

Estimation of rotational temperature of $^{121}\text{Sb}^{16}\text{O}$ molecule

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Abstract. The (0,1), (0,0), (1,0) and (2,0) bands of $B \rightarrow X$ system of antimony monoxide have been excited in rf discharge tube source and photographed in the 9th order of a two metre plane grating spectrograph (PGS-2). Intensity records of the rotational lines have been obtained. The intensity measurements of Q and P branch lines of the above four bands and J numberings are used to estimate the effective rotational temperature of the source emitting the spectrum of $^{121}\text{Sb}^{16}\text{O}$ molecule. It is concluded that $^{121}\text{Sb}^{16}\text{O}$ may be present in K type stars.

Keywords. Rotational temperature; electronic spectra; diatomic molecules.

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1. Introduction

Experimental studies in the spectra of diatomic molecules have laid emphasis mostly on the determination of vibrational and rotational constants and the determination of the intensity distribution has often been neglected. Recent advances in physics and astrophysics have forced the attention of several groups of workers in this direction. Spectra of the radiation from astronomical sources show many bands which are attributed to diatomic molecules. A number of lighter as well as heavier diatomic molecules are detected in the stellar spectra. They are also found in the atmosphere of earth, planets and in interstellar sources. During the course of our experimental work, we found some bands of SbO molecule which are suitable for intensity studies. Mukherjee [1] first reported the spectrum of antimony monoxide. Later, several workers [2–12] studied it. From their studies they reported the vibrational and rotational constants. The spectrum of SbO extends from IR to UV. But nobody tried to study the intensity distribution to estimate the rotational and vibrational temperature of the source emitting the spectrum of SbO molecule. Hence we thought it worthwhile to carry out the intensity measurements of some of the suitable bands of SbO molecule and the results obtained are reported here.

2. Experimental

The spectrum of antimony monoxide has been excited in rf discharge source. A pure sample of antimony oxide is taken in a quartz tube of 25-cm length and 8-mm diameter. The characteristic sky blue color of the discharge was established by employing high frequency

oscillator giving an output of 125 W at 10–15 MHz. External heating and continuous evacuation was necessary to maintain the stable conditions of the discharge. The (0,1), (0,0), (1,0) and (2,0) bands of $B \rightarrow X$ system at 3894.4 Å, 3774.0 Å, 3695.0 Å and 3621.7 Å respectively were photographed in a PGS-2 (Carl–Zeiss) providing a dispersion of about 0.35 Å/mm in the 9th order of the plane grating blazed at 10500 Å having 651 grooves per mm. It offers a resolution of 2×10^5 . A pre-disperser (Carl–Zeiss) in the order-sorter mode has been used to avoid the overlapping of orders. Exposures of about 9 h were necessary to photograph the rotational structure with sufficient intensity using a slit of 20 μm and Kodak T-max and ORWO WU₃ spectroscopic plates. The plates were measured on Abbe comparator (Carl–Zeiss). The error of measurement is within $\pm 0.05 \text{ cm}^{-1}$ for sharp lines. Atomic lines of antimony present in the spectrum served as internal standards. Intensity measurements were made by recording the intensity distribution amongst the rotational lines of the (0,1), (0,0), (1,0) and (2,0) bands using a microdensitometer coupled with a photometric recorder (Carl–Zeiss). The densitometer was calibrated for a spectral sensitivity of emulsion of photographic plates. It has been found that the spectral sensitivity of the emulsion remains almost constant over a small extent of the rotational structure of a particular band. Then the area under the intensity peak of a rotational line is measured by using a planimeter having an accuracy of 10^{-4} cm^2 . Thus the relative intensity measurements of rotational lines are made and average values for each line are employed to calculate the rotational temperature.

3. Results and discussion

Intensity distribution in the rotational structure of (0,1), (0,0), (1,0) and (2,0) bands together with rotational constants and J numbering reported by Chakoo and Patel [9] has been employed to calculate the rotational temperature of the molecule. The area under the intensity profile of a rotational line is measured by taking the base line corresponding to the background intensity of the emulsion. The intensities of the rotational lines of rotation–vibration bands in emission are given by

$$I_{\text{em}} = \frac{C_{\text{em}} v^4}{Q_r} (J' + J'' + 1) \exp \{ [-B_{v'} J'(J' + 1)hc] / kT \} \quad (1)$$

where C_{em} is a constant depending upon the change of the dipole moment and the total number of molecules in the initial vibrational level v and Q_r is the rotational state sum. From (1), one can obtain immediately

$$\ln \frac{I_{\text{em}}}{J' + J'' + 1} = A - \frac{B_{v'} J'(J' + 1)hc}{kT} \quad (2)$$

where $A = \ln(C_{\text{em}} v^4 / Q_r)$, which may be taken as constant for a small range of v . By plotting $\log [I_{\text{em}} / (J' + J'' + 1)]$ against $J'(J' + 1)$, a straight line is obtained whose slope is $B_{v'} hc / kT$.

Thus by measuring line intensities and using the rotational constants and J numbering, the temperature of the source can be determined. Strictly speaking eq. (1) holds for emission from a purely thermal excitation. However, it has been found experimentally that the

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Table 1. Effective rotational temperature of the source emitting the spectrum of SbO molecule.

Band	Branch	Rotational temperature (K)
(0,1)	<i>Q</i>	4561
	<i>P</i>	4745
(0,0)	<i>Q</i>	4950
	<i>P</i>	4720
(1,0)	<i>Q</i>	4808
	<i>P</i>	4760
(2,0)	<i>Q</i>	4637
	<i>P</i>	4658
Mean		4730 ± 111

normal intensity distribution in electron discharges results under the situation that the angular momentum is not strongly altered in excitation by electron collision. Considering this we have calculated the rotational temperature of the source emitting the spectrum of antimony monoxide molecule.

The well-resolved single lines free from any overlapping are considered from *Q* and *P* branches of (0,1), (0,0), (1,0) and (2,0) bands. Area under the peak of each rotational line is measured using a planimeter and the average area under the peak is used in the calculation. Considering the calibration of the standard source and spectral sensitivity of emulsion over a small range of wavelength, it is assumed that the intensity of rotational lines in emission is proportional to the area under the peak in the intensity records. Thus $\log [I_{\text{em}}/(J' + J'' + 1)]$ is plotted against $J'(J' + 1)$ for *Q* and *P* branch lines of (0,1), (0,0), (1,0) and (2,0) bands. Using the *J* numbering and the rotational constants (B'_v), the rotational temperature is calculated. The rotational temperature of SbO molecule is given in table 1.

4. Conclusions

Using intensity measurements, rotational constants and *J* numbering, the mean effective rotational temperature was found to be 4730 ± 111 K. From this value of the rotational temperature we can conclude that SbO molecule is likely to be present in the atmosphere of *K* type stars and in interstellar space. The band spectroscopic method for the determination of vibrational and rotational temperature of interstellar molecules is an important tool in astrophysics to determine the chemical composition of stars and interstellar space.

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