SF2A 2007
J. Bouvier, A. Chalabaev, C. Charbonnel (eds)

MEASUREMENT OF LINE INTENSITIES OF THE D_2 MOLECULE USING IMAGE PLATE DETECTOR.

M. Roudjane[1], W.-Ü L.Tchang-Brillet[1] and N. Champion[1]

Abstract. Preliminary intensity measurements have been performed for the first time on high resolution D_2 emission lines in the wavelength range (800-900 Å) using image plate detector. This detector has a linear response to intensities within five orders of magnitude contrarily to the photographic plates used previously. Experimental branching ratios, obtained from the measured intensities of identified lines, are compared with the theoretical one. A good agreement is found between the two results. From the profile of recorded line we succeeded to get an estimation for the temperature of our Penning discharge source.

1 Introduction

The D_2 spectrum has a great interest since this isotopomer of hydrogen molecule is present in its electronically excited states in fusion plasmas and is involved in their radiative losses. Thus, the knowledge of fundamental data like wavelengths and transition probabilities of the molecular lines is required. Moreover, the spectral analysis leading to energy levels of the D_2 molecule is a natural progression of the similar work on molecular hydrogen and offers one more opportunity to examine the accuracy of quantum calculations beyond the Born-Oppenheimer approximation.

We have been carrying out a theoretical and experimental study of the D_2 molecule excited electronic states using high resolution emission spectra in the vacuum ultraviolet region 780 - 1700 Å. The spectra recorded on photographic plates provided accurate wavelength measurements (0.0015 Å) and allowed reliable derivation of energy levels. In our analysis, we have assigned a fraction of 80 % of the 11906 lines contained in the wavelength range 780 - 1242 Å, leading to the derivation of energy levels from wave numbers belonging to the $D^1\Pi_u \rightarrow X^1\Sigma_g^+$ and $D'^1\Pi_u \rightarrow X^1\Sigma_g^+$ band systems (Roudjane et al 2006), and from the $B'^1\Sigma_u^+ \rightarrow X^1\Sigma_g^+$ band system (Roudjane et al 2007). The results related to the Werner $C^1\Pi_u \rightarrow X^1\Sigma_g^+$ and part of the Lyman $B^1\Sigma_u^+ \rightarrow X^1\Sigma_g^+$ band systems will be further published.

Recently, phosphore image plates, currently used for X-ray or radioactivity studies, have been shown (Reader et al 2000) to be also sensitive in the VUV region, with linear response to intensities. Therefore we have extended our study of the D_2 molecule by recording its emission spectrum using image plates, for the first time, in a limited wavelength range, as a preliminary step to line intensity measurements in order to achieve a quantitative comparison with theoretically calculated transition probabilities.

2 Experiment

The emission spectra of the D_2 molecule were produced by a low pressure Penning discharge source and were recorded using the high resolution 10 m VUV spectrograph at the Meudon Observatory. This instrument is equipped with a 3600 lines/mm holographic concave grating and provides a plate factor of 0.25 Å/mm. The 30 μm slit width defines a resolution limit of 8×10^{-4} nm throughout the whole range of observation. Instead of Kodak SWR photographic plates, we placed in the plate holder a 25 x 5 cm Fuji Tritium phosphore image

[1] Laboratoire d'Étude du Rayonnement et de la Matière en Astrophysique, UMR 8112 du CNRS, Observatoire de Paris, Section de Meudon, 5 place Jules Janssen, 92195 Meudon Cedex, France and Université Pierre et Marie Curie-Paris 6, Paris F-75005, France

plate and performed an exposure in the wavelength range (800-900 Å). After exposure, the plate was read using a laser scanner FLA 7000 caracterized by a resolution of 25 μm. The image was stored in the standard Tagged Image File (TIF) format with a resolution of 1200 dpi and was converted by home built program to intensity profiles for the spectral lines.

3 Results

Figure 1 compares a densitogram obtained from an emission spectrum recorded on photographic plate (a) and the intensity profiles of an emission spectrum recorded using image plate (b), both in the wavelength range 892 - 898 Å.
The identification of lines on the spectrum recorded on the image plate was supported by comparison with the spectrum recorded in the same wavelength range on the photographic plates and used in the previous analyses. However the two intensity profiles are very different. Contrarily to the densitogram from photographic plate where weak lines are visible only when intensity saturation of strong lines occurs, the spectrum from image plate shows a much larger dynamic range of intensity response. Indeed, the image plate has linear response to intensities over about five orders of magnitude.
Consequently, the image plate detector allows a quantitative comparison between the observed line intensities and the calculated transition probabilities between the excited states and the ground state. As an example, we have chosen two unblended lines sharing the same upper level and we have calculated their branching ratio from the observed intensities I and compared it to the one obtained from the theoretical calculations of transition probabilities A (s^{-1}). In Table.1 we present the observed intensities (arb. units) and the calculated probability transitions for the R(2) and P(4) lines ($J' = 3$ upper level) belonging to the $D - X(1-1)$ band and R(0) and P(2) ($J' = 1$) belonging to the $B' - X(3-1)$ band. The comparison in Table 2 between the theoretical and the experimental branching ratio for these lines shows a good agreement between the theoretical and the experimental results.
The intensity of a line is in principle proportional to the area under the line profile. However, when the line width is constant, it is proportional to the line maximum height. We used the ORIGIN software to fit spectral line shape to a Gaussian or a Voigt profiles. The result contains mainly a list of fitted line centroids, widths and areas. Figure 3 shows an example of several identified lines fitted with Voigt profile. The fit shows that the Gaussian component is broader than the Lorentzian component, and the FWHM is approximately of 0.018Å for all lines in the recorded wavelength range. This width is a convolution of the instrumental width, the Doppler width and the natural width broadened by pressure. Assuming the last one to be negligible in our experimental conditions of low pressure, taking into account the instrumental width including the slit width and the image plate scanner resolution, we found a Doppler width of about 0.015Å. Since the thermal equilibrium is not realised in the Penning discharge source, we may only estimate an effective temperature to be about 2500 K.

	$D - X(1-1)$		$B' - X(3-1)$	
	R(2)	P(4)	R(0)	P(2)
I^{exp} (arbitrary units)	2.72	4.44	2.00	2.50
A^{theo} ($\times 10^7$)	2.70	4.40	2.11	2.40

Table 1. The intensities and the transition probabilities of lines belonging to the $D - X(1-1)$ et $B' - X(3-1)$ bands.

	I^R/I^P	A^R/A^P
$D - X(1-1)$	0.61	0.61
$B' - X(3-1)$	0.80	0.78

Table 2. Comparaison between the calculated and measured branching ratios.

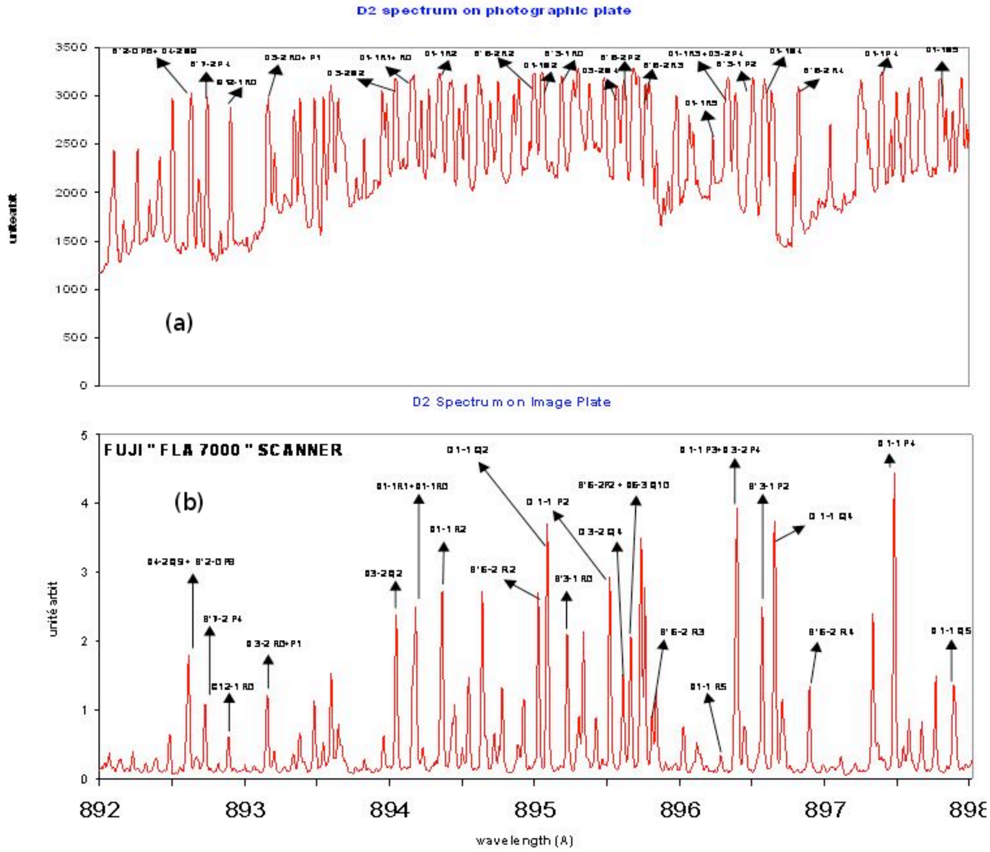
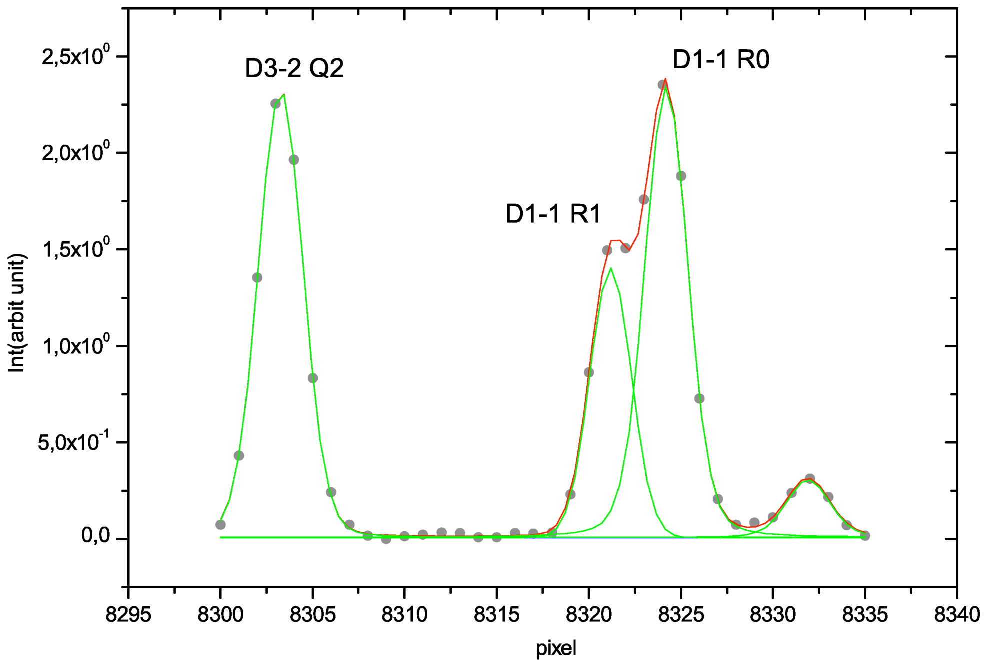


Fig. 1. The intensities of the identified lines of the D_2 molecule on both photographic plates (a) and image plates (b) in the wavelength rage 892-898 Å.



Fitting Results

Peak #	Peak Type	AreaFitT	FWHM	MaxHeight	CenterGrvty	AreaFitTP
1	Voigt	7.19311	2.86066	2.32158	8303.27276	37.22449
2	Voigt	3.93637	2.64425	1.3985	8321.18122	20.3708
3	Voigt	7.25589	2.74753	2.33755	8324.20703	37.54937
4	Voigt	0.93823	2.80271	0.29865	8331.90197	4.85533
		19.32361				

Fig. 2. Exemple of identified lines fitted with Voigt profile. (1pixel is 25μm on the plate, corresponding to 6.25 mÅ on the wavelength scale)

References

M. Roudjane, F. Launay and W.-Ü L. Tchang-Brillet. 2006, J. Chem. Phys., 125, 214305. See EPAPS Document No. E-JCPSA6-125-009646 for the line lists.

M. Roudjane, W.-Ü L. Tchang-Brillet and F. Launay. 2007, J. Chem. Phys., 127, 054307. See EPAPS Document No. E-JCPSA6-127-032729 for line list.

J. Reader, C.J. Sansonetti, R. Deslattes. 2000, Appl. Opt. 39, 627.