

Spectroscopic study of rotational energy distribution of BH ($A^1\Pi$) and electronic excitation temperature determination

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Abstract. Emission spectra of BH($A^1\Pi-X^1\Sigma^+$) system were recorded and studied using a low pressure (3.0 torr) arc in flowing hydrogen and argon + hydrogen mixture. The rotational distributions in the $A^1\Pi$ state determined from the intensities of rotational lines for the 0–0 band of the $A-X$ system conforms to a Maxwellian distribution with effective rotational temperature of $1000 \pm 50^\circ\text{K}$. Intensities of Balmer lines of hydrogen were measured and used to determine electronic excitation temperature which was found to be around 2000°K .

Keywords. Line intensity; Maxwellian distribution; effective rotational temperature; electronic excitation temperature.

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Experimental studies

The emission spectrum of BH($A^1\Pi \rightarrow X^1\Sigma^+$) first observed by Paton and Almy 1931, has been studied mainly from the analysis angle (Lotche-Holtgreven and Van der Vleugel 1931; Thunburg 1936; Almy and Horsfall 1937 and John *et al* 1967). However, there are no reports on rotational intensities and temperatures. In view of the fact that BH molecule is of astrophysical interest, such measurements are needed. Therefore, we present in this paper relative populations of rotational levels of BH($A^1\pi$) derived from intensity measurements of $A^1\Pi-X^1\Sigma^+$ band and also the electronic excitation temperatures derived from Balmer lines.

The BH($A-X$) was excited in a low pressure D.C. arc burning in flowing hydrogen/argon + hydrogen gases over boron powder contained in a cup in the lower electrode. The arc was maintained at a pressure of about 3.0 torr. The intensities of rotational lines of the 0–0 band of the $A-X$ system and the Balmer lines (H_β and H_γ) of hydrogen were measured using photographic photometry since it averages out the fluctuations of the arc.

The vibrational and electronic transition probability within a vibrational level remains reasonably constant in a single band. Therefore the populations of the rotational levels is governed by Boltzmann law and the intensity of the rotational line (J', J'') in emission within a band is given by (Hertzberg 1950).

$$I_{J', J''} = C v^4 S_{J', J''} \exp(-E_{J'}/kT). \quad (1)$$

Here J' and J'' are the rotational quantum numbers of the upper and lower energy

Table 1. Values used in equation (4).

Atomic lines	λ (A.U)	E (eV)	f	I (rel)
H $_{\beta}$	4861.33	-0.850	0.130	20.09
H $_{\gamma}$	4340.47	-0.544	0.042	11.96

levels, C , is a constant, ν , is the wavenumber of the transition, $E_{J'}$, is the rotational energy of J' level and T is the rotational temperature.

$S_{J'J''}$ values were calculated from Kovacs formula (Kovacs 1969) and $E_{J'}$ values were determined from the relation $E_{J'} = hcB_v J'(J'+1)$ where B_v , is the rotational constant ($B_v = 12.295 \text{ cm}^{-1}$). A plot of $\log I_{J'J''}/S_{J'J''}\nu^4$ against $E_{J'}$ resulted in a straightline, giving a rotational temperature of $1000 \pm 50^\circ\text{K}$.

A mixture of argon carrier gas produced no change in the intensity distribution and hence no change in temperature. The existence of low rotational temperature substantiated the mechanism (2) below



otherwise anomalous distribution is likely.

Intensity measurements of H $_{\beta}$ and H $_{\gamma}$ lines allowed the electronic excitation temperature to be determined using (3)

$$I = \frac{c \cdot g \cdot f}{\lambda^3} \cdot \exp(-E/kT). \quad (3)$$

where c is a constant, λ is the wavelength of the line, g is the statistical weight, f is the oscillator strength, E is the excitation energy of the upper level, and T is the electronic excitation temperature. The intensity of this line can be compared with the intensity (I') of another atomic line and one obtains

$$\log_e(I'/I) \cdot \frac{\lambda^3 \cdot g' \cdot f'}{\lambda'^3 \cdot g \cdot f} - = (E' - E)/kT. \quad (4)$$

This formula was applied to H $_{\beta}$ and H $_{\gamma}$ lines. For these lines $g = g'$. The values of various parameters for (4) were taken from the compilation of Griem (1964). These values together with measured values I and I' are collected in table 1. With these values electronic excitation temperature of 2000°K was obtained. It is noted that the distributions are obviously nonthermal, the rotational temperature perhaps is nearer the thermal distribution of electrons.

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