ON MAGNESIUM MONOXIDE LINES IN SUNSPOT SPECTRA

(Research Note)

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Abstract. For use in the investigations of magnesium monoxide lines in sunspot spectra, values of Franck-Condon intensity factors for the red bands and the wavelength regions for the intense bands of the red and near-ultraviolet transitions of MgO are presented. The results indicate that a search for the lines of the red and near-ultraviolet bands in the sunspot spectra could resolve the questionable presence of MgO in sunspots.

Studies of molecular lines in the spectra of sunspots have received great attention in recent years. The relative low temperature in sunspots allows a large number of molecular compounds to be formed, of which some cannot exist in the hotter photosphere. Thus, the spectrum of sunspots is known to be very rich in absorption lines, compared to the photospheric spectrum.

The diagrams of Tsuji (1964) and Dolan (1965), which give the molecular concentrations indicate that MgO molecule is one of the expected most abundant diatomic molecule in the umbrae of sunspots. However, the presence of MgO lines in sunspots appears to be doubtful (Wöhl, 1971), following the identification of the (0, 0) band lines of the red electronic transition ($B^1\Sigma^+ - A^1\Pi$). In contradiction to this conclusion, Sotirovski (1970) has reported the identification of the green bands ($B^1\Sigma^+ - X^1\Sigma^+$) of MgO in sunspot spectra. These identifications are based on the comparison of the observed equivalent widths with the calculated equivalent widths using Hénoux's (1969) sunspot model. However, it appears that the agreement between the measured and calculated equivalent widths is not satisfactory. If lines of another electronic transition could be observed it should be possible to establish the presence or absence of MgO in sunspots. In fact, Sotirovski (1971) extended his investigations for the red bands of MgO, but unfortunately, the lack of band intensities data prevented him to arrive at a definite conclusion on the presence of MgO in sunspots. It is therefore, thought worthwhile to present in this report, the values of the band intensity factors for the red bands. In addition, the possible presence of the near-ultraviolet bands in sunspots is indicated, in order that the results may be useful during a further search of MgO in sunspots.

Of particular interest for the calculation of equivalent widths, determination of rotational temperature and curve of growth analyses of molecular lines are the values of Franck-Condon intensity factors. Also, these relative band intensities provide criterion for the choice of bands by indicating which band of a given system is likely to be seen. Using the molecular constants reported by Lagerqvist and Uhler (1949), the values of the Franck-Condon factors ($q_{v'v''}$) are calculated for the red bands of MgO.

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In addition, the values of r-centroids (representing the characteristic internuclear separation for the (v', v'') transition), which will be useful for a study of the variation of electronic transition moment with internuclear separation, are calculated. These results are displayed in Table I. If it is assumed that the electronic transition moment is constant, the relative band strengths can be represented by the Franck-Condon factors. A cursory examination of Table I is sufficient to conclude that (1) the (1, 0) band is the most intense band of the system, followed by the (2, 0), (0, 1) and (0, 2) bands, and (2) the (0, 0) band is relatively weak in intensity.

TABLE I

Franck-Condon factors and r-centroids (Å) of the bands of $B^1\Sigma^+ - A^1\Pi$ transition of MgO

v'	v''					
	0	1	2	3	4	5
0	0.180	0.278	0.240	0.154	0.082	0.039
	1.801	1.768	1.738	1.709	1.681	1.655
1	0.335	0.092	0.004	0.092	0.149	0.136
	1.843	1.809	1.777	1.746	1.717	1.689
2	0.282	0.022	0.162	0.062	0.000	0.052
	1.887	1.851	1.817	1.785	1.754	1.726
3	0.142	0.197	0.039	0.051	0.116	0.038
	1.934	1.896	1.859	1.825	1.793	1.763
4	0.048	0.230	0.043	0.121	0.000	0.070
	1.983	1.942	1.964	1.868	1.834	1.802
5	0.011	0.127	0.197	0.001	0.110	0.040
	2.036	1.992	1.950	1.912	1.876	1.842

The upper member of each entry is the Franck-Condon factor (calculated by the method of Fraser and Jarmain (1953)) and the lower member is the r-centroid (calculated by the method of Nicholls and Jarmain (1956)).

It is of interest to note that in addition to the red and green band systems, the MgO spectrum exhibits two more intense band systems (C-A and D-A) in the 3830–3798 Å wavelength region. These near-ultraviolet transitions are characterized by the identification of intense bands of the $\Delta v = 0$ sequence. The line positions for the intense (0, 0) and (1, 1) bands for both the systems are available from high resolution laboratory studies by Trajmar and Ewing (1965) and Brewer *et al.* (1962). The values of $q_{v'v''}$ are also known for these band systems (Gandara *et al.*, 1970). In Table II, are presented the wavelength regions for the intense bands of the red and near-ultraviolet transitions of MgO. It can be seen from the Table II that the wavelength regions, 3820–3766 Å and 6580–5500 Å are of particular interest during a further search of MgO in sunspots. It may be noted that the near-ultraviolet spectrum of

TABLE II

Wavelength regions for the intense bands of the red and near-ultra-violet transitions of MgO

Transition	Band		Band origin $\nu(\mathrm{cm}^{-1})$	Wavelength region λ(Å)	Band intensity factor $q_{v'v''}$
	v'	v''			
$B^1\Sigma^+ - A^1\Pi$	0	2	15 194.87	6573–6363	0.240
	0	1	15 843.67	6302–6161	0.278
	1	0	17 314.85	5772–5567	0.335
	2	0	18 119.89	5510–5329	0.282
$D^1\Delta - A^1\Pi$	0	0	26 272.04	3815–3798	0.992
	1	1	26 237.41	3818–3804	0.976
$C^1\Sigma^- - A^1\Pi$	0	0	26 500.94	3785–3766	0.989
	1	1	26 466.26	3787–3778	0.965

MgO is complex due to the excessive overlapping of the rotational structure and therefore, the identification of these lines would require very high resolution spectrograms of the sunspots.

In summary, the present note indicates that a search for the red bands, (1, 0), (2, 0), (0, 1) and (0, 2) of *B-A* system and the near-ultraviolet bands, (0, 0) and (1, 1) of *C-A* and *D-A* systems would appear to resolve the questionable presence of MgO in sunspot spectra.

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