

Determination of rotational temperature of AlO from the $B^2\Sigma^+-X^2\Sigma^+$ system

M M CHAUDHARI¹, C T LONDHE² and S H BEHERE²

¹Maharashtra Mahavidyalaya, Nilanga 413 521, Dist. Latur, India

²Department of Physics, Dr Babasaheb Ambedkar Marathwada University,
Aurangabad 431 004, India

E-mail: subhashbehere@yahoo.com

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Abstract. AlO molecule was excited in a DC arc in air running between two aluminium electrodes. Rotational structure of the (0,0) band of the $B^2\Sigma^+-X^2\Sigma^+$ system of AlO molecule was photographed in the first order of a 10.6 m concave grating spectrograph. Intensity distribution amongst the well-resolved rotational lines of R_1 and R_2 branches was recorded and the average rotational temperature calculated from these has been determined as 2880 ± 100 K.

Keywords. Intensity studies; rotational temperature; AlO molecule.

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1. Introduction

The AlO molecule is of astrophysical importance. Merrill *et al* [1] observed it in the absorption spectra of M-type Mira variables. They have also inferred that the quantities of YO and ScO are more compared to AlO. It indicates the tendency of a star to move in S-type of stars. The strongest band of AlO observed in Mira and R Hya stars is the (0,0) band of the $B^2\Sigma^+-X^2\Sigma^+$ system at 4842 Å. Studies by Keenan *et al* [2] have concluded that the strength of AlO bands can be quite different in two variable stars having same temperatures. Occasionally, the AlO bands reverse to emission. In Mira stars the variations in the strength of AlO bands are correlated with the variations in the line strength from cycle to cycle. In view of a likelihood of detection of the A–X system in Mira variables, Luck and Lambert [3] emphasized upon its laboratory studies.

AlO molecule has many known electronic states, viz. $X^2\Sigma^+$, $A^2\Pi_i$, $B^2\Sigma^+$, $C^2\Pi_r$, $D^2\Sigma^+$, $E^2\Delta^i$ and $F^2\Sigma^+$. Since $A^2\Pi_i$ is close to ground state, lot of perturbations have been observed in various transitions. Almost all transitions, viz. A–X, B–X, C–X, D–X, D–A, E–A etc. are reported in emission and absorption. The C–B,

D–B and F–A transitions are reported in emission only. The blue–green $B^2\Sigma^+ - X^2\Sigma^+$ system is extensively studied and the absolute band strengths are reported by Hebert *et al* [4] and Reddy *et al* [5]. The vibrational temperature of AlO is reported by Mentall and Nicholls [6]. They produced the species in plasma generated using lasers. They have used Baush and Lomb 1.5 m spectrograph having a dispersion of 15 \AA mm^{-1} . Spectra were recorded on Kodak 103 F films. Recently, Dors *et al* [7] have spectroscopically determined the temperature of aluminium monoxide in laser ablation using 266 nm radiation.

2. Experimental

In the present study, AlO molecule was excited in a DC arc in air running between two aluminium electrodes of about 1 cm in diameter and tapered towards tips. The arc current was 3 A at 110 V. The blue–green B–X system of AlO was photographed in the first order of a 10.6 m concave grating spectrograph described by Behere and Laud [8] with a plate factor of 0.747 \AA/mm . The greenish-blue part of the arc was focused on the slit with the help of a condensing lens. Slit width was kept at $20 \text{ }\mu\text{m}$. Exposures of 10–15 min were required to record the rotational structure of the (0,0) band of the B–X system. Orwo films were used to record the spectra. In view of Harrison *et al* [9], due care was taken to ensure that the exposure falls in the normal region of the H–D curve. Films were processed with fine grain developer. Since this band covers a wavelength region less than 25 \AA , homochromatic photometry was used to determine the intensity measurements. In other words, response of the emulsion was assumed to be constant for this small region. A Carl Zeiss/Jena MD 100 microphotometer was used to record the intensities of the rotational lines. The procedure of Herbert and Tyte [10] was followed in extrapolating the contours of the rotational lines. The areas of the profiles of the rotational lines were measured with the help of a digital planimeter with an accuracy of 10^{-2} cm^2 and more. Average intensity of each line was employed to calculate the rotational temperature.

3. Calculations of rotational temperature

The relation between the intensity of rotational line $I_{J'J''}$, term value $F_{v'}(J')$ and the Hönl–London factor $S_{J'J''}$ is,

$$\ln\{I_{J'J''}/S_{J'J''}\} = -F_{v'}(J')hc/kT_{\text{rot}} + \text{constant.} \quad (1)$$

The Hönl–London factors of various branches and for different $\Delta\Lambda$ can be found in Herzberg [11]. In the present case for P branch and for $\Lambda'' = 0$

$$S_k^P = K \quad \text{and} \quad S_k^R = (K + 1), \quad (2)$$

where K is used for J'' . A graph between LHS and $F_{v'}(k')$ gives straight line whose slope is hc/kT_{rot} . Because of the resolution of grating it was possible to resolve the R_1 and R_2 components of the R branch lines appearing in $B^2\Sigma^+ - X^2\Sigma^+$ transition (figure 1).

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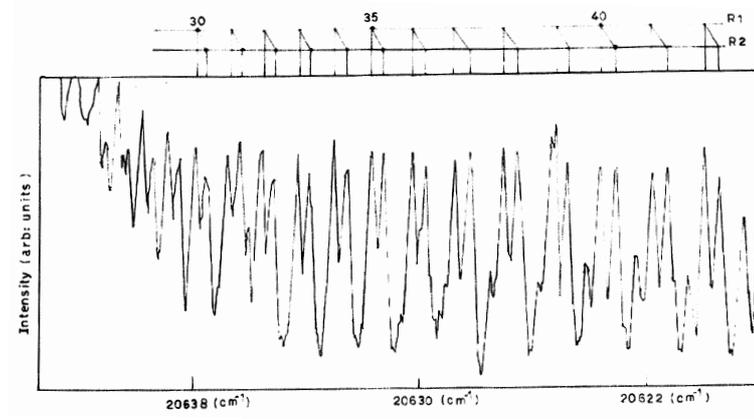


Figure 1. Part of the microphotometer trace of the 0-0 band of $B^2\Sigma^+-X^2\Sigma^+$ system of AlO.

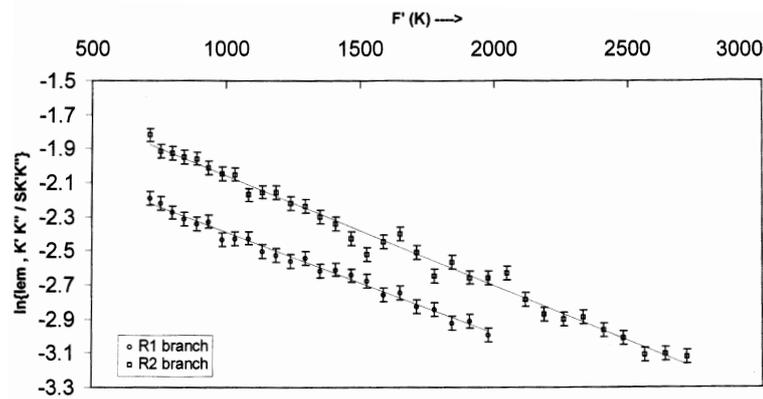


Figure 2. Determination of rotational temperature from the band intensity measurements of the blue-green system of AlO.

Only such lines in which these components show separate peaks were chosen and the intensities were measured. From the slopes of the graph (figure 2) the average temperature $T_{\text{rot}} = 2880 \pm 100$ K.

4. Results and discussion

The vibrational temperature calculated by Mentall and Nicholls [6] using the integrated band intensities of the blue-green system of AlO in the laser-produced plasma using Al target comes out to be 3600 ± 400 K. The average temperature calculated by Dors *et al* [7] using the laser ablation of Al_2O_3 for the $B^2\Sigma^+-X^2\Sigma^+$ system with the 266 nm radiation with a 20 μs delay time is 3384 K. Dors *et*

al used Nd:YAG laser which was externally synchronized to 10 Hz and frequency quadrupled by the use of two frequency doublers to generate 266 nm radiation of 6 mJ/pulse. Using 0.275 m Jarrell Ash spectrometer attached with OMA, they could record the $\Delta v = 0, \pm 1, \pm 2$ and $+3$ sequences. In this background the result in the present study gives lower value of the rotational temperature. The kinetic gas temperature thus generated varies from source to source and with the electron density of the plasma produced. The effective temperature depends on the source of excitation. Laser plasmas usually have higher temperatures, as the surface power density of a laser beam on a target is high enough to create that temperature.

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References

- [1] P W Merrill, A J Deutsch and P C Keenan, *Astrophys. J.* **136**, 21 (1962)
- [2] P C Keenan, A J Deutsch and R F Garrison, *Astrophys. J.* **158**, 261 (1969)
- [3] R E Luck and L Lambert, *Pub. Astron. Soc. Pacific* **86**, 276 (1974)
- [4] G R Hebert, R W Nicholls and C Linton, *J. Quant. Spectrosc. Radiat. Transfer* **23**, 299 (1980)
- [5] R R Reddy, Y Nazeer Ahammed, K Rama Gopal, P Abdul Azeem and S Anjaneyulu, *Astrophys. Space Sci.* **262**, 223 (1998)
- [6] J E Mentall and R W Nicholls, *J. Chem. Phys.* **46**, 2881 (1967)
- [7] L G Dors, C Parigger and J W Lewis, *Opt. Lett.* **23**, 1778 (1998)
- [8] S H Behere and B B Laud, *Marathwada University J. Sci.* **21**, 14, 1 (1982)
- [9] G R Harrison, R C Lord and J R Loofbourow, *Practical spectroscopy* (McGraw Hill Publications, New York, 1948)
- [10] G R Herbert and D C Tyte, *Proc. Phys. Soc.* **83**, 629 (1964)
- [11] G Herzberg, *Molecular spectra and molecular structure*, 2nd edition (Van Nostrand Reinhold Company, New York, 1950) pp. 205–208, 247–250