Revista Brasileira de Física, Vol. 11, Nº 4, 1981

Stark Profile and Widths of the HeI 5016 Å Line in a Plasma

J. M. BASSALO

Departamento de Física da Universidade Federal do Pará, Belém, Pará, Brasil

M. CATTANI and V. S. WALDER

Instituto de Física, Universidade de São Paulo, São Paulo, Brasil

Recebido em 20 de Agosto de 1981

Using the convergent impact theory, developed by Bassalo, Cattani and Walder, to treat the broadening and shift of atomic lines, we have analysed the Stark profile and widths of the HeI 5016 Å line. A very good agreement is found between our predictions and the experimental results of Chiang et *al*. The discrepant factor ∿ 1.7 between theory and experiment announced by Kusch, Einfeld and Sauerbrey was not found.

Usando a teoria convergente de impacto desenvolvida por Bassalo, Cattani e Walder para descrever o alargamento e deslocamento de linhas emitidas por átomos, nós analisamos o perfil Stark e larguras da linha de 5016 Å do Hélio neutro. As nossas previsões teóricas estão em muito bom acordo com os resultados experimentais de Chiang et *al*. Um fator discrepante da ordem de 1.7 entre teoria e experiência relatado por Kusch, Einfeld e Sauerbrey não foi encontrado por nós.

1. INTRODUCTION

Griem, Baranger, Kolb and Oertel[1,2] (GBKO) have developed a theory to obtain the Stark broadening and shift of lines emitted by neutral atoms and ions in a hot plasma. This theory has usually been rather successful in predicting widths and shifts of isolated lines of neutral helium[2]. However, Kusch[3] conclude from measurements, of the He I lines 5016 Å and 3889 Å, in a wall-stabilized pulsed discharge that the measured widths results in electron densities too high by a factor ∿ 1.7 if the GBKO theory was used. Einfeld and Sauerbrey[4], with a similar discharge procedure, confirmed this discrepancy for the He 15016 Å line.

Since this 1.7 factor is surprisingly large compared with ∿ ± 20% agreement to GBKO theory observed in several experiments[2] involving different devices, Chiang, Murphy, Chen and Griem[5] have re-analysed, experimentally and theoretically, the profiles of the 5016 and 3889 Å transition.

Chiang et *al.*[5] have measured the widths of the above mentioned lines in a high pressure electric shock tube of electron density $N \sim 1\times10^{17}$ cm^{-3} and temperature $T \sim 1.5$ eV. According to them, the measured half-widths are in ± 10% agreement with the calculated widt'hs based on GBKO theory, so that the factor ∿1.7 discrepancy was not confirmed. Chiang et *al.*[5] believe that this very large discrepancy found by Kusch, and Einfeld and Sauerbrey is due to a systematic error, possibly from opacity effects in the electrode regions of the pulse discharge tubes or errors in the electron density determinations.

In a recent paper, Bassalo, Cattani and Walder[6] have developed a convergent theory to treat the electron impact broadening and shift of lines of neutral atoms. They have applied this formalism to study the widths and shifts of many neutral helium lines and they have verified that the convergent and GBKO theories are equally successful to describe the experimental results.

In this paper we apply our convergent approach[6] to analyse the profile and the widths of the HeI 5016 Å line measured by Chiang et *al.*[5]. Our intention is to test the theory of Bassalo, Cattani and Walder[6] and also to verify if there is a so large discrepant factorbetween theory and experiment as was announced by Kusch[3], and Einfeld and Sauerbrey[4].

2. CALCULATION OF THE PROFILE AND WIDTHS

To evaluate the electronic impact widths ω_e and shifts d_e we use a semi-classical convergent theory developed by Bassalo, Cattani and Walder[6].

To calculate the theoretical profile of the He I 5016 Å line we consider two different approachs developed, respectively by GBKO[1,2] and by Barnard, Cooper and Smith[7].

According to GBKO[1,2] the total Stark profile $I_H(\omega)$ of an isolated neutral atom line is given by the convolution of electron impact profiles with a quasi-static quadratic Stark effect for the ion broadening:

$$I_H(\omega) = \frac{\omega_e}{\pi}\int_0^\infty \frac{dF\ \ H(F)}{\omega_e^2 + (\omega-\omega_{if}-d_e-(2\pi/e^2)C_4F^2)^2} \tag{1}$$

where ω_{if} is the energy difference between the initial $\underline{i}$ and final $\underline{f}$ states of the line, F the static electric field generated by the ions, $H(F)$ the Holtsmark distribution function for F and C_4 the Stark parameter.

This $I_H(\omega)$ profile written in dimensionless variables becomes $j_{A,R}(x)$ given by[1,2]:

$$j_{A,R}(x) = \frac{1}{\pi}\int_0^\infty \frac{d\beta\ \ H(\beta)}{1 + (x - A^{4/3}\ \beta^2)^2} \tag{2}$$

where $x = (w - \omega_{if} - d_e)/\omega_e$, A = $(2\pi C_4/\omega_e\rho_m^4)^{3/4}$, $\beta = (\pi C_4/\rho_m^3 v_i)$, v_i the mean ion velocity, R = ρ_m/ρ_D, $\rho_m = (3/4\pi N)^{1/3}$ is the mean ion-ion separation, N the ion density and ρ_D the Debye radius.

According to Barnard, Cooper and Smith[7], the total Stark profile $j(x,\rho,A)$, in dimensionless variables, is given by

$$j(x,\sigma,A) = \frac{1}{\pi}\ \frac{1 + w}{(x-d)^2 + (1+w)^2} \tag{3}$$

where $\sigma = \omega_e p_m / v_i$, $w = A^{8/9} \sigma^{-1/3} W'(k)$, $k = 1.03\, \sigma^{4/3} x$,

$d = \pm (A^{8/9} \sigma^{-1/3} D'(k) - 3A^{4/3} R)$,

the signal ± is the signal of d_e, and the functions $W'(k)$ and $D'(k)$ are tabulated by Barnard *et al.*[7]

Since in our case the line profile in only slightly modified if we neglect the Debye screening effects, we put, to simplify our calculations, R=0.

To compare experimental and theoretical profiles it is necessary to multiply $j_{A,R}(x)$ and $j(x,\sigma,A)$ by arbitrary constant factors.

In figure 1 are shown the experimental profile of the HeI 5016 Å line, measured by Chiang et *al.*[5] for $N = 1.06 \times 10^{17}$ cm^{-3} and T = 1.5 eV, and the theoretical profiles obtained with equations (1) or (2), and (3).

As one can see from figure 1, there is a good agreement between theoretical and experimental profiles.

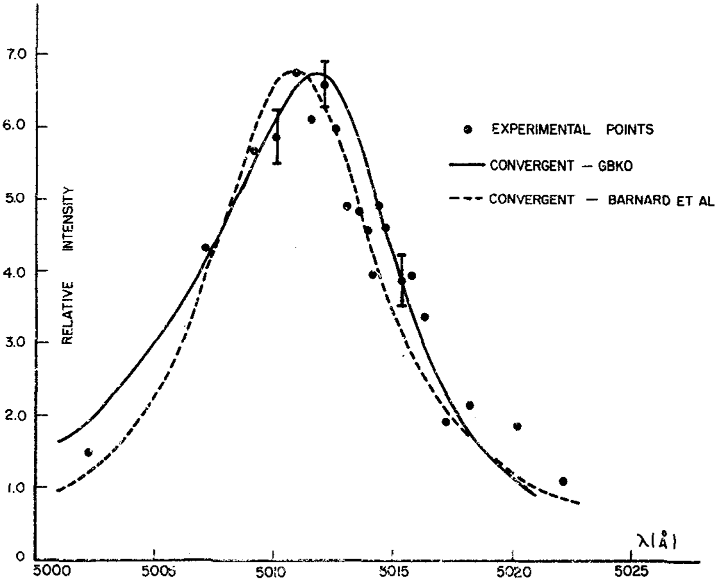

Fig.1 - Experimental and theoretical results for the Stark profile the HeI 5016 Å line for $N = 1.05 \times 10^{17}$ cm^{-3} and T = 1.5 eV.

We calculate now the total half-halfwidths ω of the He I 5016 Å line and we compare them with the experimental results of Chiang *et al.*[5].

To obtain the ions contribution to the widths we use only the approach developed by Griem[1] that seems to give the better description of the experimental widths, as was verified in our preceding paper[6].

According to Griem[1], the total half-halfwidths W is given by

$$\omega = \left[1 + 1.75A\,(1 - 0.75\,R)\right]\omega_e \qquad (4)$$

In table I are compared the theoretical widths, obtained with equation (4), with the experimental results of Chiang *et al.*[5]

Table I. Comparison between the measured and calculated widths of the He I 5016 Å line for $T = 1.5$ eV.

Electron density (10^{17} cm^{-3})	Halfwidths (Å)	
	Measured	Calculated
1.41	12.0	12.54
1.26	10.2	11.14
1.08	9.2	9.48
1.0a	9.6	9.48
1.05	9.6	9.20

As one can see from figure 1 and table I, the theoretical predictions are in ∼ ± 10% agreement with the experimental results.

So, we can conclude that: a) the agreement between theoryand experiment, within the experimental errors, is very good, b) the discrepant factor ∼ 1.7 found by Kusch[3], and Einfeld and Sauerbrey[4] was not confirmed.

J.M. Bassalo thanks the "Pró-Reitoria de Pós-Graduação e Pesquisa" for financial support.

REFERENCES

1. H.R.Griem, M.Baranger, A.C.Kolb and G.Oertel, Phys. Rev. 125, 117 (1962).
2. H.R.Griem, *Spectral Line Broadening by Plasma*, Academic Press, New York (1974).
3. H.J.Kusch, Z. Naturforsch. *26*a, 1970 (1971).
4. D.Einfeld and G.Sauerbrey, Z.Naturforsch. *31*a, 310 (1976).
5. W.T.Chiang, D.P.Murphy, Y.G. Chen and H.R.Griem, Z.Naturforsch. *32*a, 818 (1977).
6. J.M.Bassalo, M.Cattani and V.S.Walder, Phys.Rev. *22*A, 1194 (1980).
7. A.J.Barnard, J.Cooper and E.W.Smith, J.Quant.Spectrosc.Radiat.Transfer 14, 1025 (1974).