FLUORESCENCE EFFICIENCY OF ELECTRONS IN FIRST NEGATIVE GROUP OF N_2^+

by KUMAR, A., and KHARE, S. P., *Department of Physics, Institute of Advanced Studies, Meerut University, Meerut, India*

(Communicated by Prof. B. Dayal, FNA)

(*Received 11 May 1973*)

Fluorescence efficiencies ot electrons in various bands of first negative group of N_2^+ are calculated. These individual efficiencies as well as the total efficiency are in good agreement with the reduced experimental data of Davidson and O' Neil (1964).

INTRODUCTION

Molecular nitrogen is one of the important constituent of the atmosphere. When an energetic electron is absorbed in a gas, it is well known that it loses most of its energy in ionizing collisions. Due to ionizations secondaries are produced which further take part in exciting and ionizing the gas constituents. The fluorescence produced in visible region is principally due to N_2^+ first negative, N_2 first and second positive and N_2^+ Meinel Bands. The efficiency, with which the kinetic energy of the incident electron has been transferred to particular emission, is regarded as an important parameter and is investigated by various workers (Davidson & O' Neil 1964; Khare 1969; and Khare & Kumar 1973). Theoretical calculations Khare (1969) have been carried out only for 3914 Å (0, 0) band of first negative group of N_2^+. Thus it will be interesting to extend these calculations for other members of first negative group of N_2^+.

THEORY

Fluorescence efficiency η, with which the kinetic energy of the incident electron is transferred to 3914 Å (0, 0) band of N_2^+, has been investigated theoretically by another author. Khare (1969) modified the calculations and used the energy spectrum of secondary electrons to obtain η for the same band. The detailed method for such calculations is described by Khare (1969).

The intensity of the spectral line in emission $I_{v' v''}$ can be defined as the energy emitted by the source per second. If there are $N_{v'}$ atoms in the initial state then the intensity in units of photons/sec is given by

$$I_{v' v''} = K N_{v'} A_{v' v''}$$

where K is constant and $A_{v' v''}$ is the Einstein transition probability of spontaneous emission (Herzberg 1961) and is given by

$$A_{v' v''} = \nu^3_{v' v''} \overline{R}^2_e F_{v' v''}$$

where $\nu_{v' v''}$ and R^2_e are the frequency of the emitted photon and transition moment respectively. $F_{v' v''}$ is the Frank Condon factor for $v'-v''$ transition.

For the first negative group of N_2^+ we used the Frank Condon factors given by Nicholls (1961). Taking R^2_e to be constant, the intensity ratio for any two transitions can be calculated. Putting this ratio equal to the corresponding cross section ratio, the cross section for unknown transition can be determined and hence the efficiency. The experimental data of Srivastava and Mirza (1968) is used for the cross section of 3914 Å (0, 0) band.

Davidson and O' Neil have measured experimentally the values of efficiencies for different bands of first negative group of N_2^+ at pressure 600 torr. We have reduced this experimental data to a very low pressure by using the Storm-Volmer relation (Stair and Gauvin, 1967) of the form

$$\frac{1}{\eta_\rho} = \frac{1}{\eta} (1 + 2.2 \times 10^{21} \sigma_d \tau \rho)$$

where η_ρ and η are the fluorescence efficiencies at pressure ρ and at very low pressure where quenching is negligible respectively. σ_d is the deactivation cross section. τ is the radiative life time of the particular state. The deactivation cross section has been investigated by various workers. We used the results of O' Neil and Davidson (1969) for deactivation cross section and for radiative life time the value 6.58×10^{-8} Sec (Bennet & Dalby 1959) is used. σ_d has been assumed to be same for all the bands of the first negative group.

Results and Discussions

Table I gives the values of fluorescence efficiencies for different band wavelengths at very low pressure. For comparison the reduced experimental values of Davidson and O' Neil (1964) are also listed. It is evident from the table that the agreement between our values and experimental values is within the experimental error. If we consider the uncertainty of the deactivation cross section measurements the difference between theory and experiment may be explained.

Integrating these values of efficiency the total efficiency η_{Total} (1N) for first negative group of N_2^+ in the wavelength region 3900 Å to 5300 Å is obtained. This value is also shown in Table I along with the experimental value of Davidson and O' Neil (1964). Again there is a good agreement between two values.

TABLE I

Fluorescence efficiencies of electrons in first negative group of N_2^+

Wavelength	Transition	Reduced Experimental values (in %) (Davidson & O' Neil 1964)	Present results (in %)	Experi-mental Accuracy*
3914	(0, 0)	0.5237	0.487**	SO
4272	(0, 1)	0.1746	0.136	SO
4709	(0, 2)	0.0344	0.0250	SO
5228	(0, 3)	0.00719	0.00374	PO
3579	(1, 0)	—	0.0355	
3884	(1, 1)	—	0.0189	
4236	(1, 2)	—	0.0171	
4652	(1, 3)	—	0.00592	
5149	(1, 4)	—	0.00135	
	Total efficiency η_{Total} (1N)	0.73989	0.73051	

*PO-Partially overlapped, i.e., ± 35%
SO-Slightly overlapped, i.e., ± 20%
**The value calculated by Khare is multiplied by 5/4 to convert it for N_2.

ACKNOWLEDGEMENT

The financial assistance from the Department of Atomic Energy is gratefully acknowledged.

REFERENCES

Bennet, R. G., and Dalby, F. W. (1959). Experimental determination of the oscillator strength of the first negative bands of N_2^+ *J. chem. Phys.*, **31**, 434–441.

Davidson, G., and O'Neil, R. (1964). Optical radiation from nitrogen and air at high pressure excited by energetic elecırons. *J. chem. Phys.*, **41**, 3946–3955.

Hartmann, P. L. (1968). New measurements of the fluorescence efficiency of air under electron bombardment *Planet. Space Sci.*, **16**, 1315–1339.

Herzberg, G. (1961). *Molecular spectra and molecular structure*, **1**. D. van Nostrand Company, Inc. London.

Khare, S. P. (1969). Energy spectrum of the secondary electrons and the fluorescent efficiency of electrons in the 3914 Å Band. *Planet. Space Sci.*, **17**, 1257–1268.

Khare, S. P., and Kumar, A. (1973). Fluorescent efficiency of electrons in 3805 Å Band of N_2. Proceedings of the Symposium on "*Spectroscopic Studies in Astrophysical Interest*", pp. 167-162, (*Ed.*: R. K. Asundi & K. D. Abhyankar), Osmania Univ. Press, Hyderabad.

Nicholls, R. W. (1961). Frank Condon Factors to high vibrational quantum numbers I : N_2 and N_2^+. *J. Res. nant. Bur. Std.*, **65A**, 451–460.

O'Neil, R., and Davidson, G. (1969). Luminous efficiency of electron induced emission in *Nitrogen Atmospheric Emissions.* (*Ed.* by McCormac, B. M. and Omholt, A.) van Nostrand Reinhold Company, New York, 477–483.

Srivastava, B. N., and Mirza, I. M. (1968). Absolute cross sections for simultaneous ionization and excitation of N_2 by electron impact. *Phys. Rev.*, **168**, 86–88.

Stair, A. T., and Gauvin, H. P. (1967). Research on optical infrared characteristics of aurora and airglow (Artificial and natural). *Aurora and Airglow* (*Ed.* Mc Cormac, B. M.), Reinhold publishing corporation, New York, 365–390.