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HYDROXYL EMISSION OF THE UPPER ATMOSPHERE

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- USSR -

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HYDROXYL EMISSION OF THE UPPER ATMOSPHERE

[Following is a translation of an article by N. I. Fedorova entitled "Gidroksil'noe izluchenie verkhnei atmosfery" (English version above) in Izvestiya Akademii Nauk SSSR, Seriya Geofizicheskaya (Reports of the Academy of Sciences, USSR, Geophysical Series) No. 6, ~~1960~~, Moscow, pp. 836-846.]
1959

The results are given of measurements of the relative and absolute intensities of hydroxyl bands in the near infrared region from 8200 to 11200 Å on the basis of spectra of the night sky obtained at southern latitudes. There are substantial deviations from the intensities calculated by Roach. The density of the various vibratory levels has been determined from the absolute intensities of the OH bands. The density rises evenly with decrease in V'. The rotational temperature has been determined on the basis of the distribution of intensity in the P-branch; it evidently varies from night to night. The mean value is $233 \pm 16^\circ$ K.

A principal part of the radiation of the night sky in a broad region of the spectrum extending from the visible to 4.5μ is caused by rotational-oscillatory bands of hydroxyl OH molecules in the basic state of X^2 P. The intensity of the hydroxyl emission considerably surpasses the intensity of emission of other more widely distributed components of the upper atmosphere. According to electrophotometric measurements [1] the intensity of the OH bands in the near infrared region of the spectrum up to 11000 Å exceeds by a hundred times the intensity of the green line of luminescence of the night sky, and the full emission of the hydroxyl, according to theoretical estimates [2],[3], must be more than a thousand times as intense as the green line. The nature of such powerful emission on the part of a small component of the upper atmosphere presents great physical interest.

Study of the OH spectra in the luminescence of the night sky can give important information about the processes occurring in the upper atmosphere.

Meinel [4-7] was the first to point out the hydroxyl nature of the infrared radiation of the night sky; he studied the region of the spectrum from 7000 to 8900 Å in detail. Spectra in the longer wave region to 12000 Å were first obtained by V. I. Krasovskii [8-12] and identified by I. S. Shklovsky [2],[13] and Dufay [14]. The OH bands in the visible region were identified by J. Cabannes, J. Dufay and M. Dufay [15]. At the present time spectra of the night sky have been obtained to 2μ [16-18]. In recent years spectra of the night sky have been obtained in the visible and near infrared regions of the spectrum with large dispersion and better resolution [19-21], and large scale laboratory investigations have been made in the study of the rotational-oscillatory bands of OH molecules [22-24]. As a result of this work rather accurate values have been calculated for the wave-lengths of various bands and the best values of the oscillation and rotation constants of the OH molecule have been found. There still is not, however, sufficiently reliable information about the distribution of intensity in the hydroxyl spectrum and the full power of its emission, and there is inadequate data on the rotational temperature of the OH bands. This information is very important for an understanding of the processes which lead to the formation and excitation of the hydroxyl molecule.

1. Measurement of the intensity of the rotational-oscillatory bands of OH molecules

Spectra of the night sky in the regions $\lambda\lambda = 8200$-11200 Å were obtained during the winter of 1956-1957 at the Byurakan Observatory ($\varphi = 40°21'$, $\lambda = 44°15'$) with a SP-50 spectrograph equipped with an image translator. The dispersion of the instrument was about 160Å/mm, the resolution 7 Å. This was sufficient to obtain OH spectra with the P-branch dispersed on the rotational structure. Since fine focusing took up a region of the spectrum less than 800 Å the entire investigated region was covered by five series of spectra. This was done in such a way that there was a common band in two adjacent spectra in which there was an overlapping of the spectra. Figure 1 shows photographs of spectra belonging to different series. The spectra were photographed on Dn film illuminated with short exposure (0.01 sec.) to increase its sensitivity to small intensities. A standard lamp with a color temperature of 2854° K was photographed for measurement of the intensity on each film with a spectrum of the night sky. A multistage reducer was

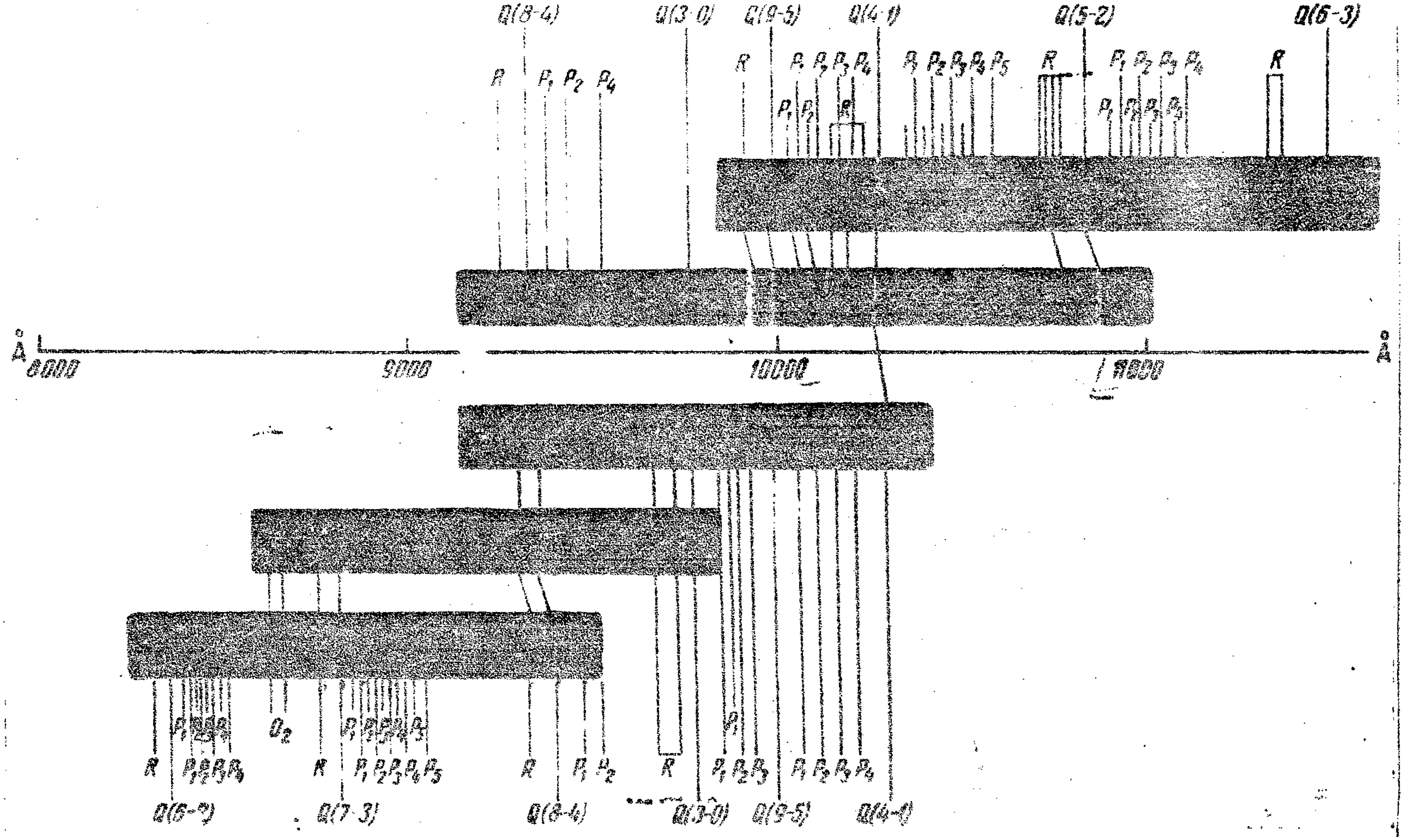

Q(8-4)
Q(3-0)
Q(9-5)
Q(4-1)
Q(5-2)
Q(6-3)
R
P_1 P_2 P_4
P_1 P_2 P_3 P_4 P_5
Å 8000
9000
10000
11000
Å
O_2
Q(6-2)
Q(7-3)
Q(8-4)
Q(3-0)
Q(9-5)
Q(4-1)

Fig. 1

simultaneously photographed with the spectrum of the night sky on another film, illuminated along with the principal one, through a green filter selected on the basis of the color of the fluorescent screen of the image translator.

The spectra were obtained with 4 to 10 second exposures and the multistage reducer was photographed each time with an exposure of three hours. The Shvartsshild constant was neglected, since it was assumed that the difference in times of exposure was small.

An attempt has been made to express the intensity of the hydroxyl groups in absolute units. To this end the spectrograph was divided in two with two filters: a KS-13 which cut off all the visible region up to 6000 Å, and a SZS-18 which cut off the red region from 6000 to 13000 Å. Thus the green line (badly focused, of course) was obtained secondarily along with the spectrum of the night sky. A standard lamp was also photographed to register the spectral sensitivity of the instrument. The spectra were processed with a registering microphotometer model MF-4 with a magnification of 1:25. The intensities of the OH bands were obtained by measurement of the areas of contours of the lines and of the band branches. The error of measurement amounted to 7-10%.

The relative intensities of the OH bands in each series of spectra were expressed in units of the Q-branch of the band overlapped with the adjacent series. The mean distribution of intensities of the bands during several nights was obtained for each series of spectra. The relative intensities of the bands vary from night to night by 10-30% and therefore the mean values were obtained with an accuracy of 10-15%, although the error of individual measurements did not exceed 10%. On the basis that the density of the levels does not change with such precision from night to night, an overlapping was made of spectra obtained at an earlier time. Table 1 gives the mean relative intensities of the OH bands in each series of spectra. In the first three columns the intensities are stated in $Q_{(4-1)}$ units, and in the last two in $Q_{(7-3)}$ units; the overlapping of these two groups was made on band (8-4).

Inasmuch as the distribution of intensity in the overlapped bands belonging to two different series of spectra (band 4-1 in the first and second series, 9-5 in the second and third, 7-3 in the fourth and fifth series of Table 1) practically coincide (in every case with an accuracy not less and sometimes greater than the accuracy of measurement of the individual series), it can be assumed that the procedure of overlapping spectra does not have

Table 1. Relative intensity of the hydroxyl bands

	Series № 1		Series № 2		Series № 3		Series № 4		Series № 5	
	Intensity	Rel. %	inten.	Rel. %	inten.	Rel. %	inten.	Rel. %	inten.	Rel. %
Band R, Q, P	4—1		4—1		8—4		8—4		6—2	
R	0,74	12	0,58	5	0,39	10	1,14	10	0,64	12
Q	1,0		1,0		0,26	10	0,93	10	0,55	8
P_1	0,42	7	0,38	5					0,40	12
P_2	0,48	8	0,41	7					0,43	15
P_3	0,33	10	0,31	7					0,32	10
P_4	0,17	10	0,17	8					0,17	12
P_5	0,09	12	0,08	10					0,08	13
ΣP	1,92	7	1,90	10	0,65	10	1,76	10	1,91	10
I	3,70	3	3,56	5	1,25	10	3,78	10	3,10	5
Band R, Q, P	5—2		9—5		9—5		7—3		7—3	
R	1,15	8	0,60	3	0,60	10	1,04	10	1,02	9
Q	1,63	10	0,45	4	0,40	10	1,0		1,0	
P_1	0,54	12	0,16	5	0,22	10	0,52	10	0,52	13
P_2	0,66	10	0,19	5	0,24	10	0,58	10	0,60	13
P_3	0,48	8	0,12	4	0,09	10	0,42	10	0,44	10
P_4	0,26	12	0,10	5	0,05	10	0,27	10	0,27	10
P_5	0,12	12					0,18	10	0,15	13
ΣP	2,75	6	0,65	6	0,79	10	2,62	10	2,58	10
I	5,5	7	1,69	2	1,78	10	4,65	10	4,57	9
Band P, Q, P			3—0		9—0					
R			0,52	27	0,34	10				
Q			0,14	13	0,18	10				
P_1			0,11	12	0,18	10				
P_2			0,13	10	0,15	10				
ΣP			0,31	12	0,45	10				

ΣP is the intensity of the P-branch (the sum of the intensities of the strong and weak components of the P-branch. Table 1 gives the intensity of the lines of only the strong component of the P-branch, large P, since the small p's, which are also obtained in our spectra, are on the average a fourth as strong as the large, measured with little accuracy; I is the full intensity of the band.

a deleterious effect on the results of measurement, and the error in determination of the relative intensities of the hydroxyl bands in the entire studied region of the spectrum hardly increases in its result by more than 10%. Thus the final results in the determination of the relative intensities of the OH bands are given in the first column of Table 2 with an error of up to 20%.

Table 2. Absolute and relative intensity of the OH bands

For Table 2, please see next page.

Transition	λ, Å	Rel. intens. in Q(4-1) units	Rel. intens. 5777 Å	Abs. int. in R*	Int. to Roach in R	Rel. int. according to spectra of northern night sky
1	2	3	4	5	6	7
R (6—2)	8300	0,22	0,97	360		
Q	8349	0,18	0,83	310		
P_1	8404	0,13	0,60	220		
P_2	8431	0,14	0,65	240		
P_3	8468	0,10	0,47	180		
P_4	8503	0,05	0,26	100		
P_5	8550	0,02	0,12	45		
ΣP		0,62	2,90	1090		
I		1,00	4,66	1700	820	
R (7—3)	8778	0,33	1,56	6610		
Q	8829	0,32	1,50	600		
P_1	8889	0,17	0,79	310		
P_2	8920	0,19	0,88	350		
P_3	8960	0,14	0,64	260		
P_4		0,09	0,14	160		
P_5		0,05	0,24	100		
ΣP		0,84	3,92	1500		
I		1,50	6,95	2800	1940	
R (8—4)	9320	0,51	2,38	1000		
Q	9381	0,42	1,94	820		
ΣP		0,73	3,40	1450		
I		1,65	7,70	3300	2970	
R (3—0)		0,47	1,98	860		
Q	9796	0,16	0,74	320		
P_1	9874	0,14	0,67	300		
P_2	9971	0,14	0,64	290		
ΣP		0,38	1,78	800		
I		0,97	4,55	1400	440	0,35
R (9—5)	9955	0,60	2,78	1200		
Q	10014	0,42	1,97	900		
P_1	10076	0,19	0,88	400		
P_2	10122	0,22	1,0	460		
P_3	10163	0,11	0,50	220		
P_4	10234	0,08	0,35	160		
ΣP		0,72	3,34	1500		
I		1,74	8,10	3700	5770	0,50
R (4—1)		0,67	3,79	1700		
Q	10290	1,00	4,76	2500		
P_1	10360	0,40	1,85	860		
P_2	10410	0,44	2,21	1000		
P_3	10470	0,44	2,21	700		
P_4	10520	0,17	0,85	400		
P_5		0,08	0,40	200		
ΣP		1,91	9,30	4400		
I		3,63	17,30	8000	1690	1,00
R (5—2)		1,16	5,13	2500		
Q	10830	1,63	7,10	3400		
P_1	10920	0,54	2,42	1200		
P_2	10968	0,66	2,93	1400		
P_3	11026	0,48	2,12	1000		
P_4	11084	0,23	1,16	600		
P_5	11140	0,12	0,63	300		
ΣP		2,75	12,40	6100		
I		5,50	24,2	12000	4000	1,5

Note accompanying Table 2: In our memorandum published in Ann. de Geophys. 14, 365, 1958, reduced absolute intensities of the OH bands were given, which had been determined on one spectrum with a very intense green line.

As has been said previously, in one series of our spectra, containing OH bands (4-1) and (5-2), the green line was obtained secondarily; the intensity of the bands in these spectra can therefore be stated in emission units of 5577 Å. The results of the measurements are given in Table 3. The error of measurement of the green line is indicated at the end of the table; it was rather large, about 10% for intense lines and up to 30% for very weak lines (as has already been pointed out, the green line obtained was very diffuse and weakened on account of poor focusing and double the amount of dispersion). In this table no account is taken of different weakening as a result of the dependences of the transparence coefficient on the length of the wave, which will test the 5577 Å and OH emission in passing through one and the same atmospheric mass. The transparence of the atmosphere was not measured by us. But, as approximate estimates show, this correction will be negligible in comparison with the errors introduced during the measurement of the intensity of the 5577 Å and the very great variation of its intensity during the night from night to night. According to the data of E.V. Pyaskovskaya-Fesenkova [25] the transparence coefficient for the wavelength corresponding to the green line $P_{\lambda=5577\ Å} = 0.88$, an the maximally different transparence coefficient for the hydroxyl $P_{\lambda=7500\ Å}$ (the transparence does not depend further on the wavelength), then for the angle of observation $z = 45°$ the correction factor will equal

$$\left(\frac{P_{5577}}{P_{OH}}\right)^{\sec z} = \left(\frac{0,88}{0,92}\right)^{1,41} = 0,94\,,$$

which is considerably less than 10%, especially if it is taken into consideration that the measurements were made at a height of 1500 meters above sea level. This correction will be of the same order for mean transparence.

The relationships between the intensity of the hydroxyl and the 5577 Å lines indicated in Table 3 are also comparable for zenith direction, since the transparence coefficient, as pointe out previously, cannot be taken into consideration and the increase on cos Z of 5577 Å and OH emission does not change their relative intensities.

In our spectra the intensity of the 5577 Å line varied from night to night by more than three times, and these changes did not correlate with the intensity of the hydroxyl band, which was rather constant during the period in which these spectra were obtained (its intensity varied by not more than 1.5 times).

Figure 2 shows two microphotographs with about the same intensity of the hydroxyl band and strongly differing intensities of the green line. The crepuscular effect did not occur in this case, as the photographing of the spectra began two hours after sunset and ended more than an hour before sunrise. Moreover, these spectra were obtained with the same exposure and at the same hour.

The intensity of the green line according to electrophotometric observations also varies very strongly; on the average from 125 to 400 relays [26,27] (the luminosity in relays is equal to 4π B, where B is the angular surface luminosity of an emitting layer in units of 10^6 quanta/cm^2·sec·stere [28], although Roach [26] points out the very broad limits of change in its intensity -- from 50 to 900R, where Roach found no correla-

Table 3. Intensity of the OH bands in green line units

Date	3 Feb.	Feb 5	Feb 6	Feb 7	Feb 8	Mean intens. in 5577 Å units
$R\ (4-1)$	2,88	6,5	6,26	1,34	1,97	3,79
Q	3,85	7,65	7,72	2,12	2,47	4,76
P_1	1,57	2,38	2,8	1,05	0,95	1,85
P_2	1,83	3,48	3,36	1,20	1,07	2,20
P_3	1,44	2,20	2,4	0,85	0,65	1,50
P_4	0,79	1,41	1,4	0,26	0,42	0,85
P_5		0,73	0,73		0,18	0,53
ΣP	7,6	16,0	13,9	4,36	4,7	9,3
I	13,0	30,0	27,0	7,83	8,7	17,3
$R\ (5-2)$	4,37	7,85	7,15	3,12	3,16	5,13
Q	7,08	9,62	10,3	4,08	4,5	7,1
P_1	1,83	4,05	3,34	1,56	1,33	2,42
P_2	2,38	4,79	4,07	2,04	1,41	2,93
P_3	1,67	3,44	3,08	1,48	1,05	2,14
P_4	0,99	1,84	1,87	0,64	0,53	1,16
P_5	0,70	0,86	0,97			0,85
ΣP	11,0	19,0	18,0	7,38	6,15	12,4
I	22,5	36,4	35,2	14,1	13,2	24,2
Rel. error in determination of green line	15%	30%	20%	10%	5%	50%

tions of the intensity of the green line with the intensity of luminosity of other components of the upper atmosphere. He also found no dependence of the intensity of 5577 Å on solar activity. A small negative correlation with magnetic disturbances was found by Roach. Since we did not measure the absolute intensity of the green line it was not known which days to give preference to and what to compare the intensity of the green line with. Therefore in the final estimate of the intensity of the OH bands in 5577 Å units we took the mean of five measurements. These results are given in the last column of Table 3. In it an error in the order of 50% was obtained. Assuming the mean value of the intensity of 5577 Å to be 250 R, the intensity of the OH bands in relays was

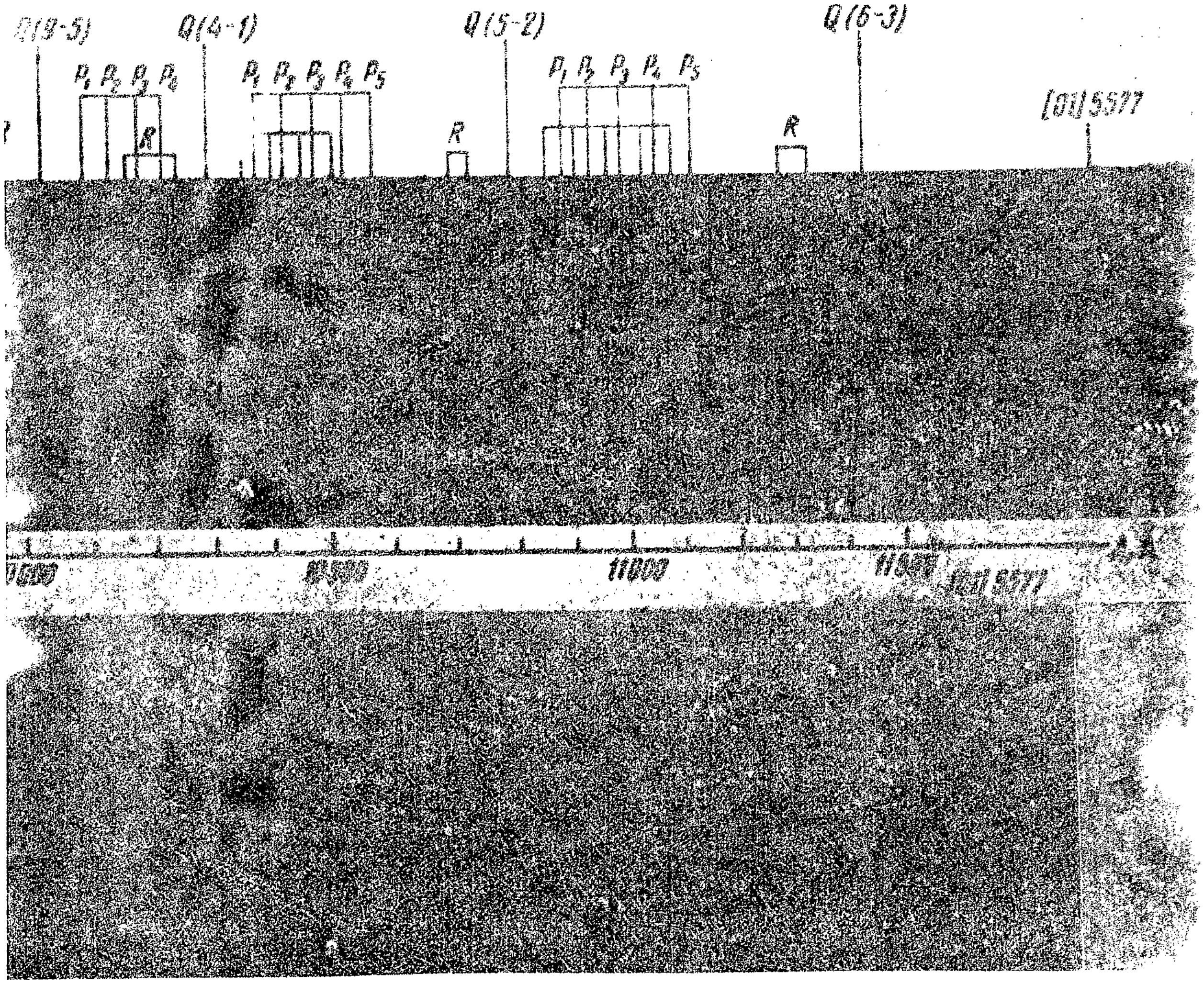
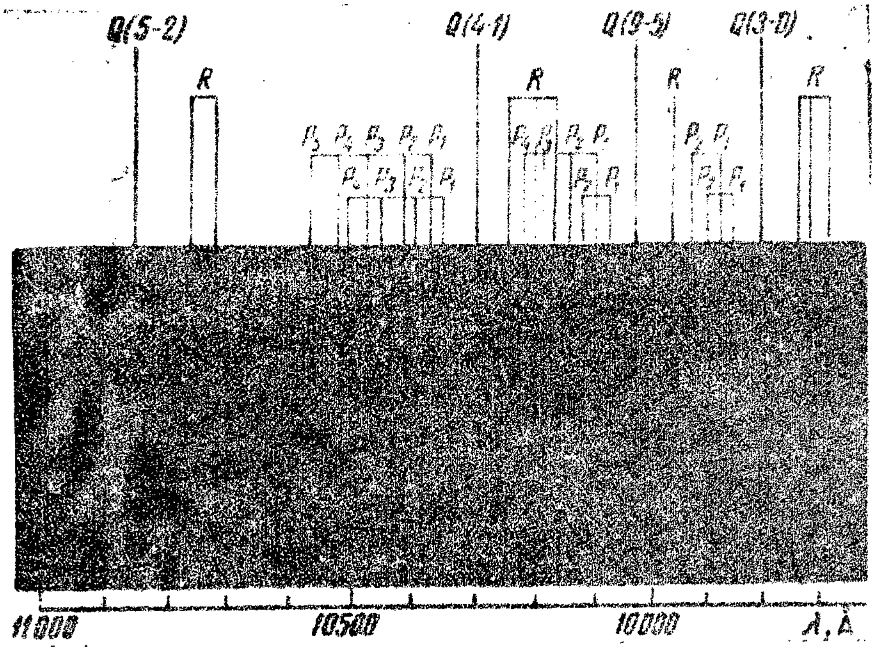

Q(9-5)
P_1 P_2 P_3 P_4
R
Q(4-1)
P_1 P_2 P_3 P_4 P_5
R
Q(5-2)
P_1 P_2 P_3 P_4 P_5
R
Q(6-3)
[OI] 5577
10500
11000
11500
[OI] 5577

Fig. 2

estimated. These values are given in the fifth column of Table 2.

Band (8-4) was located in region $\rho\sigma\tau$ of the band of absorption of water vapor. Its intensity is given in Table 2 in comparison with atmospheric absorption, which was determined by means of a lunar spectrum taken the same night. The absorption was about 35% for the Q-branch and 25% for the P-branch. In band (3-0) only two P-branch lines are observed, P_1 and P_2; the others are overlapped by band (9-5). As a result of this the intensity of band (9-5) is raised somewhat, but since the intensities of the P-branch lines fall rapidly with increase in J' (due to low rotational temperature observed in the upper atmosphere), the superimposing of the P_3 and P_4 lines on band (9-5) does not substantially change its intensity. Band (3-0) has an anomalous appearance: the intensity of its Q-branch, as seen in Figure 3, is extremely small, almost comparable with the intensity of the P-lines, but the P-lines of band (3-0) are only a little weaker than the P-lines of the adjacent band (9-5). This was also noted in the spectra of Jones [20]. The intensity of the R-branch, on the other hand, is extremely high. Usually the intensity of the R-branch is comparable with or even less than the intensity of the Q-branch. We even have doubts of the correctness of its identification, since the appearance of the R-branch varies much from photograph to photograph, something not observed in other bands. It is possible that an emission of non-hydroxyl origin is superimposed on the R-branch of band (3-0), and therefore in estimating the intensity of band (3-0) the intensity of the R-branch was made equal to that of the Q-branch. The sixth column of Table 2 shows the absolute intensities of the hydroxyl bands according to Roach [6], obtained by him by recalculating the data of Roach, Pettit and Williams [29] for the visible region of the spectrum according to the probable transitions calculated by I.S. Shklovsky [30]. As seen in Table 2 and Figure 4, there are substantial deviations not only in the absolute values of the intensities (explainable by an error in estimating the intensity of the green line), but also in estimating the relative intensities, which we made with an error of up to 20%. The deviations in determination of the intensity of band (9-5) are especially significant. Its intensity according to Roach is greatly increased and band (9-5) is almost three times as intense as band (4-1). Our measurements of the relative intensities of the OH bands in the spectrum of the northern night sky [31], given in the seventh column of Table 2, are not very accurate, it is true. But there too the band (9-5) is half as intense as band (4-1). The intensity of other OH bands is greatly reduced in comparison with our measurements, as can be seen at a glance in Figure 4: 1) measured intensities; 2) intensities calculated by Roach. Th


Q(5-2)
R
P5 P4 P3 P2 P1
P5 P3 P2 P1
Q(4-1)
R
P4 P3 P2 P1
P2 P1
Q(9-5)
R
P2 P1
P2 P1
Q(3-0)
R
11000
10500
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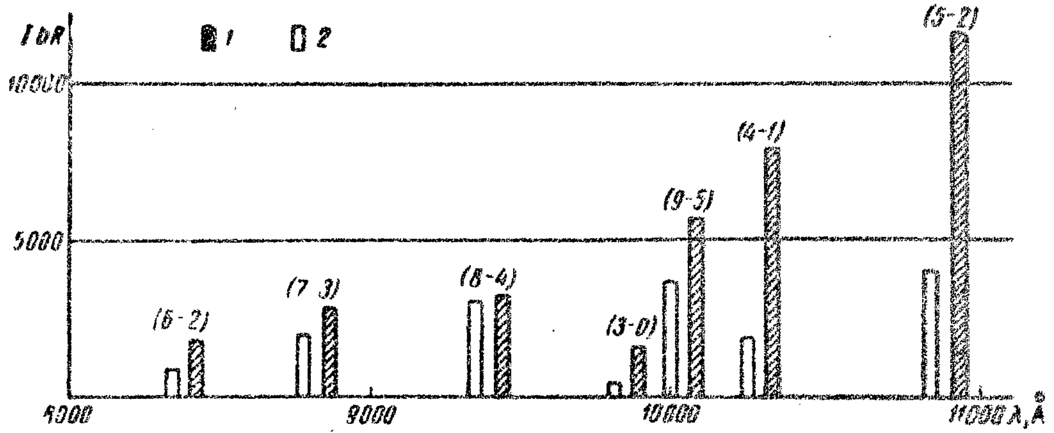
λ, Å

Fig. 3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(3-0)
(9-5)
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(5-2)
8000
9000
10000
11000 λ, Å

Fig. 4

(6-2) and (7-3) bands even have one third to one half the intensity in these measurements, although according to those of N.N. Shefov [32] made at the Zvenigorod station, at a middle latitude these bands are just as week as ours and the (3-0), (4-1) and (5-2) bands are measured to be a third as strong. Jones [16], on the basis of measurements of the absolute intensities of the OH bands by the sequences $\Delta V = 3$ and 2, also found that the intensities indicated by Roach are strongly reduced. Our estimates of the relative intensities do not diverge greatly from the qualitative estimates of V.T. Lukashenya and V.I. Drasovskii [12] and Jones [21], and also from the measurements made earlier in the region of Murmansk [31].

The absolute intensities of the OH bands was used to determine the density of the various oscillatory levels, and in doing this the probabilities of transition were utilized as calculated by I.S. Shklovsky [2],[30]. As is seen in Table 4 and Figure 5, the density rises evenly with decrease in V' and no predominant density of the ninth oscillatory level is observed as follows from the calculations of Heaps and Herzberg [33] and Roach [2]. In the calculations of I.S. Shkolsky [2],[30], the density of the ninth oscillatory level likewise does not drop out of the general course of the curve of dependence of density on V'(of the upper oscillatory level).

Table 4. Density of the oscillatory levels of OH molecules

V'	3	4	5	6	7	8	9
$см^{-3}$	$1,2\cdot10^{8}$	$1,0\cdot10^{8}$	$6,6\cdot10^{8}$	$4,6\cdot10^{7}$	$3,2\cdot10^{7}$	$2,5\cdot10^{7}$	$1,4\cdot10^{7}$

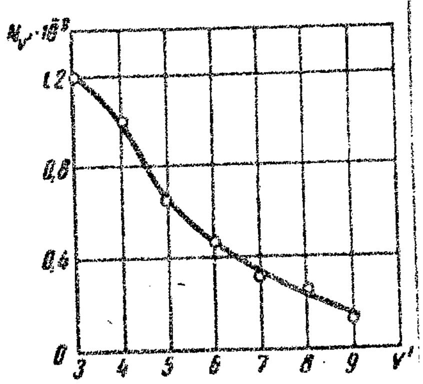

Fig. 5

2. Determination of the rotational temperature of the OH bands

We have four bands, (6-2), (7-3), (4-1) and (5-2), for the determination of rotational temperature in our spectra. These bands are not overlapped by other bands and are situated in spectral regions where there is no absorption. The method of determining the temperature is based on the temperature dependence of the distribution of intensity among the individual lines in the delicate rotational structure of the molecular bands emitted by the night sky. In the case of the OH molecule, the intensities of the rotational lines of the powerful ^2P component of the resolved P-branches are used.

The distribution of intensity in the rotational structure is determined by the expression:

$$I_{em} = (\mathrm{const})\, i(J')\, e^{-F(J')} kT,$$

where I_{em} is the intensity of the rotational lines, T is the rotational temperature, k is Boltzmann's constant, i(J) is the intensity factor, which Meinel determined for the P-branch with the formula:

$$i(J') = \frac{(J' + 1 + \Omega)(J' + 1 - \Omega)}{J' + 1},$$

where J' is the rotational quantum number of the upper state, the projection of the complete orbital moment on the intranuclear axis, $F(J')$ the rotational energy of the initial level:

$$F(J') = B_{v'} J'(J' + 1),$$

$B_{v'}$ is the rotational constant for the upper oscillating level:

$$B_{v'} = B_e - \alpha\left(v' + \frac{1}{2}\right), \quad B_e = 18{,}86\ \text{см}^{-1}, \quad \alpha = 0{,}708\ \text{см}^{-1}.$$

Plotting ln $\frac{I_{em}}{i(J')}$ as a function of $j'(j' + 1)$, we get a straight line from whose slope the temperature can be determined.

To determine the temperature the intensities of rotational lines were taken as determined by two methods: by the space of the contours and by their height. The temperature values were designated T_s and T_h respectively. As is seen in Table 5 the temperature varies little when determined by the two methods. Their mean was finally taken as the temperature.

As a rule there were two bands in each spectrum for the temperature determination. The determinations made on the basis of these bands were the same, within the limits of error in measuring temperature. Unfortunately, within these spectra are bands

Table 5. Rotational temperature of the OH bands in the emission of the night sky

Date $V'—V''$		10 Dec. $10^h—6^h$	Dec 11 дек. $8^h—6^h$	Dec 12 дек. $7^h—4^h$	Dec 26 дек. $11^h—4^h$	1 Jan. $8^h—3^h$	Jan 2 янв. $8^h—4^h$	Jan 19 янв. $10^h—5^h$	Jan 20 янв. $10^h—5^h$	Jan 26 янв. $8^h—6^h$	Mean T° K
—2	T_s	242	238	219	260	264			205		
	T_h	250	230	210	250	250			210		
—3	T_s	243	230	200	256	256	216	244		227	
	T_h	232	225	189	255	266	197	242	200	217	
ean K tor e night		240±10	230±7	204±10	256±5	262±5	206±10	243±5	205±10	222±10	230±17

Date $—V''$		Jan 28 $1^h —h^6$	9 Feb. $12^h— 7^h$	① 3 февр. $21^h —1^h$	① 5 февр. $20^h —6^h$	① 6 февр. $21^h —6^h$	① 7 февр. $21^h —6^h$	① 8 февр. $22^h—6^h$	① Средн., T° K
)	T_s		215						
	T_h	242	202						
5	T_s	246	240						
	T_h		214						
l	T_s	239	218	252	254	253	229	214	
	T_h	235	209	265	248	264	227	224	
2	T_s			258	242	248	225	220	
	T_h			266	244	242	230	210	
) дн. T°K дну ночь		235±10	213±5	260±10	248±10	252±12	228±10	217±10	236±15

1) Feb; 2) Mean T°K for 1 night

whose initial levels differ by only one, and therefore the effect of the temperature dependence on the initial level can be vaguely expressed. There were only two spectra in which there were bands with strongly differing oscillating levels: (3-0), (9-5) and (4-1). But the (3-0) and (9-5) bands are not very suitable for determining temperature, since they contain in all only two rotational lines each (the remaining overlap). The temperature determined on the basis of these two points is given in the table just the same, but it is difficult to have confidence in it. It is safer, it seems to us, to compare the mean values obtained during several nights on bands (6-2) and (7-3) with the mean values on bands (4-1) and (5-2). In the first case a temperature was obtained of $230 \pm 17^\circ$ K, in the second, $236 \pm 15^\circ$ K. Thus no dependence of temperature on the initial oscillating level was found on the basis of our date, within the limits of the errors of measurement. Meinel [34] obtained a mean temperature during several nights of $258 \pm 3^\circ$ K on band (6-2) and $265 \pm 5^\circ$ K on band (5-1). The difference, it seems to us, lies within the limits of measurement error, all the more so in that a different number of nights was used for the temperature determination in the first and second cases. But Gush and Jones [17] point out the considerable difference between the temperature $200 \pm 20^\circ$ K, obtained by them at Saskatoon ($\varphi = 42^\circ$) from a synthetic spectrum of the unresolved bands (3-1) and (4-2) by the sequence $\Delta V = 2$, and the temperature of $260 \pm 5^\circ$ K obtained by Meinel at the Yerkes Observatory ($\varphi = 42^\circ 34'$) on OH spectra with well-resolved rotational structure of the P-branch from a much higher sequence [$\Delta V = 4$ of band (5-1) and (6-2)]. It is impossible to explain this difference in the temperature determination as an effect of latitude, since the dependence of temperature on latitude is not sharply expressed for the middle latitudes, as will be seen further on, and, moreover, temperature increases with latitude, and in the given case the reverse is obtained. Since Gush and Jones determined temperature by spectra on which even the bands were poorly resolved, to confirm their results spectra should be obtained in that region with better resolution than the authors indicate.

J. Cabannes, J. Dufay and M. Dufay [15] determined the temperature of OH bands situated in the visible region from incompletely resolved P-branches. They indicate only a series of temperature magnitudes of 150-250° K. J. Dufay and M. Dufay [35] obtained a temperature between 255 and 270° K from four infrared and two visible OH bands.

We obtained the temperature value for one night as the mean of the measurements on two bands, where the error in determining the temperature was $\pm 10^\circ$ K. The differences in temperature determined on different nights was much greater than the measurement error; the temperature for the studied period varies from 200 to 260° K according to our measurements; this does not agree with the constant temperature indicated by Meinel [35] (sic) (260±5° K). Evidently there is a small dependence of temperature on intensity of the OH bands. As a rule a higher temperature corresponds to brighter spectra. But since no absolute calibration of the spectrograms was made, it is difficult to compare the spectra quantitatively with one another. Judging by blackenings, we can say that the spectra vary in intensity by not more than twice, and the maximal temperature change was in the order of 60° K.

The mean temperature value of 233±16° K obtained by us at the Byurakan Observatory, situated at a latitude $\varphi = 40°21'$, differs hardly at all from the temperature value of 240±20° K according to the measurements of V.S. Prokudina [36] at the Evenigorod station ($\varphi = 43°56'$). But these values differ strongly from the temperature determined at higher latitudes. F. K. Shuiskaya [32], at the Poshchino station ($\varphi = 60°12'$), obtained a temperature of 265±14° K in the direction of the northern horizon. Yu. I. Gal'perin [36] at the station at Loparskaya ($\varphi =$ $= 68°38'$) obtained a temperature of 290±29° K in the direction of the zenith and 330±33° K in the direction of the northern horizon. Chamberlain and Oliver [19], in Northern Greenland, also obtained a high temperature in the order of 300-350° K. According to our spectrum of the northern night sky [31], obtained in Loparskaya, the temperature appeared to be 310±30° K (on this spectrum the rotational temperature of the P-branch was incompletely resolved and, in addition, an emission of 10400 A (NI) was superimposed on band (4-1), and in band (5-2) the lines P_3, P_4 and P_5 were evidently blended with the 0-0 N_2^+ band; and so the temperature was determined with a large error). Thus there exists a latitude effect which is rather definitely expressed, as Chamberlain and Oliver [19] have already pointed out.

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