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STARK BROADENING OF Cd III LINES

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Abstract. Using a modified semiempirical approach, we have calculated Stark line widths for 10 Cd III transitions for an electron density of 10^{23}m^{-3} and temperatures from 10 000 K to 300 000 K.

1. INTRODUCTION

Investigation of Stark broadening parameters of Cd III spectral lines is of interest for a number of problems as e.g. for the laboratory plasmas, fusion plasmas and laser produced plasmas research as well as for testing and developping of the Stark broadening theory for multicharged ion lines. Moreover, such data are of interest also for the consideration of stellar plasma, since with the development of space born spectroscopic techniques, even trace elements become more and more of interest. The electron-impact broadening mechanism is the main pressure broadening mechanism in hot star atmospheres (having effective temperature $T_{eff} \gtrsim 10000$ K), and it is of interest especially for A type stars and white dwarfs. Cd III Stark broadening data are also of importance for the investigations of regularities and systematic trends particularly along isoelectronic sequences.

The sophisticated strong coupling quantum mechanical (see e.g. Griem, 1974) or semiclassical-perturbation (Sahal-Bréchot, 1969ab) formalism for Stark broadening parameter calculations are not applicable in an adequate way, for a large number of interesting spectral lines of various emitters. In such a case one can apply the modified semiempirical method (Dimitrijević and Konjević, 1980, Dimirijević and Kršljanin, 1986) which needs a considerably smaller number of atomic data. The spectrum of Cd III is poorly known, so the modified semiepirical approach is the only applicable for Stark broadening parameter calculations.

This contribution is the continuation of our efforts to provide needed data for the analysis of laboratory and astrophysical plasmas (see for example Dimitrijević 1996, Dimitrijević and Popović, 2001 and references therein).

2. THEORETICAL REMARKS

According to the modified semiempirical (MSE) approach (Dimitrijević and Konjević, 1980; Dimitrijević and Kršlajnin, 1986) the electron impact full width (FHWM) of an isolated ion line is given as (Popović and Dimitrijević, 1996)

$$W_{MSE} = N\frac{8\pi}{3}\frac{\hbar^2}{m^2}\left(\frac{2m}{\pi kT}\right)^{1/2}\frac{\pi}{\sqrt{3}}\frac{\lambda^2}{2\pi c}\cdot\{\sum_{\ell_i\pm1}\sum_{A_{i'}J_{i'}}\vec{\Re}^2[n_i\ell_iA_iJ_i,n_i(\ell_i\pm1)A_{i'}J_{i'}]\tilde{g}(x_{\ell_i,\ell_i\pm1})+$$

$$+\sum_{\ell_f\pm1}\sum_{A_{f'}J_{f'}}\vec{\Re}^2[n_f\ell_fA_fJ_f,n_f(\ell_f\pm1)A_{f'}J_{f'}]\tilde{g}(x_{\ell_f,\ell_f\pm1})+\left(\sum_{i'}\vec{\Re}^2_{ii'}\right)_{\Delta n\neq0}g(x_{n_i,n_i+1})+ \tag{1}$$

$$+\left(\sum_{f'}\vec{\Re}^2_{ff'}\right)_{\Delta n\neq0}g(x_{n_f,n_f+1})\},$$

and the corresponding Stark shift as

$$d_{MSE} = N\frac{4\pi}{3}\frac{\hbar^2}{m^2}\left(\frac{2m}{\pi kT}\right)^{1/2}\frac{\pi}{\sqrt{3}}\frac{\lambda^2}{2\pi c}\cdot\{\sum_{A_{i'}J_{i'}}\sigma_{J_iJ_{i'}}\vec{\Re}^2[n_i\ell_iA_iJ_i,n_i(\ell_i+1)A_{i'}J_{i'}]\tilde{g}_{sh}(x_{\ell_i,\ell_i+1})-$$

$$-\sum_{A_{i'}J_{i'}}\sigma_{J_iJ_{i'}}\vec{\Re}^2[n_i\ell_iA_iJ_i,n_i(\ell_i-1)A_{i'}J_{i'}]\tilde{g}_{sh}(x_{\ell_i,\ell_i-1})$$

$$-\sum_{A_{f'}J_{f'}}\sigma_{J_fJ_{f'}}\vec{\Re}^2[n_f\ell_fA_fJ_f,n_f(\ell_f+1)A_{f'}J_{f'}]\tilde{g}_{sh}(x_{\ell_f,\ell_f+1})+$$

$$+\sum_{A_{f'}J_{f'}}\sigma_{J_fJ_{f'}}\vec{\Re}^2[n_f\ell_fA_fJ_f,n_f(\ell_f-1)A_{f'}J_{f'}]\tilde{g}_{sh}(x_{\ell_f,\ell_f-1})+\left(\sum_{i'}\vec{\Re}^2_{ii'}\right)_{\Delta n\neq0}g_{sh}(x_{n_i,n_i+1})-$$

$$-2\sum_{i'(\Delta E_{ii'}<0)}\sum_{A_{i'}J_{i'}}\vec{\Re}^2(n_i\ell_iA_iJ_i,n_i\ell_{i'}A_{i'}J_{i'})g_{sh}(x_{\ell_i,\ell_{i'}})-\left(\sum_{f'}\vec{\Re}^2_{ff'}\right)_{\Delta n\neq0}g_{sh}(x_{n_f,n_f+1})+ \tag{2}$$

$$+2\sum_{f'(\Delta E_{ff'}<0)}\sum_{A_{f'}J_{f'}}\vec{\Re}^2(n_f\ell_fA_fJ_f,n_f\ell_{f'}A_{f'}J_{f'})g_{sh}(x_{\ell_f,\ell_{f'}})+\sum_k\delta_k\}$$

where the initial level is denoted as i and the final one as f and the square of the matrix element $\{\vec{\Re}^2[n_k\ell_k A_k J_k, (\ell_k \pm 1)A_{k'}J_{k'}], \quad k = i, f\}$ is

$$\vec{\Re}^2[n_k\ell_k A_k J_k, n_k(\ell_k \pm 1)A'_k J'_k] = \frac{\ell_>}{2J_k+1} Q[\ell_k A_k, (\ell_k \pm 1)A'_k] Q(J_k, J'_k)[R^{n^*_k(\ell_k\pm1)}_{n^*_k\ell_k}]^2 \tag{3}$$

Also, $\ell_> = \max(\ell_k, \ell_k \pm 1)$ and

$$\left(\sum_{k'} \vec{\Re}^2_{kk'}\right)_{\Delta n\neq 0} = \left(\frac{3n^*_k}{2Z}\right)^2 \frac{1}{9}(n^{*2}_k + 3\ell^2_k + 3\ell_k + 11) \tag{4}$$

In Eqs. (1) and (2)

$$x_{\ell_k,\ell_{k'}} = \frac{E}{\Delta E_{\ell_k,\ell_{k'}}}, \quad k = i, f$$

and $E = \frac{3}{2}kT$ is the electron kinetic energy and $\Delta E_{\ell_k,\ell_{k'}} = |E_{\ell_k} - E_{\ell_{k'}}|$ is the energy difference between levels ℓ_k and $\ell_k \pm 1$ $(k = i, f)$,

$$x_{n_k,n_k+1} \approx \frac{E}{\Delta E_{n_k,n_k+1}},$$

where for $\Delta n \neq 0$, the energy difference between energy levels with n_k and n_k+1, $\Delta E_{n_k,n_k+1}$ is estimated as $\Delta E_{n_k,n_k+1} \approx 2Z^2 E_H/n^{*3}_k$, $n^*_k = [E_H Z^2/(E_{ion} - E_k)]^{1/2}$ is the effective principal quantum number, Z is the residual ionic charge (for example Z=1 for neutrals) and E_{ion} is the appropriate spectral series limit.

If we have an oscillator strength, e.g. from literature, the corresponding matrix element may be calculated as

$$\vec{\Re}^2_{k,k'} \approx 3\frac{E_H}{E_{k'} - E_k} \cdot f_{k'k} \qquad (E_{k'} > E_k), \quad k = i, f$$

or

$$\vec{\Re}^2_{k,k'} \approx 3\frac{E_H}{E_k - E_{k'}} \frac{2k'+1}{2k+1} \cdot f_{kk'} \qquad (E_{k'} < E_k), \quad k = i, f \tag{5}$$

where $f_{k'k}$ (for $E_{k'} > E_k$) and $f_{kk'}$ (for $E_{k'} < E_k$) are oscillator strengths and E_H is the hydrogen ionization energy.

In Eqs. (1 – 4) N and T are electron density and temperature, respectively, while $Q(\ell A, \ell' A')$ and $Q(J, J')$ are multiplet and line factors. The value of A depends on the coupling approximation (see e.g. Sobel'man, 1979). In the case of the LS coupling approximation, applied here, $A = L$, for the jK approximation $A = K$ and for the jj approximation $A = j$. The $[R^{n^*_k\ell_k\pm1}_{n^*_k\ell_k}]$ is the radial integral, and with $g(x)$ (Griem, 1974), $\tilde{g}(x)$ (Dimitrijević and Konjević, 1980) and $g_{sh}(x)$ (Griem, 1974), $\tilde{g}_{sh}(x)$ (Dimitrijević and Kršljanin, 1986) are denoted the corresponding Gaunt factors for width and shift, respectively. The factor $\sigma_{kk'} = (E_{k'} - E_k)/|E_{k'} - E_k|$, where E_k and $E_{k'}$ are the energy of the considered and its perturbing level. The sum $\sum_k \delta_k$ is different from zero only if perturbing levels with $\Delta n \neq 0$ strongly violating the assumed approximations exist, so that they should be taken into account separately, and may be evaluated as

$$\delta_i = \pm\vec{\Re}^2_{ii'}[g_{sh}(\frac{E}{\Delta E_{i,i'}}) \mp g_{sh}(x_{n_i,n_i+1})], \quad (7)$$

for the upper level, and

$$\delta_f = \mp\vec{\Re}^2_{ff'}[g_{sh}(\frac{E}{\Delta E_{f,f'}}) \mp g_{sh}(x_{n_f,n_f+1})], \quad (8)$$

for the lower level. In eqs. (7) and (8) the lower signs correspond to $\Delta E_{kk'} < 0$, $k = i, f$.

3. RESULTS AND DISCUSSION

Energy levels for Cd III lines have been taken from Bashkin and Stoner (1975). Oscillator strengths have been calculated by using the method of Bates and Damgaard (1949) and the tables of Oertel and Shomo (1968). Our results for ten Cd III transitions, for perturber density of 10^{23}m^{-3} and temperatures T = 10 000 - 300 000K will be published in Milovanović et al (2002).

Table 1
This Table shows Stark broadening full half-widths (FWHM) for Cd III for the electron density of 10^{23} m^{-3} and temperatures from 10 000 up to 300 000 K.

TRANSITION	$T(K)$	WIDTH(Å)
CdIII	10000	0.6119E-01
	20000	0.4327E-01
	50000	0.2736E-01
5s $^3D_3$-5p $^3P^0_2$	100000	0.1939E-01
λ =1874.095Å	150000	0.1661E-01
	300000	0.1419E-01
CdIII	10000	0.4184E-01
	20000	0.2959E-01
	50000	0.1871E-01
5s $^3D_3$-5p $^3D^0_3$	100000	0.1323E-01
λ =1601.579Å	150000	0.1118E-01
	300000	0.9388E-02

For the first time we have provided the Stark broadening parameters for ten Cd III transitions. We hope that the present results will be of interest in the the stellar, laboratory, fusion and laser produced plasma investigation and modeling.

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