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ON EQUILIBRIUM ABUNDANCE OF C_2 MOLECULES UNDER SUNSPOT CONDITIONS

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ABSTRACT

An extensive molecular equilibrium calculation has been performed under sunspot conditions in order to resolve the current dispute on the presence of C_2 lines in the spectrum of sunspots. Equilibrium abundance of C_2 has been computed under the conditions of umbral cores, umbrae and the normal photosphere. As the results, it is found that the umbral cores yield unfavorable environment for C_2 formation. It is concluded that C_2 molecular lines are not likely to be observed in the spectrum of sunspots.

I. INTRODUCTION

The presence of C_2 lines in the spectrum of sunspot umbrae has been disputed by several workers. Branch (1969), Schadee (1970) and Harvey (1972) questioned their presence in sunspots, while Wöhl (1971, 1972) claims positive evidence for their existence. Accordingly, an attempt has been made to explore the possibility whether or not umbral cores might provide favorable environment for formation of C_2 molecules.

For this purpose equilibrium calculations have been made to obtain C_2 number density at each depth of the umbral core.

II. MOLECULAR EQUILIBRIUM CALCULATIONS

Under the condition of theromodynamic equilibrium the dissociation constant K (AB) of a diatomic molecule is related to the number density of the elements A and B as,

$$N(AB) = N(A)\,N(B)/K(AB)$$

where N (A), N (B) and N (AB) are the number density of the elements A, B and the molecule AB. In order to solve the equation, the dissociation constants must be evaluated for a given temperature. These dissociation functions can be obtained from The Joint Army-Navy-Air Force Thermochemical Table (1968).

With the available molecular dissociation constants the detailed equation of state has been calculated with the equations of constraints subject to (1) conservation of electric charge, (2) conservation of gas pressure and (3) conservation of the relative number density of each element to be considered to form molecules. The detailed formulation to set up these equations are summarized in Beebe (1968).

III. RESULTS AND CONCLUSION

Making use of the computer program developed by Beebe (1968) the set of equations for the molecular dissociative equilibrium has been carried out both for the umbral and the umbral core conditions. In calculating the equilibrium molecular abundance, Yun's working model of umbral cores (1978) and the umbral model by Yun (1971) have been employed. In the calculation 33 atomic elements have been considered and 60 molecules are allowed to be formed, as presented in table I and Table II.

The resulting equilibrium abundances of C_2 and CO computed at each depth of the model atmospheres of umbral cores(Yun, 1978), umbrae (Yun, 1971) and the normal photosphere are plotted against the logarithmic standard optical depth τ_0 at 5000 Å in Figure 1. It is noted from

Table I. Molecules to Be Formed

H_2, CH, NH, OH, SiH, SH, C_2, CN, CO, SiC, CS, N_2, NO, SiN, SN, O_2, SiO, SO, Si_2, SiS, S_2, HO_2, CO_2, NO_2, SiO_3, SO_2, MgH, MgN, MgO, TiO, TiO_2, ZrH, ZrC, ZrO, ZrO_2, H_2O, HCN, HCO, HNO, NH_2, NH_3, CH_2, CH_3, CH_4, C_4, C_2N_2, C_2H_2, CH_2O, CHNO, HNC, NCO, C_2H, C_3, C_2N, N_2H, NCN, N_3, N_2O_3, SiC_2

Table II. Atomic Elements to Be Considered

Elements	Abundances	Ionization Potential (Ev)
H	0.100 (01)	13.595
He	0.200 (00)	24.581
Li	0.912 (-11)	5.390
Be	0.229 (-03)	9.320
C	0.525 (-03)	11.256
N	0.912 (-03)	14.530
O	0.912 (-03)	13.614
Na	0.200 (-05)	5.138
Mg	0.251 (-04)	7.644
Al	0.158 (-05)	5.984
Si	0.316 (-04)	8.149
P	0.219 (-06)	10.484
S	0.200 (-04)	10.357
K	0.501 (-07)	4.339
Ca	0.141 (-05)	6.111
Sc	0.661 (-09)	6.540
Ti	0.479 (-07)	6.820
V	0.501 (-08)	6.740
Cr	0.229 (-06)	6.764
Mn	0.794 (-07)	7.432
Fe	0.372 (-05)	7.870
Co	0.437 (-07)	7.860
Ni	0.813 (-06)	7.633
Cu	0.110 (-06)	7.724
Zn	0.251 (-07)	9.391
Ge	0.195 (-08)	7.880
Rb	0.302 (-09)	4.176
Sr	0.398 (-09)	5.692
Nb	0.501 (-10)	6.880
Zr	0.170 (-09)	6.840
Ba	0.129 (-09)	5.210
Y	0.251 (-09)	6.380
La	0.251 (-10)	5.610

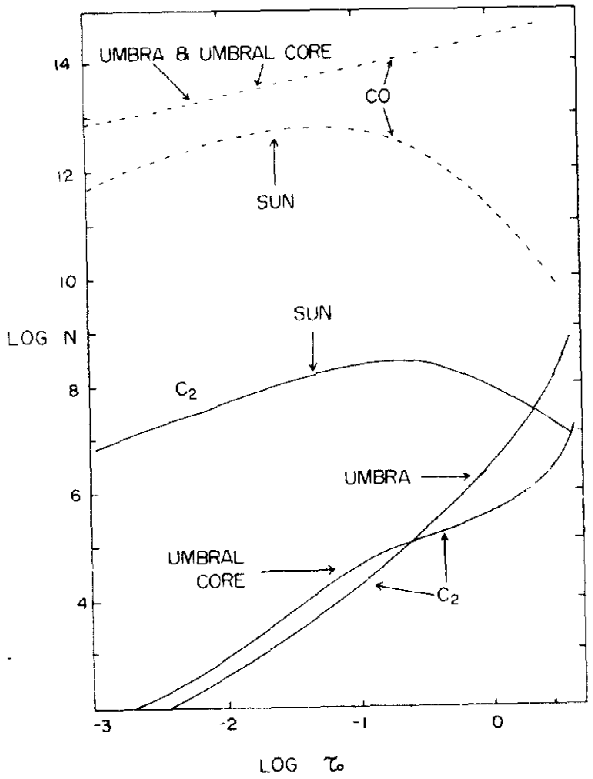

Figure 1. Computed C2 and CO abundances in the model atmospheres of a typical umbral core (Yun, 1978), an umbra (Yun, 1971) and the normal photosphere.

the figure that as temperature descreases, CO formation becomes more favorable than C_2 formation. Accordingly, C_2 number density in the umbral cores is considerably lower than that of the normal photosphere by several orders of magnitude. In conclusion, under these circumstances C_2 lines are not likely to be observed in the spectrum of sunspot umbrae.

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