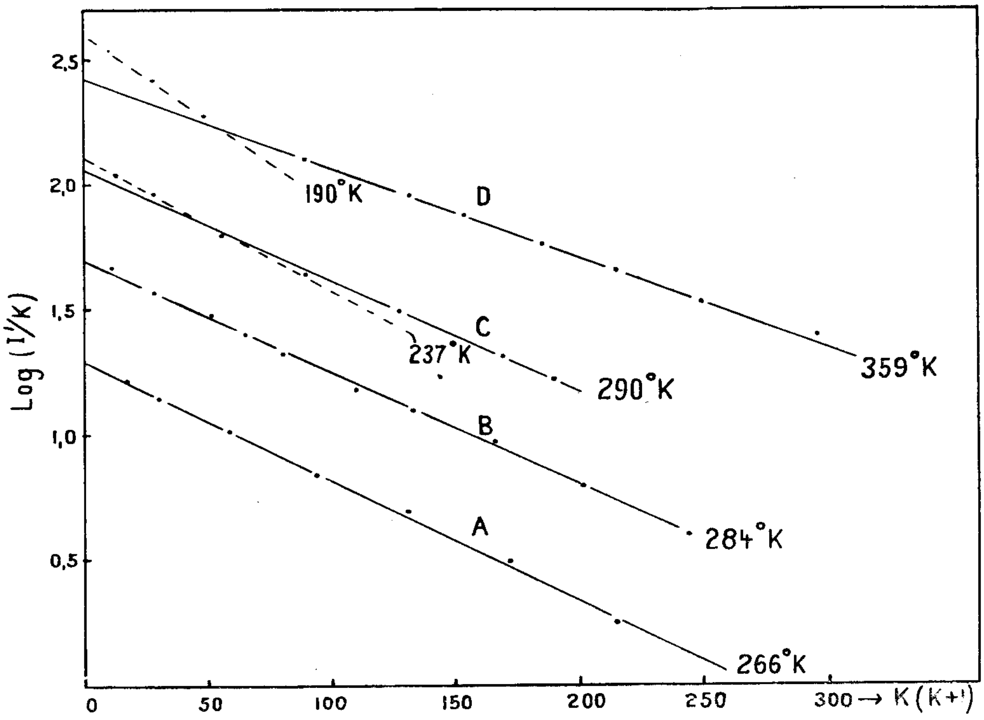
Log (I'/K)
2,5
2,0
1,5
1,0
0,5
0
50
100
150
200
250
300 → K(K+1)
190°K
D
237°K
C
290°K
359°K
B
284°K
A
266°K

Fig. 5.

of (I) and (K) and the resulting values are given in the tables.

The curves $(I'-K)$ are given in Fig. 4. From the position of their maxima, we find the quantities K'_m and T'_m.

The curves $[\log (I'/K) - K(K+1)]$ are given in Fig. 5. With the exception of plates C and D the curves are now approximately straight lines, defining one definite temperature for each band.

By means of the relations (5) and (6) we can determine the displacement of the maximum of (I') relative to that of (I) and the relation between T'_m and T_m is given by the equation

$$T'_m = \frac{d_m}{d_0} T_m \qquad (7)$$

where d_m is the interval between successive lines at the maximum point. The values of T_m' determined from equation (7) agree well with those found directly from the $(I'-K)$ curves. In order that the error of T_m shall not be transferred to T_m', we have preferred to measure T_m also directly from the intensity curves.

The temperatures derived from the position of the intensity maximum are collected in Table 5.

T_m is the temperature derived from the position of the maximum directly found from the spectrogram Fig. 2. T_m' and T_m'' are temperatures corrected for overlapping. T_m' is derived from the corrected intensity curves Fig. 4 and T_m'' is found from T_m by means of equation (7).

The temperatures found from the intensity distribution curves are collected in Table 6.

T_1, T_2 and T correspond to the intensity distribution directly measured leading to the $\varkappa$-curves of Fig. 3. T_1 is a low temperature indicated by the $\varkappa$-curve at small quant numbers, T_2 is a higher temperature indicated by the $\varkappa$-curve for large quant numbers.

Table 5.

Temperatures from intensity maximum.

Spectrum	T_m	T_m'	T_m''
A	195° K	267° K	286° K
B	192 »	267 »	280 »
C	169 »	238 »	241 »
D	152 »	216 »	214 »
Mean	177° K	247° K	255° K

Table 6.

Temperatures from intensity distribution.

Spectrum	T_1	T_2	T	T_1'	T_2'
A	195° K	229° K	218° K		266° K
B	192 »	240 »	215 »		284 »
C	171 »	246 »	218 »	237° K	290 »
D	157 »	271 »	238 »	190 »	359 »
Mean	179° K	246° K	222° K	178° K	300° K

T is the temperature obtained when we try to satisfy the relation between $\log (I/K)$ and $K(K+1)$ by one single straight line, drawn on Fig. 3 in such a way that it fits in with the observed points in the best possible way.

T_1' and T_2' are the lowest and highest temperature derived from the intensity distribution corrected for overlapping. (Fig. 5).

4. **Discussion of the results.**

It appears that the relation between $\log (I/K)$ and $K(K+1)$ as a rule is not satisfied by one single straight line. This result may be interpreted in various ways.

We might assume that the distribution of rotational energy is influenced by the excitation process in such a way that the Maxwell distribution law no longer holds. When we remember that the auroral spectrograms have been exposed during several nights, it is on the other hand quite possible that the temperature during the exposure may undergo variations.

If so the position of the intensity maximum will give us a temperature somewhat higher than the smallest temperature which the excited nitrogen have had during the exposure.

This apparent deviation from that intensity distribution which corresponds to a Maxwellian distribution of rotational energy, is particularly marked in the case of spectrum D. The $\varkappa$-curve for large quant numbers gives a temperature 330° which is 180° higher than the temperature obtained from the position of maximum intensity.

In order to verify this result we took a photometer curve from the other end of the band. The intensity curves are indicated by D_1 and D_2 in Fig. 2 and 3. They both lead to essentially the same result, namely that a considerable temperature variation has taken place during the exposure.

On account of the fact that the dispersion of the instrument is nearly so large that the individual components may appear separated, we should expect that the effect of overlapping is not so large as that expressed by the equations (5) and (7). This means that our correction for overlapping gives too large temperatures.

The band temperatures therefore must lay somewhere between T_m and T_m' or between T_1 and T_2',

In the papers previously published by one of us (1,2) the true band temperature was found comparing the auroral bands with spectra of the same nitrogen band taken in the laboratory at known temperatures and with a spectrograph of about the same dispersion as that used for the aurorae.

We found the auroral band temperature by comparing the position of the intensity maximum of the auroral band with that of the 4278 band taken at room temperature and at that of liquid air.

When we proceed in this way, we can compare intensity maxima and intensity distribution curves as they are derived from the directly measured intensities, and *the uncertain correction for overlapping will be superfluous.*

The correction obtained in this way for the auroral band temperature can be expressed by the following relation, which is in effect the one used in the previous publications (1), (2).

$$(T_m')_{\text{corrected}} = 1{,}057\ T_m + 38{,}3 \qquad (8)$$

According to Table 5 the average value of T_m is 177° K. This gives for the corrected value:

$$(T_m)_{\text{corr.}} = 225{,}^{\circ}4\ K.$$

As nearly as it can be stated at present, this temperature should give us the true average temperature of the excited nitrogen molecules in the auroral region.

We found in the previous papers referred to (1,2) that this corrected temperature derived from the position of the intensity maximum was approximately equal to the temperature derived directly from the intensity distribution ($\varkappa$-curves) without correcting for overlapping.

Within the limit of error this result also holds good for the present observational material. From Table (6) it appears that the average value of the temperature (T) derived from the uncorrected $\varkappa$-curves, Fig. 3 comes out equal to 222° K, which is nearly equal to the corrected value (225,4° K) found from the position of the intensity maximum.

As mentioned in the first paragraph of the present paper, the same rule has been found to hold by our laboratory experiments, and even for bands taken with a dispersion considerably smaller than that used for the auroral bands.

Various errors acting in different directions happen to cancel each other, so that the temperature derived from the intensity distribution directly measured gives — within the limit of error — the true band temperature.

In order to check our correction formula (8) and to increase the accuracy with which the temperature of the auroral region can be measured our investigations will be continued and with the spectrograph, used at Tromsö, we intend to take not only auroral bands, but also the negative nitrogen bands, emitted from sources of known temperature.

The observational material here treated consisting of four auroral spectrograms with necessary intensity scales on each plate thus leads to the result, that the average temperature of the excited nitrogen molecules in the auroral region should be:

$$225{,}4^{\circ}\ K \text{ or:}$$
$$-\ 47{,}6^{\circ} \text{ centigrades.}$$

This value is somewhat lower than that previously found which was — 30° C.

Although the results differ by about 17°, they place the band temperature on approximately the same level on the temperature scale. As already mentioned the temperature in the auroral region may undergo variations which are large as compared with the difference shown by average values obtained from our two series of measurements.

The question now arises, which is the lowest temperature which may exist in the normal not excited upper atmosphere?

This temperature may be considerably lower than that found to be the average temperature of the excited state. First of all the average must be somewhat higher than the minimum and secondly the minimum band temperature or the minimum temperature of the excited molecules may be larger than that of the surrounding normal atmosphere not struck by the solar electric rays.

The increase of the rotational energy and the corresponding increase of the apparent temperature due to the excitation process will depend on the nature of the electric rays. If they are mainly electron-rays, our experiments have shown that they only produce a very small change of the distribution of rotational energy, and the band temperature should be approximately equal to the true temperature of the unexcited surrounding atmosphere. If, however, the auroral luminescence is partly produced by positive rays with atomic carriers, the excitation will be accompanied by a considerable increase of the apparent band temperature.

In a previous paper (3) one of us showed that the excitation with canal rays may produce an increase of the apparent temperature of about 85°. Previous investigations by one of us (5) on the properties of the rays producing the aurorae led to the result that at any rate those types which show a pronounced radiant structure must be produced by electron rays, and if this holds for most aurorae, it would follow that the true temperature of the auroral region cannot be much lower than that found from the intensity distribution within the R-branch of the negative nitrogen bands.

In other words the average temperature in the auroral region — that means in an interval between 100—125 km. above the ground — should be approximately the same as that existing in the lower region of the stratosphere between say 15—30 km. above the ground.

In a paper recently published (6) *Rosseland* and *Steensholt* have tried to calculate the temperature of the auroral region from the intensity distribution found by Vegard for the *vibrational* bands of the negative nitrogen group appearing in the auroral spectrum. A simple consideration, however, might have shown, that their attempt necessarily would have to fail.

Except in the case of extremely high temperatures the intensity distribution of the vibrational bands will be mainly governed by the Franck-Condon principle, and in order to have any marked influence the temperature must be so large, that the energy taken up by each degree of freedom in the thermal motion, is of the order of magnitude of $(h\omega)$, where ω is the vibrational frequency. Putting $\omega = 2000$ cm.$^{-1}$ we find that a temperature of about 4000 K is required to make the average thermal energy of each molecule equal to $(h\omega)$.

The previous investigations of one of us regarding the temperature of the auroral region determined from the rotational bands had shown, however, that the temperature is less than $^1/_{10}$ of this amount, and its influence on the intensity distribution of vibrational bands must be negligible.

The deviation from the Franck-Condon distribution, due to temperature is difficult to determine exactly both experimentally and theoretically. The theoretical formulae given by Rosseland and Steensholt evidently breaks down at somewhat low temperatures. From the intensity distribution of vibrational nitrogen bands within the auroral spectrum given by Vegard (1) they deduce temperatures of several thousand degrees, which are about ten times too large. Their theory would also give temperatures of the order of thousand degrees in the case of vibrational bands actually emitted from a source maintained at the temperature of liquid hydrogen, or even liquid helium,

It is therefore not possible to determine the temperature of the auroral region from the intensity distribution of the *vibrational* bands.

Summary.

1. From February 1933 to end of March 1934 four successfull plates with spectrograms of the auroral band 4278 were obtained with a large glass spectrograph at the Auroral Observatory, Tromsö.
2. Intensity scales were obtained by means of a «Zeiss Stufenfilter» in front of the slit and by a separate intensity scale on the same plate taken with a constant source by varying the time of exposure.
3. The temperature was measured both from the position of the maximum on the intensity curve and from the law of intensity distribution.
4. The temperature was first found by treating the directly measured intensity as if the individual components were separated.

   Then we found an upper limit for the increase of the calculated band temperature due to photographic overlapping of the individual components.
5. The corrected temperature was found by comparing with spectra of the 4278 band, taken at known temperatures by spectrographs of about the same dispersion.
6. The intensity distribution curve of the R-branch differed in some cases considerably from that which corresponds to a Maxwellian distribution of rotational energy, and this deviation is probably due to changes of temperature taking place in the auroral region.
7. The average auroral band temperature of the excited molecules derived from the four spectrograms was found to be 225°,4 K or—47,6° centigrades.
8. The average band temperature is to be regarded as an upper limit of the temperature which exists without excitation. The amount by which the temperature of the normal not excited upper atmosphere may be smaller than the apparent band temperature, will depend on the excitation process.
9. The excitation with cathode rays produces very little change in the intensity distribution and the apparent temperature, while canal rays was found by Vegard to produce an increase of about 85° in the band temperature.
10. If the auroral light was excited by positive rays the true average temperature of the auroral region in a normal state might be considerably lower than ÷ 47,6° Centigrades, but according to Vegard most aurorae are produced by cathode rays and in that case the apparent band temperature should be approximately equal to the night temperature of the normal atmosphere in the interval between say 100 and 125 km.

In conclusion we wish to express our sincere thanks to Mr. S. Steensholt and Mr. H. Th. Ringdal for valuable assistance in connection with these investigations.

We are also indebted to Statens Videnskapelige Forskningsfond and Universitetets Jubileumsfond for granting us funds necessary for the performance of these investigations.

Physical Institute, Oslo.
The Auroral Observatory, Tromsö.

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Printed May 22nd, 1935.

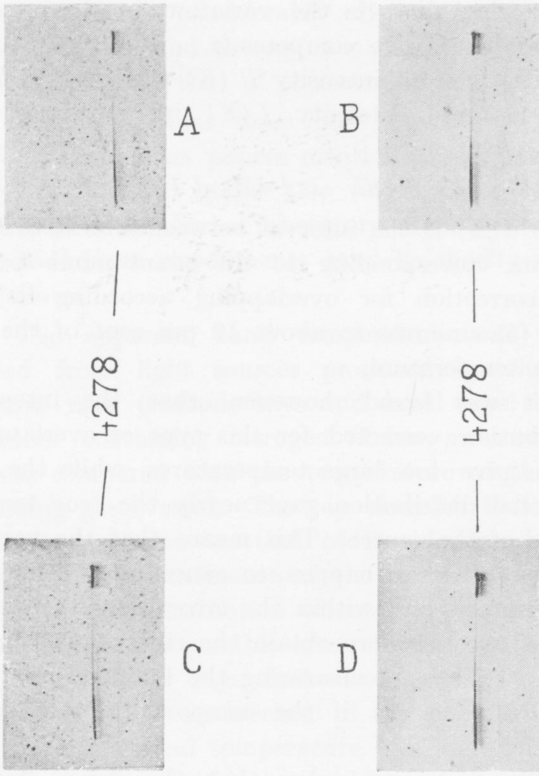

Fig. 1 a.

Spectrogram A.

Exposed on Ilford Double *x*-press plate from $^{15}/_{2}$—$^{20}/_{2}$ 1933. Effective exposure 6 hours with northlight.

Spectrogram B.

Exposed on Ilford Double *x*-press plate from $^{21}/_{2}$—$^{26}/_{2}$ 1933. Effective time of exposure 18—19 hours.

Spectrogram C.

Exposed on Ilford Double *x*-press from $^{17}/_{3}$—$^{7}/_{4}$ 1933. Effective time of exposure 9 hours.

Spectrogram D.

Exposed on Ilford Double *x*-press from $^{3}/_{3}$ to $^{23}/_{3}$ 1934. Effective time of exposure 21 hours.

The same slit aperture was used by all spectrograms. In all cases the band 3914 was too faint to be measured and only the band 4278 is suitable for temperature measurements. Photographic reproductions of this band as it was obtained on the four spectrograms are shown in fig. 1 a. The corresponding photometer curves are given in Fig. 1 b.

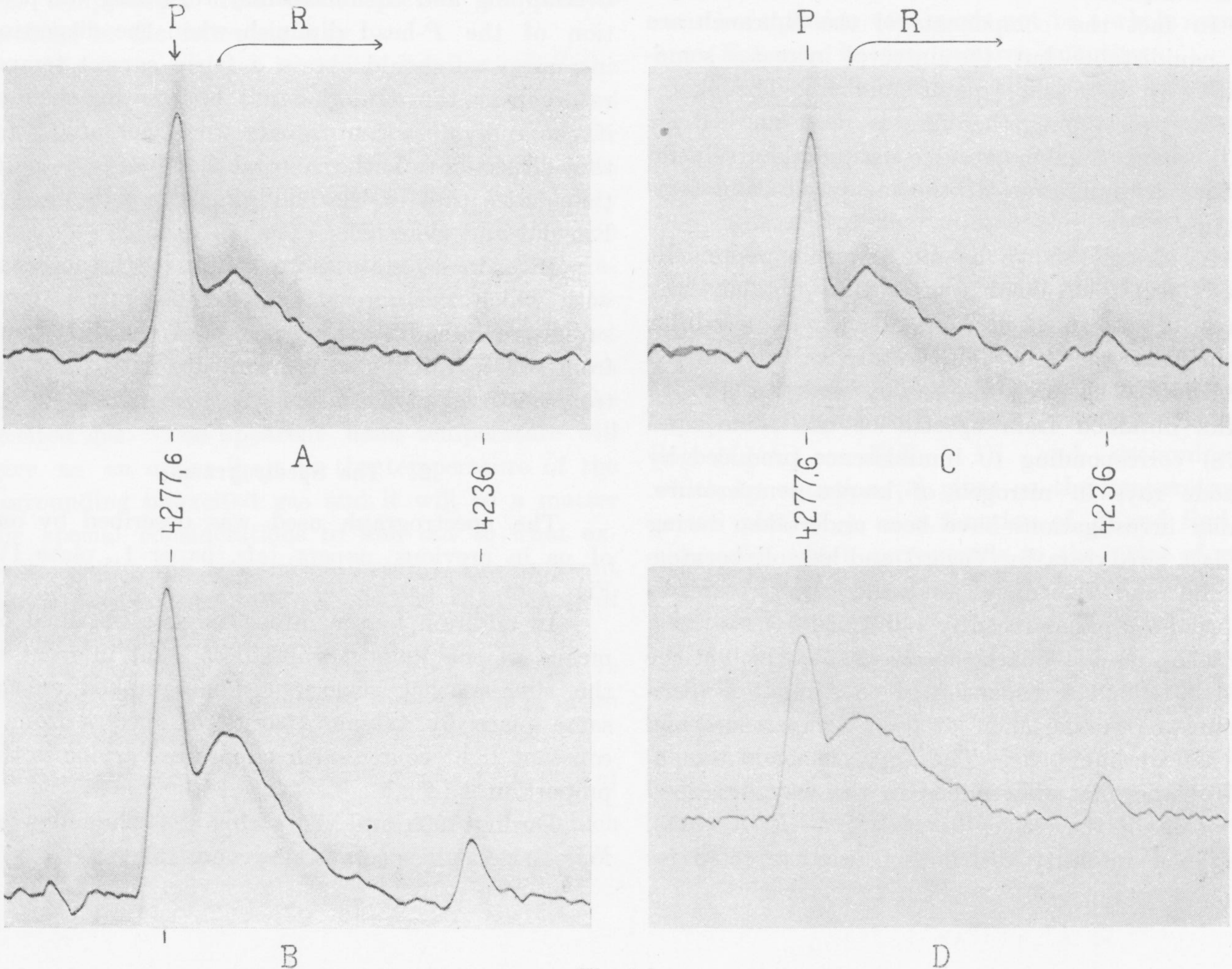

Fig. 1 b.