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PLASMA SCREENING EFFECTS ON STARK BROADENING OF ION LINES AT THE ADIABATIC LIMIT

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Résumé.-On présent les effects d'écran sur l'élargissement Stark des raies des ions en approximation adiabatique en utilisant deux types des potentiels models d'écran.

Abstract.-The plasma screening effects on the Stark broadening parameters of ion lines at the adiabatic limit are shown by the use of both Coulomb cut-off and Debye-Hückel screening model potentials.

Because of the significant contribution of strong and elastic collisions to the broadening of spectral lines, the investigation of classical adiabatic solutions is very important for the modern Stark broadening theory. The solution obtained at the adiabatic limit is often used either as the reference point or as a constitutional part in the formation of some semi-classical impact theories.

The classical adiabatic approach for Stark broadening employing straight line perturber orbits and neglecting Debye shielding was developed by Lindholm and Foley [1],[2]. Proceeding from this theory, Roberts and Davis [3] derived the Stark broadening parameters of ion lines assuming hyperbolic perturber orbits in the Coulomb field. However, in some cases, e.g. for the lines originating from more excited atomic states, the influence of Debye screening may be significant even at lower electron densities.

Plasma shielding effects may be taken into account by using different approximations depending upon the plasma conditions. For lower electron densities one can use the Debye-Hückel potential ($V(r) = -(1/r)exp(-r/r_D)$, for $0 \leq r < \infty$), while for higher densities the upper cut-off in the integral over impact parameter ρ is more appropriate. Recently, the Coulomb cut-off potential [4] ($V(r) = -1/r + 1/r_C$, for $r \leq r_C$ and $V(r) = 0$, for $r > r_C$), suitable especially for non-ideal plasmas, is also used (r is the electron-ion distance, r_C is the cut-off parameter which can be assumed to be equal to r_D - Debye radius).

In this paper we analyse the influence of the two different approaches to the phase shift and line shift to width ratio (with special emphasis on adiabatic limit) in order to see if the differences can be experimentally observed. In such a case a high precision experiment might show the suitability of a particular method for the Debye screening correction.

Using polar coordinates and atomic units, the phase shift induced during the collision with a single perturber is given as:

$$\eta(Z,k) = 2{\rho_0}^3 \int_{r_0}^{\infty} \frac{dr}{r^3\sqrt{r^2 - {\rho_0}^2k^2 - 2r^2Z\rho_0V(r)}} .$$

In the above expressions, $\rho_0 = (C_4/v)^{1/3}$ is the Wiesskopf radius, where C_4 is the quadratic Stark constant and v is perturber velocity, $Z = 1/\rho_0v^2$ is a measure of the ratio of perturber potential energy to kinetic energy, and $k = \rho/\rho_0$. The lower integration limit is r_0 - the distance of emiter-perturber maximum approach. For $r_D \rightarrow \infty$, the solution of Roberts and Davis (1967) is recovered, while in high velocity limit ($v \rightarrow \infty$, $Z \rightarrow 0$), one gets the result of Lindholm-Foley's theory: $\eta = \eta_4^0 = \pi/2k^3$.

The influence of screening effects on the phase shift is presented in Fig.1. The discrepancy between the two screening models is significant near the Debye-radii values and more pronounced with the increasing of plasma density (lower k_D) and with the decreasing of perturber's velocity (greater Z). The phase shift in Debye-Hückel potential becomes more sensitive to plasma density (values of k_D) at lower velocities of an incoming particle (case b).

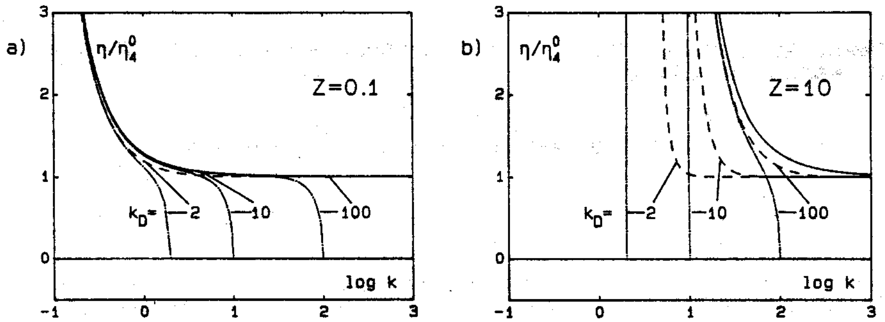

Fig.1.-The phase shift η/η_4^0 for the Debye-Hückel (- - -), the Coulomb cut-off (—·—) and the Coulomb potential (——) as a function of k and $k_D = r_D/\rho_0$ for $Z = 0.1$ (a) and $Z = 10$ (b).

In Fig.2. we present the influence of the two screening potentials on the Stark broadening parameters, ie. shift to width ratio d/w, using the well-known relation:

$$w(Z, k_D) + id(Z, k_D) = 2\pi N_e v \rho_0{}^2 \int_0^\infty (1 - exp(-i\eta(Z, k, \rho_0, r_D)))kdk$$

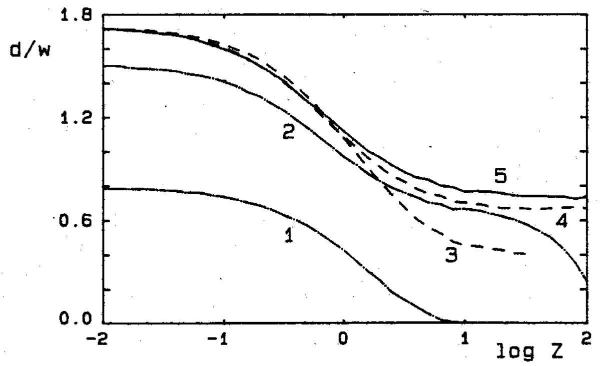

Fig.2.-The shift to width ratio (d/w) as a function of Z for Coulomb cut- off potential (1:$k_D = 2$, 2:$k_D = 10$), Debye-Hückel one (3:$k_D = 2$, 4:$k_D = 10$) and the Coulomb unshielded one (5:$k_D = \infty$).

In comparison with the Coulomb unshielded potential, effects of the screening on d/w ratio become pronounced for lower velocities of the incoming particle ($Z \geq 1$) in the case of Debye-Hückel potential, while for the Coulomb cut-off potential model, these differences are significant for the whole range of Z values.

One can see that the use of one or another potential model can produce difference in d/w ratios of the order of 10% for some typical experimental conditions ($k_D = 10, Z = 1$) and that this difference increases for larger plasma densities (e.g. see the curve 1 for $k_D = 2$) as well as towards the low temperature limit.

References

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