RELATIVE POPULATIONS OF THE UPPER VIBRATIONAL LEVELS OF 2PGN$_2$ BANDS IN AURORAE AT VARIOUS LATITUDES

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ABSTRACT: The observational data of different stations show that the vibrational temperatures of the 2PGN$_2$ bands in aurorae are the same at different latitudes.

In a study [1] with a small amount of experimental material, it was found that the vibrational temperature determined by the relative populations of the upper vibrational levels of 2PGN$_2$ was higher for the typical high-latitude aurorae than for aurorae at middle and low latitudes. Therefore, the opinion was given that the 2PGN$_2$ in an aurora at high latitudes is excited by a more rigorous agent. /83

In order to confirm or refute this opinion, we examined more extensive observational materials. We used a precise value for the probability of transition of the vibrational bands. For the Loparskaya station, we analyzed 19 cases of aurorae. The relative intensities I of the 2PGN$_2$ bands (sequence $\Delta v = 2$) and the nitrogen line λ 3466 Å N I for these cases are given in Table 1. The spectra were obtained on the standard spectrograph SP-49. A film of the type D_N was used. An incandescent lamp was used as the source for standardization and calibration of the apparatus. The weakening of the light in the lower atmosphere was calculated with the aid of the coefficients of atmospheric absorption presented in [2]. The error from inaccurate calculations of the atmospheric absorption was amall, since similar wavelengths were being compared. We examined only the intensities of the bands with Δv = 2, since the bands of this sequence are the least blended. An examination of only one sequence for determining the relative populations provides for decreasing the error in calculating the atmospheric absorption and the spectral sensitivity of the apparatus. We can see from Table 3 in [3] how great the divergence in the values for $N_{v'}$ were in determinations by different sequences. By certain relative intensities of the bands, and with the aid of the formulas in [4], we determined the value of $g(v')$ - the rate of population of the upper vibrational levels :

$$I(v'v'') = \frac{g(v')\,h\nu^4(v'v'')\,p(v'v'')}{\sum_{v''} p(v'v'')\,\nu^3(v'v'')}, \qquad (1)$$

$$\frac{g(v_1')}{g(v_2')} = \frac{I(v_1'v_x'')\,\nu^4(v_2'v_y'')\,p(v_2'v_y'')\sum_{v''} p(v_1'v'')\,\nu^3(v_1'v'')}{I(v_2'v_y'')\,\nu^4(v_1'v_x'')\,p(v_1'v_x'')\sum_{v''} p(v_2'v'')\,\nu^3(v_2'v'')}. \qquad (2)$$

We can easily proceed from the values of $g(v')$ to the values of the relative populations of the upper vibrational levels $N_{v'}$, according to the relationship $g(v') \approx N_{v'}\Sigma p\nu^3$ from [3], where ν is the wave number. Since the value of $\Sigma p\nu^3$ is close to unity (see

TABLE 1. RELATIVE INTENSITIES AND RELATIVE POPULATIONS OF THE $2PGN_2$ BANDS (Δv = 2) IN AURORAE. (LOPARSKAYA STATION, ϕ = 63°30'N) /84

Date	I_{2PGN_2} ($\Delta v = 2$)			I [NI]	$g(v')$ ($\Delta v = 2$)		
	λ 3805 Å (0,2)	λ 3755 Å (1,3)	λ 3710Å (2,4)	λ 3466Å	$v' = 0$	$v' = 1$	$v' = 2$
	402	355	118	79	1	0,62	0,24
10—11.II 1958	935	914	390	405	1	0,69	0,35
	579	503	130	240	1	0,62	0,22
9—10.IX 1958	96	72	40	—	1	0,53	0,35
10—11.XI 1958	32	33	—	14	1	0,73	—
18—19.XI 1958	54	38	—	15	1	0,50	—
2—3.XII 1958	30	21	—	24	1	0,50	—
4—5.XII 1958	95	—	31	38	1	—	0,27
8—9.XII 1958	128	100	18	39	1	0,55	0,12
11—12.XII 1958	100	102	28	—	1	0,72	0,23
12—13.XII 1958	216	192	75	—	1	0,63	0,29
13—14.XII 1958	138	128	46	—	1	0,66	0,28
15—16.XII 1958	60	38	—	—	1	0,45	—
8—9.I 1959	47	37	—	—	1	0,56	—
9—10.I 1959	101	100	—	38	1	0,70	—
10—11.I 1959	118	107	18	—	1	0,64	0,22
16—17.I 1959	258	205	54	111	1	0,56	0,17
18—19.I 1959	116	89	28	24	1	0,54	0,20
3—4.III 1959	52	38	7	—	1	0,52	0,11
14—15.IV 1959	74	51	—	24	1	0,49	—
17—18.XII 1959	39	37	—	21	1	0,67	—
Average					1	0,59±0,02*	0,23±0,02*

* Mean square error.

Table 2), then $g(v')$ is also very close to $N_{v'}$[in determining the relative populations of $2PGN_2$, most authors find the value of $g(v')$]. /85 The calculated values of $g(v')$ are given in Table 1. The values of p (the probability of transition of the vibrational bands) were taken from [5] and are shown in Table 2.

TABLE 2. WAVELENGTHS AND PROBABILITIES OF TRANSITION OF THE VIBRATIONAL BANDS $2PGN_2$

v'/v''	0	1	2	3	4	5	6	7	8	9	$\sum_{v''} p\nu^3$	$\sum_{v''} p\nu^3$
0	3371 0,41	3577 0,32	3805 0,15	4059 0,06	4344 0,02	4667 0,005					$2{,}160 \cdot 10^{13}$	1
1	3159 0,31	3339 0,02	3537 0,20	3755 0,20	3998 0,12	4270 0,05	4574 0,02	4917 0,01			$2{,}147 \cdot 10^{13}$	0,994
2	2977 0,09	3136 0,25	3309 0,03	3500 0,06	3710 0,16	3943 0,15	4200 0,09	4490 0,04	4815 0,02		$2{,}116 \cdot 10^{13}$	0,980
3	2820 0,01	2962 0,16	3117 0,13	3285 0,10	— —	3672 0,09	3895 0,15	4142 0,11	4417 0,06	4724 0,03	$2{,}060 \cdot 10^{13}$	0,954

TABLE 3. RELATIVE POPULATIONS OF THE UPPER VIBRATIONAL LEVELS OF $2PGN_2$ IN AURORAE AT VARIOUS GEOMAGNETIC LATITUDES

Station	Date	Φ	v'		
			0	1	2
Tromsö*	1954—1956	67°06′	1,00	0,56 (1)[6*]	0,26 (0,46)
Loparskaya**. . . .	1958—1959	63 30	1,00	0,59 (1)	0,23 (0,39)
Saskatoon***. . . .		60 30	1,00	0,55 (1)	0,20 (0,40)
Roshchino[4*]	1957(Sept.)	56 35	1,00	0,55 (1)	0,21 (0,38)
Zvenigorod[5*] . . .	1957(July)	51	1,00	0,54 (1)	0,22 (0,39)
Average			1,00	0,56 (1)	0,22 (0,38)

* According to the average values of I_{2PGN_2} obtained in [6] and [7]; the values of p were taken from [5].

** From Table 1.

*** From Table 3 in [3].

4*, 5* Revised data from a determination of I in an aurora on August 8, 1958 (Zvenigorod) and in aurorae on September 22-23 and 29-30, 1957 (Roshchino) with values of p from [5].

6* The values in relation to the level $v = 1$ are shown in the parentheses.

Table 3 shows the results of determining the relative values of $g(v')$ for three vibrational levels, $v'= 0$, 1, and 2 (sequence $\Delta v = 2$), in aurorae at various geomagnetic latitudes in the northern hemisphere. All these results were obtained mainly according to photographic spectra with exposures on the order of several hours. Therefore, the values of $g(v')$ are averaged values characteristic of various forms of aurorae at a given latitude. The error in the photographic method of determining the intensity is about 20%. It can be even greater because of an inaccurate calculation of the blending bands, a disregard of the transmittance, etc. We can see from examining Tables 1 and 3 that the variance of the values for different aurorae and at different latitudes does not exceed the limits of the measurement errors. Therefore, the average order of magnitude for $g(v')$ in aurorae at various lattudes is 1:0.56:0.22. According to the theoretical calculations of Bates [8], these values for the relative populations of the upper vibrational levels correspond to the case of excitation of 2PG by an electron collision of an N_2 molecule in its original state. This had also been indicated previously in a number of studies. The value of the parameter of the vibrational temperature, obviously, does not exceed 500-1000° K for all the latitudes being examined.

Thus, in examining extensive materials on determinations of the relative populations of the upper vibrational levels $2PGN_2$ at various latitudes, we did not confirm the assumption in [1] on the differences of T_{vibr} in aurorae at middle and low latitudes (the values of Φ changed from 67 to 51°).

For the cases of aurorae examined at Loparskaya, the ratio I_{2PGN}/I_{3466} [NI] changed from aurora to aurora, comprising on the average $I_{3805}/I_{3466} = 3.1$; $I_{3755}/I_{3466} = 2.5$; $I_{3710}/I_{3466} = 0.8$. The divergences from the average value sometimes reached 65%. But, despite such great variations, there is a certain tendency for the ratios 2PG/3466 to increase with an increase in the latitude (see Table 3 in [1]), which, obviously, is the effect of the varying height of the emission at various latitudes.

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