

Emission of λ 6300A in Martian atmosphere

D. C. AGARWAL

*J. K. Institute of Applied Physics and Technology
University of Allahabad, Allahabad*

(Received 27 October 1969)

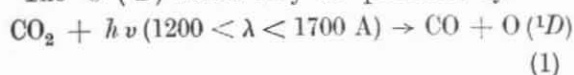
ABSTRACT. The paper deals with the emission of λ 6300A of OI in the Martian atmosphere. Using the recently measured rate of coefficients of ion-atom interchange and other ionic reactions, the volume emission of this radiation is calculated out and found to be approximately 5 κ .

1. Introduction

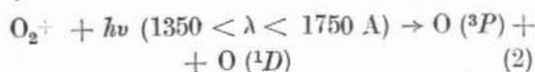
The atmosphere of the planet Mars has been studied by several investigators. Three models, namely, F₂, F₁ and E models have been proposed by them for the Martian atmosphere. As in the earth's atmosphere, there is every possibility for the emission of λ 6300A in the Martian atmosphere. The purpose of the present paper is to calculate the intensity of this radiation for all the three models of the Martian atmosphere.

2. Production and deactivation of O (¹D) atoms

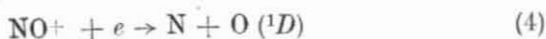
The O (¹D) atoms may be produced by—



(Groth 1937, Mahan 1960 and Wijnen 1956).



(Ghosh and Sharma 1961) and



(Chamberlain 1961)

For the reaction (3), the spin conservation rule does not hold good and so, this reaction has not been considered in the present calculations. CO₂ is dissociated by the solar ultraviolet radiations in the wavelength range 1700–1050 Å (Chamberlain 1962). The photo-dissociation of CO₂ in the wavelength range 200–1700 may produce O(¹D) atoms (Moll *et al.* 1966).

Probability of photo-dissociation of CO₂ at

an altitude z is given by—

$$P_z = \gamma \sum_{\nu} n (h\nu)_z \sigma_{\nu}, \text{CO}_2 \quad (5)$$

where, $n (h\nu)_z$ = photon flux corresponding to a frequency at an altitude z ,

$\sigma_{\nu}, \text{CO}_2$ = absorption cross-section of CO₂ for the frequency ν and

γ = efficiency of the observed quantum for the dissociation of CO₂.

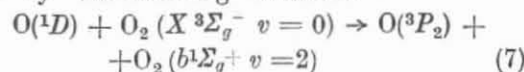
In the absence of the precise informations, γ is assumed to be unity. Utilising the values of absorption coefficients of CO₂ given by Nakata *et al.* (1965) and the photon flux data* given by Hinteregger *et al.* (1965), photon flux and dissociation probability at various altitudes are obtained. Rate of production (R_z) of O(¹D) atoms is then obtained from the relation—

$$R_z = n (\text{CO}_2)_z \cdot P_z \quad (6)$$

where, $n (\text{CO}_2)_z$ is the concentration of CO₂ at the altitude z .

Production of O(¹D) atoms by the photo-dissociation of O₂ in the wavelength range 1350–1750 Å has been calculated (*see Agarwal p. 391*). The absorption cross-section of O₂ has been taken from the data given by Hinteregger *et al.* (1965). The distribution of O₂ given by Chamberlain and McElroy (1966) has been utilized here.†

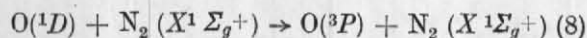
Let us now consider the deactivation of O(¹D) atoms. The deactivation of O(¹D) atoms has been considerably discussed in the literature. Bates and Dalgarno (1953) pointed out that O(¹D) atoms should be very rapidly deactivated by the following reactions—



*The values are corrected for the the atmosphere of Mars by multiplying each by 0.44, the dilution factor.

†Its values have been extrapolated down to an altitude of 90 km.

as this reaction is nearly in exact resonance. Deactivation by N_2 , namely,

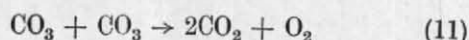
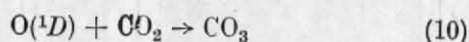
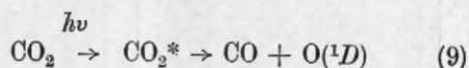


is disallowed by the spin conservation rule (S. K. Gupta, private communication, 1969). From an analysis of amount emission in the earth's atmosphere, Wallace and Chamberlain (1959) concluded that $10^{-10} > k_7 > 5 \times 10^{-12} \text{ cm}^3 \text{ sec}^{-1}$. Dalgarno and Walker (1964) have shown that if $k_7 = 10^{-10} \text{ cm}^3 \text{ sec}^{-1}$ is assumed, the red line intensity in the day airglow of the earth's atmosphere can be explained. DeMore and Raper (1962) have shown that O_2 is approximately 4.5 times faster than N_2 in deactivating $O(^1D)$ atoms.

While discussing the photochemistry of O_3 in the earth's atmosphere, Hunt (1966a) concluded that in order to maintain the required concentration of $O(^1D)$ atoms in the ozonosphere, which effectively controls the O_3 abundance, the deactivation of $O(^1D)$ by O_2 and N_2 should be slow. He proposed that $k_7 = 2.5 \times 10^{-14} \text{ cm}^3 \text{ sec}^{-1}$ and $k_8 = 5 \times 10^{-15} \text{ cm}^3 \text{ sec}^{-1}$. These rate coefficients can be discarded on the ground that the concentrations of $O(^1D)$ derived by them in the lower atmosphere of the earth would give an unacceptably large red line in the day airglow. However, in a modified photochemical theory of the ozonosphere (Hunt 1966 b) for an oxygen-hydrogen atmosphere, he finds that if $k_7 = 5 \times 10^{-12} \text{ cm}^3 \text{ sec}^{-1}$ is accepted, the calculated O_3 abundance agrees with the observed value and that $O(^1D)$ concentration lies within the acceptable limits. Warneck and Sullivan (1966) obtained from a laboratory study that $k_7 = 4.0 \times 10^{-15} \text{ cm}^3 \text{ sec}^{-1}$ which also be considered as being low. We have assumed its value as $10^{-10} \text{ cm}^3 \text{ sec}^{-1}$ as given by Dalgarno and Walker (1964).

Deactivation of $O(^1D)$ atoms with CO_2 also occurs with the formation of CO_3 molecules (Katkis and Taubes 1962; Warneck 1966; Young and Ung 1966; Raper and DeMore 1964; Young and Graham Black 1967; and Weissberger *et al.* 1967). Slanger (1966) on the assumption that the recombination of $O(^1D)$ and $O(^3P)$ atoms does not hold good, gave the following reaction scheme for the production and loss of metastable

CO_3 molecules.



Young and Ung (1966) showed that $O(^1D)$ complexes with CO_2 with a rate coefficient greater than $10^{-12} \text{ cm}^3 \text{ sec}^{-1}$ and that $O(^1D)$ forms CO_3 at least five times more rapidly than it is deactivated to $O(^3P)$ by CO_2 . In the present calculations, I have taken $k_{10} = 10^{-12} \text{ cm}^3 \text{ sec}^{-1}$.

The deactivation through superelastic collisions with electrons is negligible (Chamberlain 1961). Neglecting the reaction (8), the equilibrium concentrations of $O(^1D)$ at any altitude z is given by—

$$n [O(^1D)]_z = \frac{q_1(O^1D)_z + q_2(O^1D)_z + k_3(O_2^+)(e)}{k_7 n(O_2)_z + k_{10} n(CO_2)_z + 0.0091} \quad (12)$$

where, $q_1(O^1D)_z$ and $q_2(O^1D)_z$ are the production rates of $O(^1D)$ atoms by the photo-dissociation of O_2 and CO_2 respectively at the altitude z and 0.0091 sec^{-1} is the transition probability for 6300 A lines.

In practice, the first and the last terms in the numerator, and the first term in the denominator of Eq.(12) are negligible. Since $q_2(O^1D)$ is equal to $J_2 n(CO_2)$, where J_2 is constant at high altitudes, there is an extended region with $n(O^1D) = J_2/k_{10} = 6.0 \times 10^5 \text{ cm}^{-3}$; approximately the same in all the three models, namely, F_2 , F_1 and E models of the Martian atmosphere. This maximum density extends from about 100 to 150 km in each model. Total emission from—

$$R_{6300, z} = n(O^1D)_z \times 0.0069$$

is thus about 15 KR. A more recent value of $k_{10} = 3 \times 10^{-12}$ (Noxon 1970) reduces this to 5 KR.

3. Conclusions

- (1) The maximum number density of $O(^1D)$ atoms extends from 100 to 150 km.
- (2) Total emission of λ 6300 A is about 5 KR.

REFERENCES

- Bates, D. R. and Dalgarno, A.
Chamberlain, J. W.
- Chamberlain, J. W. and McElroy, M. B.
Dalgarno, A. and Walker, J. C. G.
DeMore, W. and Raper, O. F.
Ghosh, S. N. and Sharma, A.
Groth, W.
Hinteregger, H. E., Hall, L. A. and Schmidtke, G.
Hunt, B. G.
- Katakis, D. and Taube, H.
Mahan, B. H.
Moll, N. G., Clutter, D. R. and Thomposon, W. E.
Nakata, P. S., Watanable, K. and Matsunaga, F. M.
Noxon, J. F.
Raper, O. F. and DeMore, W. B.
Slanger, T. G.
Wallace, L. and Chamberlain, J. W.
Warneck, P.
Warneck, P. and Sulliman, J. O.
Weissberger, E., Breckenridge, W. H. and Taube, H.
Wijen, M. H.
Young, R. A. and Black, Graham
- 1953 *J. atmos. terr. Phys.*, **4**, p. 112.
1961 *Physics of the Aurora and Airglow*. Academic Press Inc., New York.
1966 *Science*, **152**, p. 21.
1961 *J. atmos. Sci.*, **21**, p. 463.
1962 *J. chem. Phys.*, **37**, p. 2048.
1961 *J. atmos. terr. Phys.*, **20**, p. 110.
1937 *Z. phys. Chem.*, **B37**, p. 307.
1965 *Space Res.*, **5**, p. 1175.
1966a *J. atmos. Sci.*, **23**, p. 88.
1966b *J. geophys. Res.*, **71**, p. 1385.
1962 *J. chem. Phys.*, **36**, p. 416.
1960 *Ibid.*, **33**, p. 959.
1966 *Ibid.*, **45**, p. 4469.
1965 *Science of Light*, **14**, p. 54.
1970 *J. chem. Phys.* (to be published)
1964 *J. chem. Phys.*, **40**, p. 1047.
1966 *Ibid.*, **45**, p. 4127.
1959 *Planet. Space Sci.*, **2**, p. 60.
1964 *J. chem. Phys.*, **41**, p. 3435.
1966 *Planet. Space Sci.*, **14**, p. 1225.
1967 *J. chem. Phys.*, **47**, p. 1764.
1956 *Ibid.*, **24**, p. 851.
1966 *Ibid.*, **44**, p. 3038.