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STARK SHIFT IN THE Ne II SPECTRUM

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Abstract. Experimental Stark shifts for 38 Ne II spectral lines at electron temperature 35 300 K and electron density of 1.83 10^{23} m^{-3}, as well as calculated Stark shift values for 22 multiplets for electron density of 10^{23} m^{-3} and for electron temperatures from 5 000 K up to 100 000 K, are presented.

1. INTRODUCTION

After earlier investigations of Ne II Stark shifts (d) the first measurements of d at convenient plasma parameters, T and N, have been carried out in only one experiment (Purić et al. 1987) where d-values of 18 Ne II spectral lines from 13 multiplets have been measured at T=35 000 K and N=1.42 10^{23} m^{-3}.

Theoretical semiclassical calculations have been made up to T = 40 000 K for only seven Ne II multiplets (Griem 1974).

We have measured Stark shift values of 38 Ne II spectral lines that belong to 22 multiplets and we have calculated Stark shift values for 22 multiplets, 30 from them are new determinations. Our plasma parameters were T=35 300 K and N=1.83 10^{23} m^{-3}. Our value of N is about 30% higher than those in the experiment of Purić et al. (1987) providing higher accuracy. For the calculations of the d-values we used the updated version of the semiclassical perturbation formalism (SCPF).

2. EXPERIMENT

The modified version of the linear low pressure pulsed arc (Djeniže et al. 1992, 2002, Milosavljević 2001) has been used as an optically thin plasma source. The working gas was pure neon at 133 Pa filling pressure in the flowing regime. Spectroscopic observations of isolated spectral lines were made along the axis of the discharge tube. The line profiles were recorded using a step-by-step technique with a photomultiplier (EMI 9789 QB) and a grating spectrograph (Zeiss PGS-2, reciprocal linear dispersion 0.73 nm/mm in the first order) system.

The measured profiles were of the Voigt type due to the convolutions of the Lorentzian, Stark and the Gaussian profiles from Doppler and instrumental broadening. For

the electron density and temperature of our experiments the Lorentzian fraction in the Voigt profile was dominant (over 88%). Van der Waals and resonance broadening were estimated to be smaller by more than one order of magnitude in comparison to Stark, Doppler and instrumental broadening. The standard deconvolution procedure (Davies & Vaughan 1963, Milosavljević & Poparić 2001) was applied using the least squares algorithm.

The plasma parameters were determined using standard diagnostic methods (Rompe & Steenbeck 1967). Thus, the electron temperature (T) was determined from the Boltzmann plot of the relative intensities of Ne II spectral lines.

The electron temperature decay is presented in Fig. 3 in Djeniže et al. (2002), together with the electron density (N) decay. The latter was measured using a well-known single laser interferometry technique (Ashby et al. 1965) for the 632.8 nm He-Ne laser wavelength with an estimated error of ±4%.

3. STARK SHIFT MEASUREMENTS

The Stark shifts were measured relatively to the unshifted spectral lines emitted by the same plasma (Milosavljević et al. 2000) and references therein. The Stark shift of spectral line can be measured experimentally by evaluating the position of the spectral line center recorded at two different electron density values during the plasma decay. In principle, the method requires recording of the spectral line profile at the high electron density that causes an appreciable shift and then later when the electron concentration has dropped to the value lower by at least an order of magnitude. The Stark shift data were corrected for the electron temperature decay (Popović et al. 1992). Stark shift data are determined with ± 0.8 pm error at a given N and T.

4. METHOD OF CALCULATION

The semiclassical perturbation formalism, as well as the corresponding computer code (Dimitrijević & Sahal-Bréchot 1996ab), have been updated and optimized several times (see Djeniže et al. (2002) and references therein). The calculation procedure, with the discussion of updating and validity criteria, has been briefly reviewed (e.g. in Dimitrijević & Sahal-Bréchot (1996ab)).

Atomic energy levels not existing (or revised) from Moore (1971; Bashkin & Stoner 1978) have been taken in Quinet (1994). One should mention that the Ne II spectrum is not well determined experimentally so that the set of experimental perturbing atomic energy levels needed for a semiclassical perturbation method calculation with the usual average accuracy of ±30%, is not complete.

5. RESULTS

The results of the measured Stark shift (d_m) values at T=35 300 K electron temperature and 1.83 10^{23} m^{-3} electron density are shown in Table 1.

Our calculated Stark shift values are presented in Table 2.

Table 1: Our measured Stark shift (d_m) values for the Ne II spectral lines at 35 300 K electron temperature and 1.83 10^{23} m^{-3} electron density. Positive shift is toward the red.

Transition	*Multiplet*	$\lambda(nm)$	$d_{exp}(pm)$
3s-3p	^4P-$^4P^0$	369.419	-0.7
	(1)	366.411	-0.2
	^4P-$^4D^0$	333.487	-0.6
	(2)	336.063	0.0
		332.716	-0.8
	^4P-$^4S^0$	300.166	-0.8
	(4)	302.886	0.0
	^2P-$^2D^0$	372.708	-2.5
	(5)		
	^2P-$^2P^0$	332.375	0.0
	(7)	337.828	0.0
3s'-3p'	^2D-$^2F^0$	356.853	-0.6
	(9)		
	^2D-$^2P^0$	331.975	-1.0
	(10)		
3p-3d	$^4P^0$-^4D	303.448	0.0
	(8)	302.704	0.4
		303.773	0.2
	$^4D^0$-^4D	332.920	0.8
	(12)	335.790	1.4
		337.410	3.1
		336.289	0.9
		337.939	2.5
	$^2D^0$-^2F	341.771	2.4
	(20)	341.482	3.1
	$^2D^0$-^2D	341.682	4.2
	(21)		
	$^2D^0$-^4P	337.187	0.7
	(22)		
	$^2S^0$-^2P	350.361	0.0
	(28)		
	$^2P^0$-^2P	362.806	3.5
	(41)		
	$^4S^0$-^2D	365.993	4.0
	(33)	363.275	6.9
	$^4S^0$-^4F	357.126	2.9
	(31)		
	$^4S^0$-^4P	356.584	2.2
	(34)		
3p'-3d'	$^2P^0$-^2D	333.612	1.3

Table 1: (continued)

Transition	*Multiplet*	$\lambda(nm)$	$d_{exp}(pm)$
3p-4s	$^2P^0$-^2P	337.728	5.4
	$^4D^0$-^4P	303.965	6.4
		303.598	2.0
3d-4f	^4F-$^4F^0$	439.194	-7.2
	(56)	440.930	-5.5
	^4F-$^4G^0$	429.040	-3.3
	(57)	441.320	-14.9

6. CONCLUSION AND DISCUSSION

In order to make easier the comparison between measured and calculated Stark shift values, the theoretical Stark shift dependence on the electron temperature together with the values of other authors and our experimental results at electron density 10^{23} m^{-3} are presented graphically in Fig. 1.

Generally, we have obtained very small shift values. Both experimental and measured d values are below one pm, within our experimental accuracy (±0.8 pm). Our measured and calculated d values have the same sign (see Fig. 1, Tables 1 and 2).

Stark shifts, corresponding to the 3p-3d and 3p-4s transition arrays have finite and positive values. Measured shift values, corresponding to the 3d-4f transition are negative and confirm the earlier obtained sign in Purić et al. (1987). Our calculated (SCPF) d values are smaller than those from Griem (1974), by up to a factor 6.

Satisfactory agreement exists between our measured and calculated d values in the case of the lines that belong to the 3p-3d transition. Earlier measured 3p-3d shift values (Purić et al. 1987) agree also with our calculated values.

It should be pointed out that we have not performed calculations of d values belonging to lines in 3d-4f transition because of the incompleteness of the set of the experimentally determined perturbing energy levels.

The large theoretical d values for 3p $^2P^0$-4s ^2P, 3p $^4D^0$-4s ^4P and 3p $^4P^0$-4s ^4P multiplets are due to close 4p $^2P^0$ and 4p $^4P^0$ perturbing levels contributing positively to the shift. The reason for strong disagreement with our measurements might indicate that 4p $^2P^0$ and 4p $^4P^0$ levels are in fact a combination of different contributions which results in decrease of their influence.

We have presented in this work experimental Stark shifts for 38 Ne II spectral lines at electron temperature 35 300 K and electron density 1.83 10^{23} m^{-3}, as well as calculated Stark shift values for 22 multiplets for electron density 10^{23} m^{-3} and for electron temperatures from 5 000 K up to 100 000 K. The shift values found are, generally, small. In the case of the 3s-3p and 3s′-3p′ transitions they are practically equal to zero. The common characteristics of these d values is the weak dependence on the electron temperature up to 100 000 K. Thus, these can be used for diagnostics purposes as data independent of self-absorption in the optically thick astrophysical plasmas.

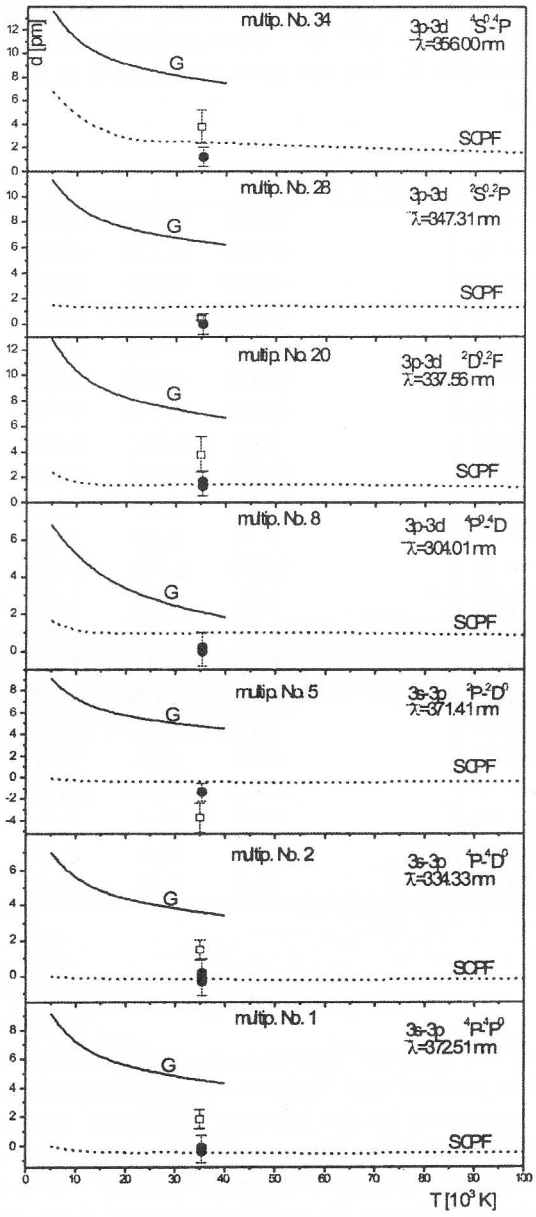

Fig. 1: Stark shift (d in pm) dependence on the electron temperature for various transitions at 10^{23} m^{-3} electron density. ● our experimental data and □, from Purić et al. (1987). G, theoretical calculations taken form Griem (1974) and our calculated (SCPF) Stark shift values taken from Table 2. The error bars of ±0.8 pm represent the uncertainties of the shift measurements. Positive shift is toward the red.

Table 2: Electron Stark shift (d in pm) calculated by using the semiclassical perturbation formalism (SCPF) at 10^{23} m^{-3} electron density for electron temperatures from 5 000 K up to 100 000 K. $\bar{\lambda}$ is the mean wavelength in the multiplet. Positive shift is toward the red.

Transition	$\lambda(nm)$	$T(10^4K)$:	0.5	1	2	3	5	10
3s ^{4}P-3p ^{4}P^0	372.51		0.003	-0.365	-0.480	-0.432	-0.543	-0.455
3s ^{4}P-3p ^{4}D^0	334.33		-0.035	-0.136	-0.187	-0.178	-0.216	-0.189
3s ^{4}P-3p ^{4}S^0	298.83		-0.039	0.021	0.052	0.049	0.065	0.037
3s ^{2}P-3p ^{2}D^0	371.41		-0.113	-0.287	-0.394	-0.379	-0.455	-0.381
3s ^{2}P-3p ^{2}P^0	334.27		-0.107	-0.058	-0.047	-0.032	-0.036	-0.060
3s$'$ ^{2}D-3p$'$ ^{2}F^0	357.21		-0.128	-0.246	-0.332	-0.308	-0.377	-0.321
3s$'$ ^{2}D-3p$'$ ^{2}P^0	333.78		-0.056	-0.113	-0.141	-0.131	-0.158	-0.150
3p ^{4}P^0-3d ^{4}D	304.01		1.66	0.987	0.937	0.968	1.04	0.869
3p ^{4}D^0-3d ^{4}D	335.26		0.820	0.879	0.860	0.964	1.01	0.864
3p ^{2}D^0-3d ^{4}F	342.15		2.51	1.45	1.34	1.43	1.49	1.27
3p ^{2}D^0-3d ^{2}F	337.56		2.45	1.42	1.30	1.38	1.45	1.24
3p ^{2}D^0-3d ^{2}D	343.23		0.760	0.797	0.782	0.892	0.975	0.828
3p ^{2}D^0-3d ^{4}P	335.26		2.81	1.70	1.53	1.57	1.63	1.40
3p ^{2}S^0-3d ^{2}P	347.31		1.47	1.36	1.22	1.36	1.42	1.26
3p ^{2}P^0-3d ^{2}P	365.18		1.30	1.24	1.12	1.30	1.35	1.23
3p ^{4}S^0-3d ^{2}D	365.00		0.526	0.573	0.507	0.674	0.709	0.644
3p ^{4}S^0-3d ^{4}F	363.78		1.12	1.13	1.05	1.23	1.25	1.13
3p ^{4}S^0-3d ^{4}P	356.00		6.79	4.40	2.46	2.61	2.17	1.58
3p$'$ ^{2}P^0-3d$'$ ^{2}P	342.27		0.871	0.883	0.826	0.966	1.01	0.850
3p ^{2}P^0-4s ^{2}P	341.23		27.3	21.0	15.7	14.4	11.9	9.32
3p ^{4}D^0-4s ^{4}P	304.53		22.2	17.1	12.9	11.7	9.68	7.61
3p ^{4}P^0-4s ^{4}P	278.52		19.0	14.7	11.3	10.1	8.46	6.58

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