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SPECTROSCOPIC DIAGNOSTICS OF A.D.C. NITROGEN PLASMA JET

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Transition probabilities, Stark broadening and shift of NI have been measured and spectroscopic diagnostics of nitrogen plasma jet have been performed.

I. EXPERIMENTAL SET-UP. The jet is produced in a closed vessel /1/. The anode arc channel is made of two parts (1)-(2) at the same electrical potential separated by a gap of 5 mm for spectroscopic observations of the arc. A BN ring (3) insulates the first anode from the second one (4). This device stabilizes the arc and permits analysis of the arc column, of the jet and of its plume.

The whole measurement : calibration, experimental data recording, and data treatment (Abel's inversion, restitution of spectral line profiles...) is performed with a data acquisition system connected to a computer.

II. TRANSITION PROBABILITIES OF NI LINES AND STARK

PARAMETERS MEASURED IN THE ARC. From stark broadening of H α we have measured an electronic concentration of $1.05 \pm 0.15 \cdot 10^{17} \text{ cm}^{-3}$ on the axis of the arc $\sim 2/3$; it had been previously shown that the line was not self-absorbed. We had also verified that 0.1 Nl/mn of H $_2$ mixed with nitrogen (volume ratio was 5%) did not disturb the arc voltage or the microscopic properties of the plasma of interest (continuum emission at 495.5 nm and 493.5 nm line profile). Under these conditions L.C.T.E. is realized /1/ according to the criterions of DRAWIN /4/ ; consequently, starting from the equilibrium composition we have determined a temperature of $13200 \pm 400 \text{ K}$ and the concentration of NI : $3.4 \pm 4 \cdot 10^{17} \text{ cm}^{-3}$. From these measurements and those of volume emission coefficient we have determined the transition probabilities with a relative error of 50%. (table I). Our results are in good agreement with those of MOTSCHMANN /5/ and RICHTER /6/. For the lines before 550 nm our results are 20% higher than those of MOTSCHMANN, even though WIESE has increased these last measures by more than 50%. Calculations by GRIEM /8/ give results which are generally

higher than the measured values.

We have especially studied the profiles of the 746.8 nm and 493.5 nm lines and determined their neutral collision shift and broadening /1/. Resonance broadening has been included for the 746.8 nm line.

We have neglected the Doppler effect for the 493.5 nm line profile, its Stark width (2ω) and shift (d) being computed by fitting the experimental profile to a Lorentz profile. We have deduced the Stark parameters of the 746.8 nm line by comparison of the experimental profile to profiles resulting from the convolution of a Doppler profile (at the temperature of measurement) with Lorentz profiles. The results are shown in figure II, where we have also quoted the values computed by /9/ and /10/ ; for N_e between 5 and $10 \cdot 10^{16} \text{ cm}^{-3}$ and T between 11500 K and 13500 K we propose the following : $2\omega = 8.2 \cdot 10^{-3} \text{ nm}$, $d = 4 \cdot 10^{-3} \text{ nm}$ for 746.8 nm line and $2\omega = 1.95 \cdot 10^{-2} \text{ nm}$, $d = 2.8 \cdot 10^{-3} \text{ nm}$ for 493.5 nm line.

III. PLASMA JET DIAGNOSTICS. For the study of L.T.E. in the plasma jet /4/ we have calculated the relaxation times of energy exchanges between the different degrees of freedom and we have determined the characteristic times of relaxation to chemical equilibrium. The slower process is N $_2$ dissociation ($N_2 + M \rightarrow N + N + M$); associative-ionization follows very rapidly ($N + N \rightleftharpoons N_2 + e^-$) and then charge exchange ($N_2^+ + N \rightarrow N_2 + N^+$) occurs : Ionization by electronic collision is not really significant, but even with a low concentration N_2^+ is of major importance.

L.C.T.E. is only realized in the core where N_e is higher than $4 \cdot 10^{15} \text{ cm}^{-3}$ ($T > 8600 \text{ K}$). Otherwise in the plume jet for example, vibration-vibration relaxation and dissociation times are great compared to hydrodynamic times. Anyhow, considering the very low relaxation times for rotation-rotation and rotation-transformation processes, rotational temperature of molecules is always equal to neutral

translational temperature.

Consequently we have developed methods for the measurement of rotational temperature /1/ and the following diagnostic method /11/ is proposed : the experimental profile is compared to theoretical profiles computed under the assumption of L.C.T.E.. Volume emission coefficients are calculated for all the rotation lines of the band under consideration (we assume that they are sufficiently narrow compared to the apparatus function and so are supposed to have a limited Dirac profile according to their intensities). We sum over the lines concerned, and perform a convolution with a triangular or Gaussian function. This is done for all of the bands of the sequence. The rotational temperature can be deduced from the rotational profile of the vibration band even if L.C.T.E. is not realized. Furthermore this method emphasises the difference between the rotational and vibrational temperatures.

CONCLUSION. A computer driven data acquisition system has permitted the measurement of the transition probabilities of NI lines and also Stark parameters of the 746,8 nm and 493,5 nm lines. Furthermore we have shown that L.C.T.E. is not realized in the plume, consequently only the rotational temperature is representative of the translational temperature of neutrals.

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λ nm	A_{si}	λ nm	A_{si}	λ nm	A_{si}
870.326	200.	742.364	50.	517.000	1.9
871.171	111.	744.230	102.	518.15	1.5
871.884	53.	746.831	159.	518.69	0.8
872.891	29.	946.068	25.	413.763	2.4
874.736	7.2	856.774	74.	414.342	5.1
818.485	82.	859.401	260.	415.146	9.1
818.801	125.	862.924	250.	541.188	8.9
820.036	47.	865.587	89.	540.145	4.5
821.071	48.	902.892	188.	438.440	4.2
821.632	176.	906.072	207.	439.130	9.0
822.312	214.	491.490	6.0	422.304	3.8
824.237	102.	493.503	13.3	422.474	3.7
		532.870	2.0		
		528.118	2.3		

Table I. NI transition probabilities ($A_{si} 10^5 \text{sec}^{-1}$)

Figure 1 - Plasma device

Figure II - Stark width