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1. INTRODUCTION

The Stark broadening of isolated neutral helium lines in a plasma is adequately described by the generalized impact theory [1] (GBKO) for electron densities which are sufficiently small so that the plasma frequency is much smaller than the level splitting (between, say, the upper level of the transition and the closest neighboring level for which the dipole matrix element is nonzero). At higher electron densities the extension of the integration over electron impact parameters from the strong collision cutoff to infinity results in an overestimate of the broadening, and the integration should be cut off at a maximum impact parameter equal to 1.123 times the Debye length (equivalent cutoff [1]). In this model there is no contribution from impact parameters larger than the cutoff, and unshielded contribution from smaller impact parameters. The screening effects reported for helium I lines in this paper should certainly be measurable in the shifts and most likely also in the widths.

2. DEBYE SHIELDING

In order to treat Debye shielding effects systematically for each perturbing level and for each perturber velocity the cutoff in the impact parameter integration was introduced prior to the summation over perturbing levels and prior to the velocity integration. This is essential because different states are shielded at different electron densities depending upon their angular frequency separation from the upper (or lower) level, and because complete Debye shielding occurs at relatively low electron densities for the smaller velocities. It was required that minimum and maximum impact parameters be set equal if the former became larger than the latter. This insures not only that there is never a negative contribution to the width at small velocities, but also that Debye shielding in the strong collision term is included in a consistent manner.

The unshielded results do not agree in every detail with the GBKO results because of the following modifications to the theory [2,3]. More interacting levels were taken into account, for upper as well as lower levels of the transitions. The important functions a(z) and b(z), numerically inaccurate in GBKO, were corrected. (This reduced the widths by typically one to five percent, the shifts by ten percent.) Quadrupole contributions to widths and shifts were included explicitly and back reaction of the atom on the perturbers was included in an approximate way. (The latter correction, important for many ion lines, proved insignificant in helium I and should also be small in other neutrals.)

The matrix elements were obtained by the method of Bates and Damgaard [4] whose formulae (with some minor corrections) were programmed for an IBM digital computer so that the use of the tables could be avoided [5]. The strong collision cutoff as defined in GBKO was used throughout, rather than the one used by Griem in a subsequent paper [6]. The latter yields larger results, because the increase in the strong collision term is only partially offset by a reduction in the weak collision contribution. The width of the He I 5016 line, e. g., would increase by typically 5 percent. Currently available experimental accuracies do not permit a decision between the two cutoff procedures.

3. RESULTS

The numerical results in table I were obtained on an IBM 7094 digital computer at Langley. Besides multiplet number and wavelength (Å) the table lists half halfwidths w(Å) and shift to width (half halfwidth) ratios as functions of temperature and electron density. The half halfwidth and shift to width ratio at the lowest electron density for any line were computed without any Debye shielding. This may overestimate the shift slightly at these electron densities.

TABLE I: Widths w(Å) and shift/width ratios (in parentheses)

Line	T(°K)	Electron Density (cm^{-3}): 10^{15}	10^{16}	10^{17}	10^{18}
3889	10,000	1.06^{-2} (0.77)	1.06^{-1} (0.73)	1.06 (0.66)	10.0 (0.45)
(2)	20,000	1.14^{-2} (0.52)	1.14^{-1} (0.50)	1.14 (0.45)	10.9 (0.32)
	40,000	1.16^{-2} (0.36)	1.16^{-1} (0.35)	1.16 (0.32)	11.3 (0.23)
5016	10,000	3.55^{-2} (-0.45)	3.54^{-1} (-0.38)	3.26 (-0.26)	23.9 (-0.12)
(4)	20,000	3.30^{-2} (-0.39	3.29^{-1} (-0.33)	3.09 (-0.24)	24.9 (-0.13)
	40,000	3.03^{-2} (-0.33)	3.02^{-1} (-0.28)	2.88 (-0.20)	24.5 (-0.12)
5876	10,000	1.67^{-2} (-0.35)	1.67^{-1} (-0.33)	1.67 (-0.28)	15.7 (-0.13)
(11)	20,000	1.71^{-2} (-0.18)	1.71^{-1} (-0.16)	1.70 (-0.13)	16.4 (-0.02)
	40,000	1.72^{-2} (-0.06)	1.72^{-1} (-0.05)	1.71 (-0.02)	16.7 (+0.06)
4713	10,000	3.39^{-2} (1.3)	3.39^{-1} (1.3)	3.38 (1.2)	32.6 (0.74)
(12)	20,000	4.07^{-2} (1.0)	4.07^{-1} (0.96)	4.06 (0.90)	39.7 (0.67)
	40,000	4.47^{-2} (0.76)	4.47^{-1} (0.74)	4.47 (0.70)	

The superscript denotes the power of ten by which the number should be multiplied.

The multiplet number appears in parentheses below the wavelength.

4. DISCUSSION AND CONCLUSIONS

It is interesting to note that the generally smaller widths predicted herein are in better agreement with measurements by Lincke [7] and his evaluation of other results [8] than the latest GBKO results [9]. He finds that the theoretical widths [9] are too large by typically 10 percent. The He I 5016 line (found to be predicted too wide by about 20 percent) happens to show Debye shielding at moderate densities according to table I.

While direct measurements of the effects of Debye shielding have not been published as of this writing there are preliminary measurements on the He I 5016 and 5876 lines which indicate Debye shielding effects near 10^{18} electrons/cm^3 [10]. Since widths are much more satisfactory than shifts from a theoretical point of view a comparison of measured and predicted widths would be the best quantitative test of the present predictions. However, the relative change of shifts with electron density at constant temperature is more easily measurable and would demonstrate Debye shielding in line broadening at relatively low densities in at least a qualitative way.

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