

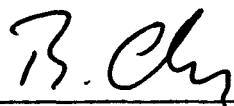
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TÍTULO: A STUDY OF OH(8,3) BAND EMISSION
IN NIGHT AIRGLOW

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A STUDY OF OH (8,3) BAND EMISSION IN NIGHT AIRGLOW

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ABSTRACT

General information about Hydroxyl (OH) emission in Night Airglow is described. Further, a spectroscopic study of OH (8,3) band and the derivation of Rotational Temperature are presented.

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I. INTRODUCTION

The purpose of this report is to describe the Hydroxyl (OH) emission in night airglow and to discuss the OH rotational temperature which will give us information on upper atmospheric temperature. Therefore, we will summarize the investigations about OH emission, and intend to discuss the spectroscopic study of it.

Since Meinel's original work (Meinel, 1950), the Hydroxyl emission has been studied by many workers. This work has been concerned with identification of spectra, absolute intensity, emission height, excitation mechanism, rotational and vibrational temperature and time variations, etc. The OH band spectra are due to Vibration-Rotation transitions of vibrationally excited OH molecules in ground electronic $^2\pi$ state level.

In the night airglow, only the bands which are emitted from the vibrational level lower than 9 have been found, and its total energy emitted is about 4.5×10^6 Rayleighs, i.e., 3.2 erg/cm^2 (column) sec. (Chamberlain, 1961).

The wavelength region is $3,800 \text{ \AA} \sim 4.9 \text{ \mu}$, and almost all of the energy is distributed in the near and far infra-red regions.

(8,3) band, i.e., the transition from vibrational level $v = 8$ to $v = 3$, which we are going to study, has its band origin at 7274.5 \AA^0 and its bandwidth is about 300 \AA^0 , band intensity $400 \sim 500$ Rayleighs.

1. SPECTRAL IDENTIFICATIONS

The identifications of OH spectra have been done by, especially, Meinel (1950), Chamberlain (1961) and Kvifte (1959) from night airglow observations, and by Herman and Hornbeck (1953) and Dieke and Crosswhite (1948) from Laboratory experiments. Table 1 shows the origin of each band. The (8,3) band, in night airglow, has been measured by Wallace (1960) and his data is the most reliable for our enquiry. Numerical data of individual lines in this band are shown in Section III.

2. BAND INTENSITIES

The observed band intensities presented by several workers are shown in Table 1.

TABLE 1

Band origins and band intensities of OH molecular spectra.

$\begin{array}{c} \nu'' \\ \nu' \end{array}$	0	1	2	3	4	5	6	7	8	9
1	28,007									
2	14,336	29,369								
3	^{3,600} 9788.0	15,047	30,854							
4	³⁰⁰ 7521.5	^{6,700} 10,273	15,824	32,483						
5	³⁵ 6168.6	^{1,150} 7911.0	10,000 10,828	16,682	34,294					
6	⁻⁵ 5273.3	¹⁰⁰ 6496.5	^{1,600} 8341.7	15,000 11,433	17,642	36,334				
7	4640.6	²⁵ 5562.2	²³⁰ 6861.7	3,250 8824.1	22,000 12,115	18,734	38,674			
8	4172.9	4903.5	⁷⁵ 5886.3	⁴⁸⁰ 7274.5	^{2,450} 9373.0	12,898	19,997	41,409		
9	3816.6	4418.8	5201.4	6256.0	7748.3	10,010	13,817	21,496	44,702	

The upper lines show the mean absolute intensities in Rayleigh (by several workers) and the lower the band origins in Å (Chamberlain, 1961).

DIURNAL VARIATIONS

The most typical variation in a night is a decrease towards midnight and an increase to morning twilight, i.e., it has a minimum near midnight. The magnitude of variation is probably a factor of 2. (Nakamura, 1961, Shefov, 1972).

The second type decreases monotonically through the night and the third one is almost flat (Nakamura, 1961).

SEASONAL VARIATIONS

It has been reported that there is a maximum in winter and minimum in summer and the magnitude of the change could be one order. However, some workers have reported no seasonal variation (e.g. Kvifte, 1967).

It is interesting to note that seasonal variation of the vibrational temperature is from 11,500°K in winter to 5600 °K in summer (Shefov, 1972). This temperature provides information on excitation rate to upper vibrational levels.

SOLAR CYCLE VARIATION

Little is known about the solar cycle variation because of lack of long period data collection. But Soviet workers, having

systematically measured OH night airglow since the I.G.Y., suggested a correlation with solar cycle (e.g. Shefov, 1972).

3. EMISSION HEIGHT

Rocket observation, today, is the most reliable method to determine the altitude of the airglow emitting layer. Recent results are shown below in Table 2. The emission profile of OH (8,3) band given by Baker and Waddoups (1967) is shown in Fig. 1.

Experiments	Measured band	Latitude $^{\circ}\text{N}$	Height of Max. (Km)	Thickness at 50% emission (Km)
Packer, 1961	7400 ~ 10,200 \AA	32	83	
Packer, 1961	(8,3)	32	90	
Baker et al, 1967	(8,3)	32	97	21
Harrison, 1970	(6,2)	75	95	15

TABLE 2: Rocket measurements of OH night airglow altitude

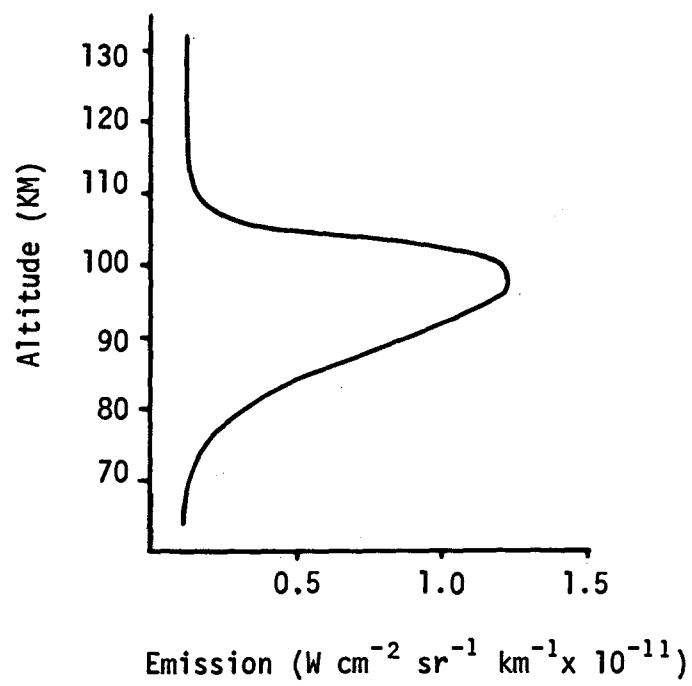


FIG. 1 - Emission hight profile of OH(8,3) band, by Baker and Waddoups. (1967)

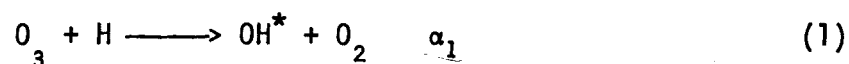
The fact that the emission layer stays low in the thermosphere and its thickness is so narrow might be explained by the emission mechanism being strongly dependent on the ambient conditions, i.e., the concentrations of the atmospheric constituents, temperature and density. Deactivation process of excited OH molecules would determine the lower limit of the layer and the upper side might be limited by the concentrations of atoms and molecules which would contribute to produce the excited OH.

It may be important to observe the time variation of emission height, diurnal and seasonal to help clarify OH production mechanisms. But the difficulties of this type of measurement are limited rocket launching and unreliable ground based measurements by means of Triangulation and the van Rhijn methods.

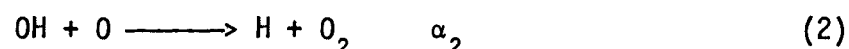
There is also a suggestion that the emission height is different with emission bands. It may be that excitation mechanism is different with height (e.q. Wallace, 1962).

4. EXCITED OH PRODUCTION MECHANISM

Ozone-Hydrogen chemical reaction, suggested by Bates and Nicolet (1950), Herzberg (1951), has chiefly been discussed so far;



where asterisk indicates a vibrationally excited molecule. This would be followed by,



to provide a recycling of the Hydrogen atom.

Recent works about the reaction rate coefficient, α_1 , show (e.g. see Sivjee et al., 1972),

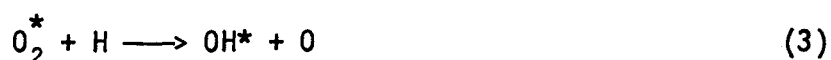
$$\alpha_1 = 2.6 \times 10^{-11} \exp \left(\frac{-500^{\circ}K}{T} \right) \text{ cm}^3 \text{ sec}^{-1}$$

It should be noted that this rate is temperature sensitive, since the emission layer is in the lower thermosphere where temperature is increasing rapidly with height, vertical motion of it could cause large changes of intensity.

The exothermic process (1) releases 3.32 eV and this energy is just enough to excite the 9 th vibrational level (see Fig. 4). This seems consistent with the fact that only bands originating from $v \leq 9$ have been observed in the night airglow (see Chamberlain's text,

P 558, 1961). On the other hand, however, the population rate for vibrational levels calculated from band intensities can not explain this preferential excitation to $v = 9$ (Kvifte, 1961, Yano and Takahashi, 1971).

Krassovsky (1963) proposed, however, the contribution of vibrational excited Oxygen molecules. In this case OH molecules may be excited to various vibrational levels because of various excited O_2^* molecules, i.e.,



The recycle of Hydrogen atom is as in reaction (2).

In recent papers, other possible mechanisms have been proposed and it has been suggested that the production mechanism would not be simple but might consist of various photochemical processes. Nicolet (1970) and Krassovsky (1971) suggested the following reaction in addition to the above reactions,



$$\alpha_4 = 3 \times 10^{-12} \sqrt{T} \text{ cm}^3 \text{ sec}^{-1}; \text{ Nicolet (1970)}$$

where the production of HO_2 molecules could be due to three-body reaction, (Nicolet, 1970) i.e.



$$\alpha_5 = 3,3 \times 10^{-33} \exp\left(\frac{800}{T}\right) \text{ cm}^6 \text{ sec}^{-1}$$

Some correlations between OH emission and the other emissions will provide us useful information on the excitation mechanisms. There are Sodium (5893\AA) and Oxygen (5577\AA) emission layers close to the OH layer. The former has a maximum emission rate near to 90 km and the latter to 100 km. Some correlation has been noted between the intensities of these emissions (Wallace, 1962 and Krassovsky, 1963).

Furthermore, a relation with O_2 atmospheric band $(0,1) \lambda 8645 \text{\AA}$ in $b' \Sigma_g^- \longrightarrow X^3 \Sigma_g^-$ transition (Berg and Shefov, 1962) and H_α line (Krassovsky et al, 1961) has also reported.

II. ROTATIONAL TEMPERATURE OF OH MOLECULES

Spectroscopic analysis of the Vibration-Rotation spectra gives the population rate of the molecules in the upper rotational levels. Now, assuming that the molecules are in thermal equilibrium, the distribution of the particles in rotational levels obeys Maxwell-Boltzmann's law. Turning to the OH molecules in the upper atmosphere, it is well established experimentally that they are in a certain thermal equilibrium with Rotational Temperature (Trot.) which is a parameter of the Maxwell-Boltzmann factor equal to the gas kinetic ambiente temperature

(see, e.g. Wallace, 1962). For example with an estimated mean life time of excited OH of 10 m sec., the number of collisions during the life time at a height of 90 km must be about 200.

Therefore, there is a way to estimate an atmospheric temperature at the OH emission layer by measuring the Vibration-Rotation spectra. This kind of measurements have been done but with a long time exposure of the spectrometer because of low sensitivity. Recently, improvement and development of spectrometer and electronics make it possible to measure short time variation of the line spectra in an OH band.

1. DIURNAL VARIATION OF ROTATIONAL TEMPERATURE

Sivjee et al. (1972) has reported a large variation of rotational temperature through a night, ascending towards midnight and descending towards morning varying between 150°K to 270°K .

Dick (1972), however, observed, with the same type of measurement, that Trot. has a minimum at near midnight and that the magnitude of the variation is a few tens of degrees (see Fig. 2).

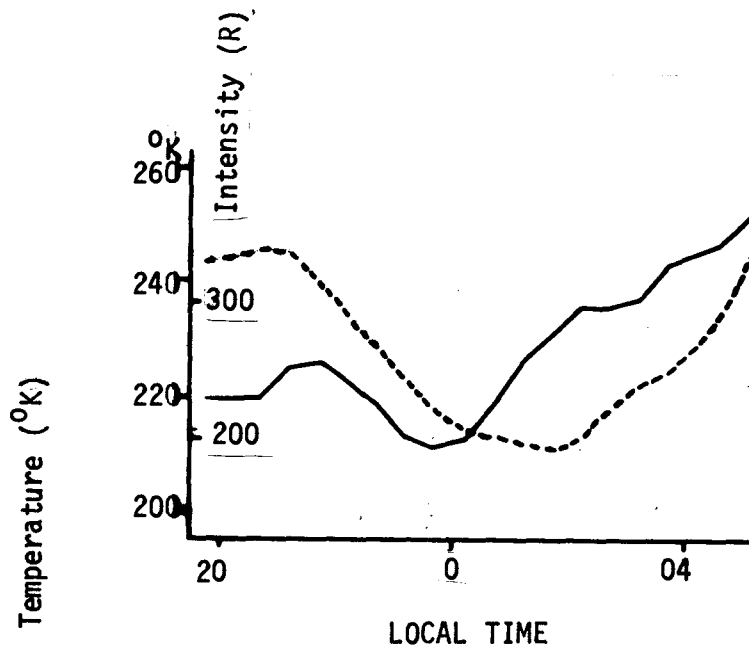


FIG. 2 - Diurnal variation of OH rotational temperature (full line) and intensity (dashed line), measuring OH (8,3) P_1 branch, by Dick (1972).

But he also mentioned the existence of a variation similar to that reportedly Sivjee et al. (1972) for an atypical case.

Shefov (1972) summarized the data from the Soviet Union and indicated several types of variation but the diurnal excursion were less than 50°K .

On the other hand, Harrison et al. (1971) observed no systematic variation greater than the uncertainty of less than 20°K .

Now, the problem is how to explain this temperature variation. It seems difficult to imagine that the observed temperature variation in a short period could be due to a real change of the atmospheric temperature in the emitting region unless such a variation is due to either tidal or gravity wave oscillations, because one must require too large and rapid a heat inflow and outflow in this layer. A change of the emission height itself would be more reasonable (Sivjee et al., 1972 and Shefov, 1972).

The other possibility is that excited OH molecules are produced at different altitudes with different mechanisms and these excitation mechanisms vary during the night (e.g., Wallace, 1972). Rocket measurement on emission height will help this discussion directly.

2. SEASONAL VARIATION

There has been a suggestion of a winter maximum and summer minimum by several investigators. Typical measurements are shown in below Table 3.

Author	Latitude	Trot. °K		Measured bands
		Winter	Summer	
Wallace, 1961	42°N	230	200	(6,2) (5,1)
Krassovsky et al, 1961	62°N	300	220	(9,3)
Kvifte G.J., 1967	60°N	210 ±10°K	210 ±10°K	(9,4), (8,3), (6,1)
Harrison et al., 1971	51°N	224	185	(4,1)
Harrison et al., 1971	51°N	233	192	(5,2)

TABLE 3 : Seasonal variation of OH rotational temperature

Wallace (1961) indicated seasonal variation to be less than 30°K, and this seems to correspond with a seasonal variation of atmospheric temperature. (Murgatroyd, 1965).

3. LATITUDE VARIATION

Fig. 3 shows the mean rotational temperature measured at various latitudes in 1950 to 1970.

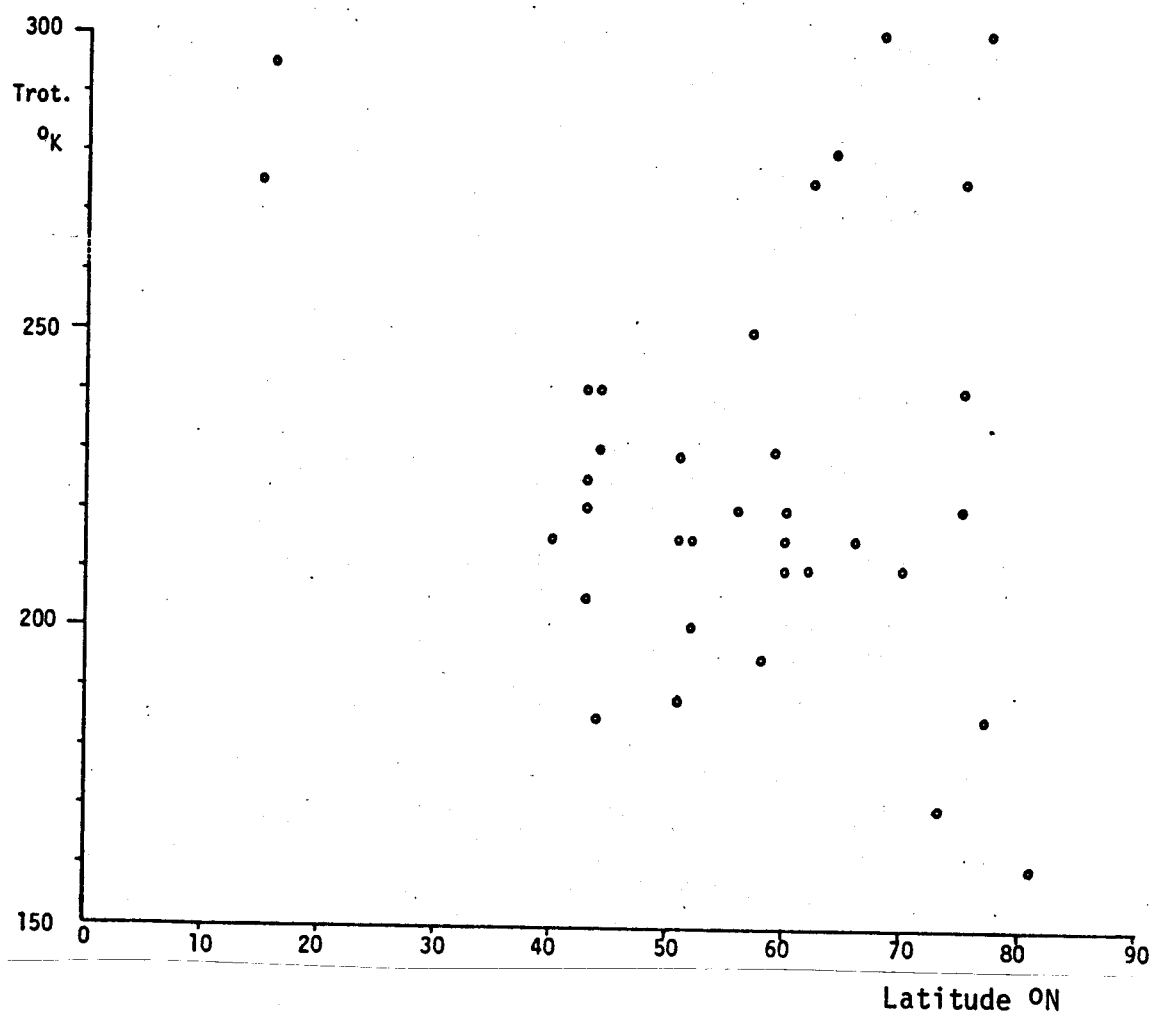


FIG. 3 - OH rotational temperature VS. latitude

Despite a lack of data at low latitudes and the existence of a seasonal variation of Trot., a minimum at middle latitudes and an increase towards high latitudes are observable. This effect seems to correspond to the dependence of the atmospheric temperature with latitude (Murgatroyd, 1965). The large scattering of Trot. at high latitudes might be due to a strong effect of solar activity. The two high temperatures at low latitudes are of interest but the measurements are too poor to discuss.

Correlation between the band intensity and Trot. does not always exist. Although on some occasion the phase of its variation is the same as that of Trot., this does not always hold (e.g. Shefov, 1972, Dick, 1972 and Harrison et al., 1971).

III. OH (8,3) BAND SPECTRA AND ITS ROTATIONAL STRUCTURE

The band spectra of OH molecules is due to Vibration-Rotation transitions in electronic ground state $^2\pi$ level. Its vibrational levels, $G_0(v)$, are shown in Fig. 4 and Table 4.

v	$G_o(v) \text{ cm}^{-1}$
0	0
1	3568.4
2	6971.1
3	10210.5
4	13287.0
5	16201.0
6	18952.1
7	21538.0
8	23949.4
9	26184.3

TABLE 4: Vibrational energy levels in electronic ground state $^2\pi$ of OH molecule, calculated by Kvifte (1959).

where,

$$G_o(v) = G(v) - G(o)$$

$G(o)$ is the vibrational energy of the $v = 0$ level

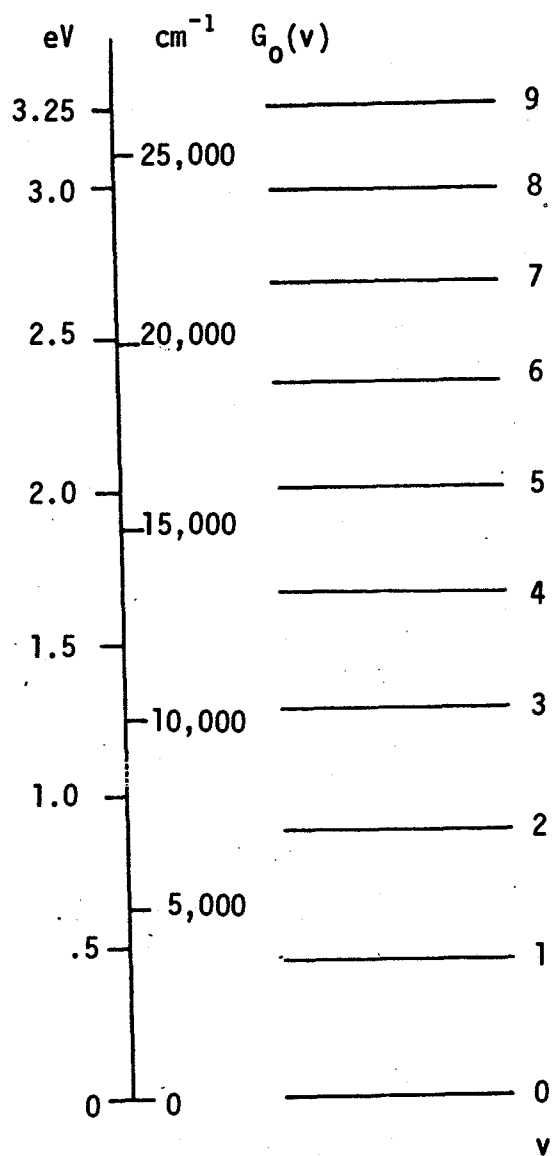


FIG. 4. - Vibrational energy levels of OH molecule.

According to Hill and Van Vleck (1928), the rotational energies in the $^2\pi_{\frac{3}{2}, \frac{1}{2}}$ levels, $F_{1,2}$, in the case of intermediate coupling, are given by, (see Herzberg's text P232, 1950).

$$^2\pi_{\frac{3}{2}}; F_1(J) = B_V \left\{ \left(J + \frac{1}{2}\right)^2 - 1 - \frac{1}{2} \left[4\left(J + \frac{1}{2}\right)^2 + Y_V(Y_V - 4) \right]^{\frac{1}{2}} \right\} - D_V J^4; J = K + \frac{1}{2}$$

$$^2\pi_{\frac{1}{2}}; F_2(J) = B_V \left\{ \left(J + \frac{1}{2}\right)^2 - 1 + \frac{1}{2} \left[4\left(J + \frac{1}{2}\right)^2 + Y_V(Y_V - 4) \right]^{\frac{1}{2}} \right\} - D_V (J+1)^4;$$

$$; J = K - \frac{1}{2} \quad (6)$$

where B_V , Y_V and D_V are the spectroscopic molecular constants, J the total angular momentum quantum number and K the rotational quantum number.

In calculating the rotational levels of $v = 8$ and $v = 3$ we used the night airglow data by Wallace (1960) for the former and the laboratory experiment data by Dieke and Crosswhite (1948) for the latter. The values of spectroscopic molecular constants used here are as follows, (Wallace, 1960).

$$B_8 = 12.89 \pm 0.01$$

$$Y_8 = -10.93 \pm 0.03$$

$$D_8 = 0.0018$$

Table 5, Fig. 5 and Table 6 show the f-values and the wavelengths of individual lines calculated by the method mentioned above.

TABLE 5

Energy levels of the OH molecule in the $X^2\pi$ state,

$v = 8$

	$^2\pi \frac{3}{2}$		$^2\pi \frac{1}{2}$	
K	f_1	$F_1(K)$	f_2	$F_2(K)$
1	23949.4	0	24079.1	129.7
2	24008.8	59.4	24120.6	171.2
3	24092.7	143.3	24190.9	241.5
4	24201.4	252.0	24286.7	337.3
5	24333.7	384.3	24409.4	460.0
6	24490.8	541.4	24558.6	609.2
7	24671.3	721.9	24732.7	783.3
8	24876.4	927.0	24932.7	983.3

TABLE 5 (Cont.)

$v = 3$

	$2\pi \frac{3}{2}$		$2\pi \frac{1}{2}$	
K	f_1	$F_1(K)$	f_2	$F_2(K)$
1	10210.5	0	10336.6	126.1
2	10284.9	74.4	10391.2	190.7
3	10390.8	180.3	10481.0	270.5
4	10527.3	316.8	10605.1	394.6
5	10695.0	484.5	10763.0	552.5
6	10894.1	683.6	10954.3	743.8
7	11124.5	914.0	11178.3	967.8
8	11386.0	1175.5	11434.6	1224.1
9	11678.3	1467.8	11722.7	1512.2

where, $f = G_0(v) + F(K)$ in cm^{-1}

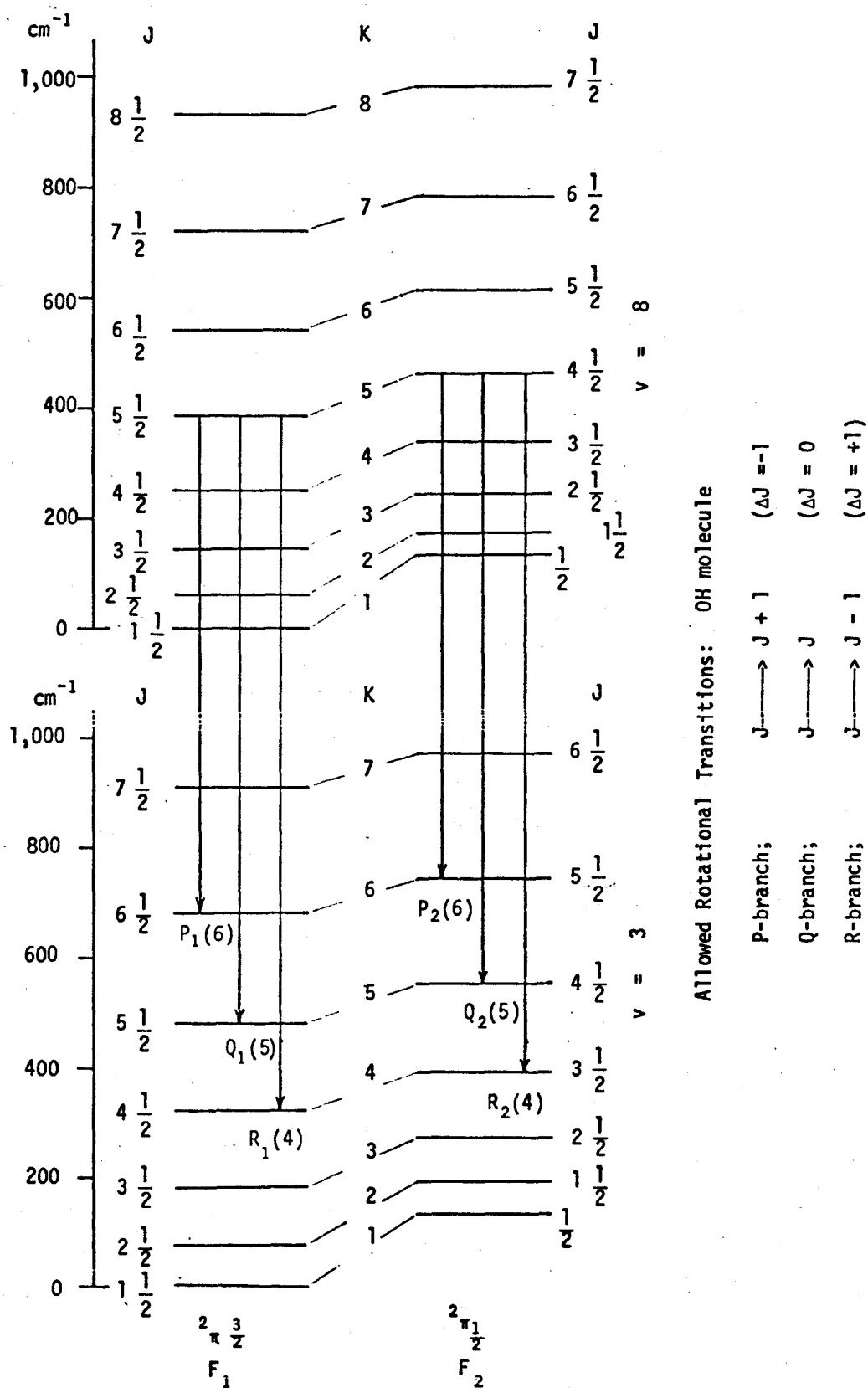


FIG. 5 - Rotational energy levels of $v = 8$ and $v = 3$ and the several transitions.

TABLE 6

Wave numbers and wavelengths of OH(8,3) Band*

Branch	Rot. Q No K"	$2_{\pi} \frac{3}{2}$		$2_{\pi} \frac{1}{2}$	
		$\nu_{vac.} (cm^{-1})$	$\lambda_{air}^{(**)} (\text{\AA})$	$\nu_{vac} (cm^{-1})$	$\nu_{air} (\text{\AA})$
P _{1,2}	2	13664.5	7316.4	13687.9	7303.7
	3	13618.0	7341.1	13639.6	7329.6
	4	13565.4	7369.7	13585.8	7358.6
	5	13506.4	7401.9	13523.7	7392.4
	6	13439.6	7438.7	13455.1	7430.1
	7	13366.3	7479.4	13380.3	7471.6
	8	13285.3	7525.0	13298.1	7517.8
	9	13198.1	7574.8	13210.0	7568.0
R _{1,2}	1	13798.3	7245.3	13784.0	7252.7
	2	13807.8	7240.1	13799.7	7244.3
	3	13810.6	7239.0	13805.7	7241.1
	4	13806.4	7241.1	13804.3	7242.2
	5	13795.8	7246.6	13795.6	7246.9
	6	13777.2	7256.4	13778.4	7255.7
	7	13751.9	7269.7	13754.4	7268.4
Q _{1,2}	1	13738.9	7276.4	13742.5	7274.8
	2	13723.9	7284.4	13729.4	7281.7
	3	13701.9	7296.1	13709.9	7291.8
	4	13674.1	7311.0	13681.6	7307.3
	5	13638.7	7330.3	13646.4	7326.0
	6	13596.7	7352.9	13604.3	7348.6
	7	13546.8	7379.8	13554.4	7375.7
	8	13490.4	7410.6	13498.1	7406.4

(*) Calculated from Table 5

(**) Relation between λ_{air} and λ_{vac} ;

$$\frac{1}{n_s \cdot \lambda_{air}} = \lambda_{vac}, \quad n_s = 1.0002755 \text{ at } 7300 \text{ \AA} \text{ regions.}$$

FIG. 6 - OH (8,3) Band Spectral Profile ; Band Intensity: 400 (R) , Trot. 220⁰K

IV - THE LINE INTENSITIES AND DERIVATION OF ROTATIONAL TEMPERATURE OF OH MOLECULES

Assuming thermal equilibrium of the OH molecules, the intensities of the lines in a band are expressed by, (see Herzberg's text P127, 1950)

$$I(J) = C \nu^3 S_J \exp. \left(- \frac{F(J) hc}{k \text{ Trot.}} \right) \quad \text{Quanta/cm}^3 \text{ sec} \quad (7)$$

where J: the total angular momentum quantum number in upper rotational level.

ν : wave number of the line (cm^{-1})

S_J : line strength (or intensity factor)

$F(J)$: the rotational energy of the upper vibrational level (cm^{-1})

C: a constant (including normalized factor)

K, h, c: the constants in usual meaning

A formula for S_J , line strength, has been given by Hönl and London (1925) for Hund's coupling case (a) (see Herzberg's text P208, 1950). In the case of the electronic $^2\pi - ^2\pi$ transition, i.e. $\Lambda = 1$, $\Delta\Lambda = 0$ where Λ is the angular momentum quantum number of molecule, this formula becomes as shown in Table 7.

It should be noted that this S_J calculated belonging to Hund's case (a) is a good approximation when the J number is small, but

for large J numbers, i.e., for large rotation, this coupling transfers to intermediate coupling between Hund's case (a) and (b)*.

TABLE 7

Line strengths of $X^2\pi$ ground state
Rotation-Vibration bands of OH molecule

$$\begin{aligned}
 S_J^P &= \frac{(J'+1+\Omega)(J'+1-\Omega)}{J'+1} = \frac{(J'+1)^2 - \frac{9}{4}}{J'+1} & ; \Omega = \frac{3}{2} & P_1 \\
 &= \frac{(J'+1)^2 - \frac{1}{4}}{J'+1} & ; \Omega = \frac{1}{2} & P_2 \\
 S_J^R &= \frac{(J'+\Omega)(J'-\Omega)}{J'} = \frac{J'^2 - \frac{9}{4}}{J'} & ; \Omega = \frac{3}{2} & R_1 \\
 &= \frac{J'^2 - \frac{1}{4}}{J'} & ; \Omega = \frac{1}{2} & R_2 \\
 S_J^Q &= \frac{(2J'+1)\Omega^2}{J'(J'+1)} = \frac{9}{4} \frac{(2J'+1)}{J'(J'+1)} & ; \Omega = \frac{3}{2} & Q_1 \\
 &= \frac{1}{4} \frac{2J'+1}{J'(J'+1)} & ; \Omega = \frac{1}{2} & Q_2
 \end{aligned}$$

where, J' is the total angular momentum quantum number in the upper vibrational levels, Ω is the quantum number of the resultant electronic angular momentum about the internuclear axis including electronic spin (Hund's case (a)).

* See page 28 marginal notes.

TABLE 7 (Cont.)

K	$2 \pi \frac{3}{2}$				$2 \pi \frac{1}{2}$			
	J'	S_J^{P1}	S_J^{R1}	S_J^{Q1}	J'	S_J^{P2}	S_J^{R2}	S_J^{Q2}
1	3/2	1.600	0	2.400	1/2	1.333	0	0.667
2	5/2	2.857	1.600	1.543	3/2	2.400	1.333	0.267
3	7/2	4.000	2.857	1.143	5/2	3.429	2.400	0.171
4	9/2	5.091	4.000	0.909	7/2	4.444	3.429	0.127
5	11/2	6.154	5.091	0.755	9/2	5.455	4.444	0.101
6	13/2	7.133	6.154	0.646	11/2	6.462	5.455	0.0839
7	15/2	8.235	7.133	0.565	13/2	7.467	6.462	0.0718
8	17/2	9.263	8.235	0.502	15/2	8.471	7.467	0.0628
9	19/2	10.29	9.263	0.451	17/2	9.474	8.471	0.0557
10	21/2	11.30	10.29	0.410	19/2	10.48	9.474	0.0501

The results of calculation using equation (7), "Relative intensities of OH(8,3) band lines and branches with various temperatures" are shown in Table 8. Also, Fig. 6 shows the spectral profile of the (8,3) band assuming the band intensity 400 Rayleighs and the rotational temperature 220°K.

Now, taking the logarithm of equation (7), Fig. 7 shows the relation $\ln(I(J)/\nu 3_{S_J})$ and $F(J)$ with Trot. constant, 150, 200, 250 300 and 350°K. Hence one can estimate a rotational temperature from the slope of this linear graph measuring the intensities of $P_1(2)$, $P_1(3)$, $P_1(4)$ and $P_1(5)$ lines.

Besides, the intensities of the branches $P_{1,2}$, $Q_{1,2}$, and $R_{1,2}$ also vary with temperature variation in the same way as the lines. Fig. 8 shows the temperature dependency of the intensity ratios of R to Q branch, R/Q , and P to Q, P/Q , of (8,3) band. It is also possible to get a rotational temperature measuring these intensity ratios.

(*) Wallace (1961) used the S_J calculated belonging to Hund's case (b).

In the case of intermediate coupling, see Benedict (1953) and Wallace (1960).

TABLE 8

Relative Intensities of OH (8,3) Band P_1 Lines and Branches with various Temperatures.

Trot ρ K	$P_1(2)$	$P_1(3)$	$P_1(4)$	$P_1(5)$	$P_1(6)$	ΣP	ΣQ	ΣR
150	0.1214	0.1213	0.0750	0.0332	0.0111	0.4742	0.3027	0.2231
160	0.1135	0.1175	0.0764	0.0361	0.0131	0.4771	0.2903	0.2326
170	0.1065	0.1138	0.0774	0.0387	0.0150	0.4797	0.2790	0.2413
180	0.1002	0.1101	0.0779	0.0410	0.0169	0.4820	0.2686	0.2494
190	0.0946	0.1065	0.0781	0.0430	0.0188	0.4840	0.2591	0.2569
200	0.0895	0.1031	0.0780	0.0448	0.0206	0.4859	0.2502	0.2639
210	0.0849	0.0999	0.0777	0.0463	0.0223	0.4875	0.2420	0.2705
220	0.0808	0.0968	0.0773	0.0477	0.0239	0.4889	0.2345	0.2766
230	0.0770	0.0938	0.0768	0.0488	0.0254	0.4902	0.2274	0.2824
240	0.0735	0.0910	0.0761	0.0498	0.0268	0.4914	0.2208	0.2878
250	0.0703	0.0883	0.0754	0.0506	0.0281	0.4925	0.2147	0.2928
260	0.0674	0.0858	0.0746	0.0513	0.0294	0.4934	0.2090	0.2976
270	0.0648	0.0834	0.0738	0.0519	0.0305	0.4943	0.2036	0.3021
280	0.0623	0.0811	0.0729	0.0524	0.0316	0.4950	0.1981	0.3064
290	0.0600	0.0790	0.0720	0.0528	0.0326	0.4958	0.1938	0.3104
300	0.0579	0.0769	0.0712	0.0531	0.0335	0.4964	0.1894	0.3142
310	0.0559	0.0750	0.0703	0.0533	0.0343	0.4970	0.1852	0.3178
320	0.0541	0.0732	0.0694	0.0535	0.0351	0.4976	0.1812	0.3212
330	0.0524	0.0714	0.0685	0.0536	0.0358	0.4980	0.1775	0.3245
340	0.0508	0.0698	0.0677	0.0536	0.0365	0.4984	0.1740	0.3276
350	0.0493	0.0682	0.0668	0.0537	0.0371	0.4989	0.1706	0.3305

The intensities are normalized, i.e., $\Sigma P + \Sigma Q + \Sigma R = 1$

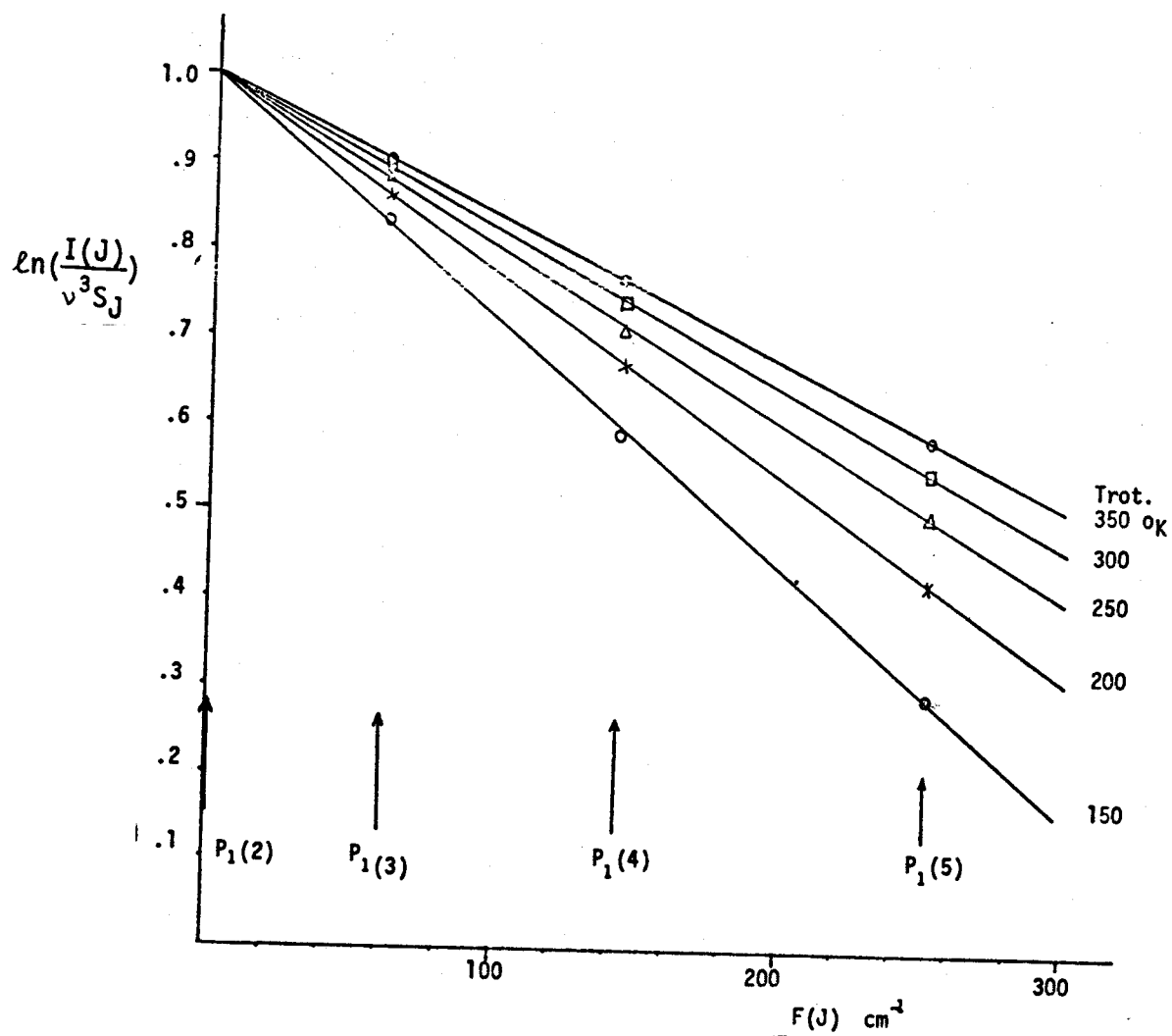


FIG. 7 - Temperature dependence of the lines of P branch

$\ln(I(J)/v^3 S_J)$ vs. $F(J)$

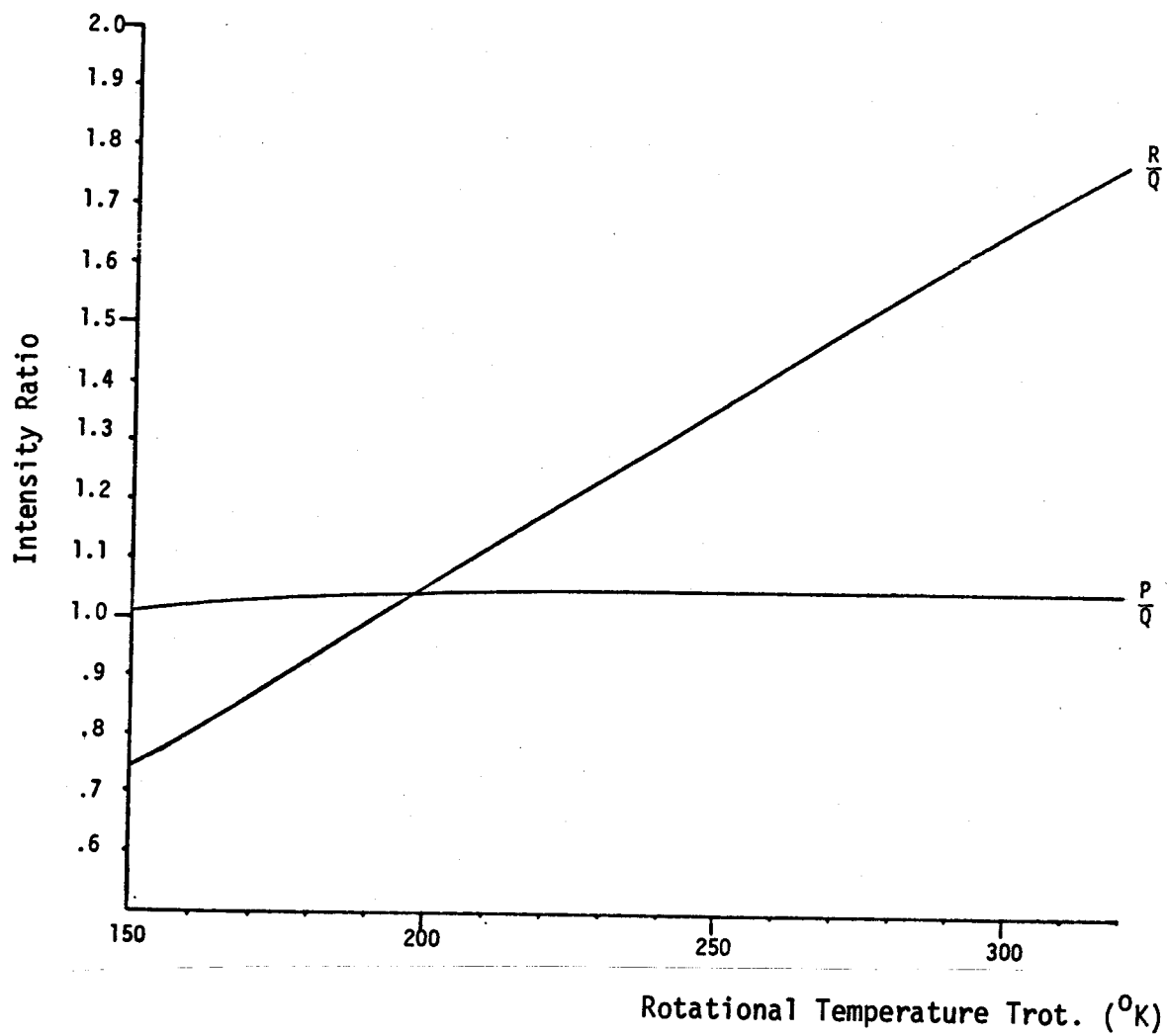


FIG. 8 - Intensity Ratios $\frac{R}{Q}$ and $\frac{P}{Q}$ vs. Trot.

V - DISCUSSION

The object of the OH airglow measurement eventually arrives at a discussion of the structure of the upper atmosphere and thermodynamic problems related on it.

In Table 9 we attempt to classify the OH measurement and its physical themes.

The purposes of the measurement of OH rotational temperature are,

- (1) Estimation of the upper atmospheric temperature,
- (2) Time and specific variations of emission layer, going further, a discussion on dynamical motion, i.e. tidal, turbulence and eddy diffusion in the upper atmosphere.
- (3) Investigation of OH excitation mechanism.

Although there are a number of data of Trot., they are not sufficient to investigate the above phenomena. High precision, less than $\Delta T = \pm 10^0 K$ and short time period measurement, at least each half an hour should be required.

Besides, most measuring stations are localized in the mid-latitude northern hemisphere, not in southern latitudes. Hence our

measurement at São José dos Campos, (23°S), Brasil has significance in this content.

The measurement will be done in two steps. In the first step, measuring P, Q and R branches individually, we estimate a Trot. as mentioned in Section IV (see Fig. 8) using a filter tilting type photometer. This type of measurement has been done since July 1972.

Secondly, we use a Fabry-Perot interferometer and are going to measure P-branch, $P_1(2)$, $P_1(3)$, $P_1(4)$ and $P_1(5)$ lines individually as mentioned in Sec. IV (see Fig. 7). A proto-type Fabry-Perot interferometer (1.5 inches diameter) has been constructed in the workshop of INPE.

These two types of measurement and some observation results will be presented in a following report.

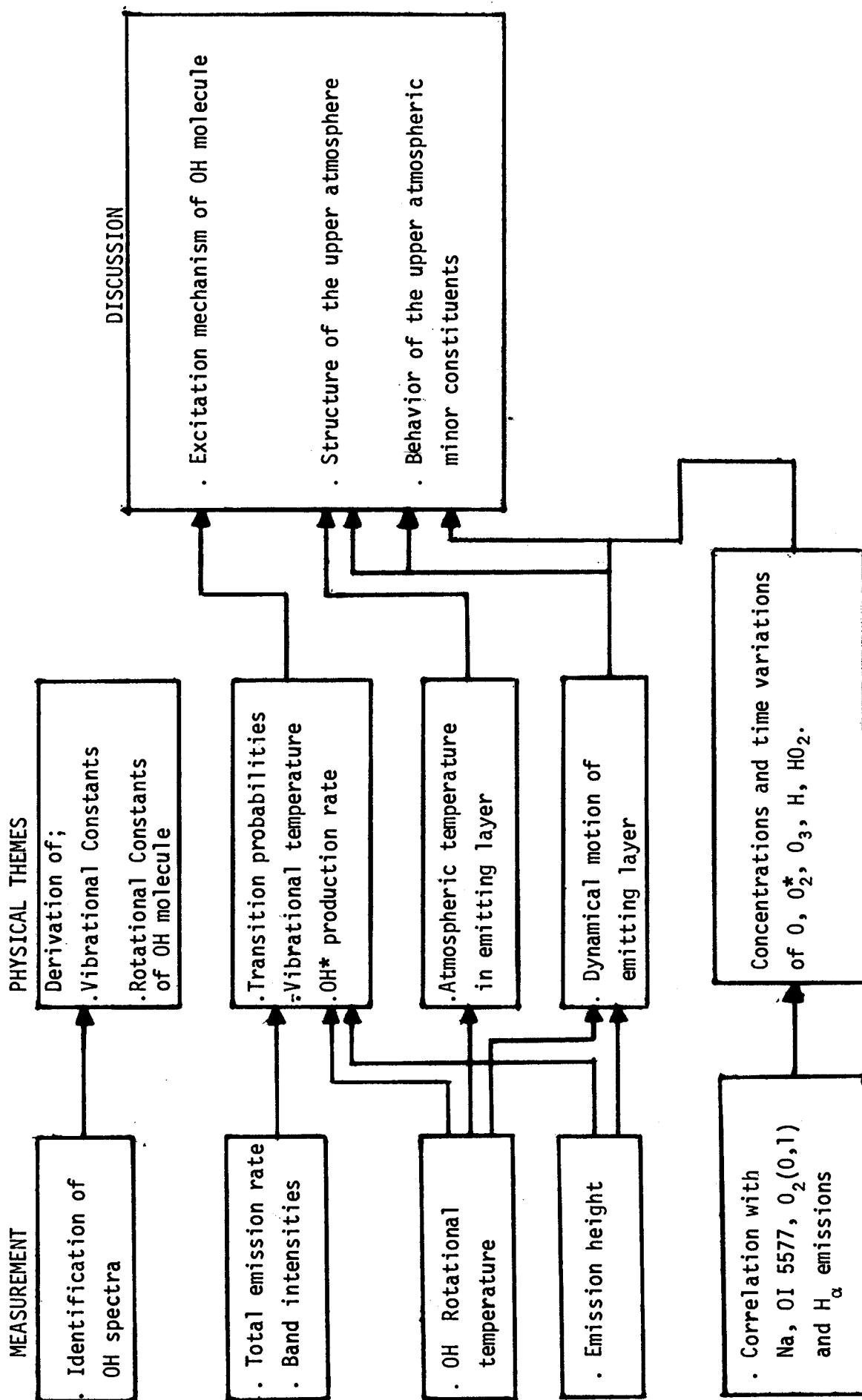


TABLE 9: Classification of OH night airglow measurement

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