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# ON THE STARK BROADENING OF F VI AND Cl VII LINES

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**Abstract.** Using a semiclassical approach, we have calculated electron-, proton-, and doubly charged helium-impact line widths and shifts for 2 F VI and 10 Cl VII multiplets, for perturber densities $10^{17}$– $10^{22}$ cm$^{-3}$ and temperatures T = 100,000 – 2,000,000 K.

## 1. INTRODUCTION

Chlorine and fluorine spectral lines have been observed in Solar (Moore, Minnaert and Houtgast, 1966), as well as in stellar spectra (Merrill, 1956). Trimble (1991) reports that chlorine and fluorine have been found in the ejecta of SN 1987 A supernova. Fluorine is a product of hydrogen burning in stellar interiors and envelopes and chlorine a product of alpha processes - neutron capture on slow time scale. Consequently, the data on the spectral line broadening parameters of fluorine and chlorine at various ionization stages are of interest for the considering and modelling of stellar plasma, particularly subphotospheric layers (Seaton, 1987) and radiative transfer in stellar interiors. For the investigation and developing of soft X-ray lasers, such data are also of interest (see e.g. Griem and Moreno, 1990; Fill and Schöning, 1994). Line broadening data for multiply charged ions are equally of significance for the fusion plasmas and laser-produced plasmas research and for the investigation of Stark broadening parameter systematic trends along isoelectronic sequences.

Within the semiclassical-perturbation formalism (Sahal-Bréchot 1969ab), we have calculated electron-, proton-, and He III-impact line widths and shifts for 2 fluorine VI and 10 chlorine VII multiplets. The used semiclassical perturbation formalism has been discussed and reviewed e.g. in Dimitrijević *et al.* (1991) and Dimitrijević and Sahal - Bréchot (1996).

## 2. RESULTS AND DISCUSSION

Energy levels for fluorine VI and chlorine VII lines have been taken from Bashkin and Stoner (1978). All other details of calculations are given in Dimitrijević and Sahal-Bréchot (1998a).

**Table 1**

This Table shows electron- and proton-impact broadening full half- widths (FWHM) and shifts for F VI for a perturber density of $10^{19}$ cm$^{-3}$ and temperatures from 100,000 up to 2,000,000 K. By deviding C with the full linewidth, we obtain an estimate of the maximum perturber density for which the line may be treated as isolated and tabulated data may be used.

PERTURBER DENSITY = 1.E+19cm-3

| PERTURBERS ARE: | | ELECTRONS | | PROTONS | |
|---|---|---|---|---|---|
| TRANSITION | T(K) | WIDTH(Å) | SHIFT(Å) | WIDTH(Å) | SHIFT(Å) |
| F VI 2S 2P | 100000. | 0.322E-01 | -0.329E-03 | 0.117E-03 | -0.174E-03 |
| 535.2 A | 200000. | 0.229E-01 | -0.549E-03 | 0.322E-03 | -0.366E-03 |
| C=0.54E+22 | 500000. | 0.149E-01 | -0.586E-03 | 0.899E-03 | -0.780E-03 |
| | 1000000. | 0.111E-01 | -0.608E-03 | 0.142E-02 | -0.112E-02 |
| | 1500000. | 0.953E-02 | -0.574E-03 | 0.175E-02 | -0.133E-02 |
| | 2000000. | 0.859E-02 | -0.567E-03 | 0.190E-02 | -0.142E-02 |
| F VI 2P 3S | 100000. | 0.928E-02 | 0.613E-03 | 0.279E-03 | 0.655E-03 |
| 173.1 A | 200000. | 0.699E-02 | 0.795E-03 | 0.667E-03 | 0.102E-02 |
| C=0.70E+20 | 500000. | 0.500E-02 | 0.760E-03 | 0.136E-02 | 0.149E-02 |
| | 1000000. | 0.397E-02 | 0.736E-03 | 0.185E-02 | 0.180E-02 |
| | 1500000. | 0.349E-02 | 0.670E-03 | 0.218E-02 | 0.199E-02 |
| | 2000000. | 0.319E-02 | 0.617E-03 | 0.238E-02 | 0.210E-02 |

**Table 2**

This Table shows electron- and proton-impact broadening full half- widths (FWHM) and shifts for Cl VII for a perturber density of $10^{19}$ cm$^{-3}$ and temperatures from 100,000 up to 2,000,000 K. By deviding C with the full line width we obtain an estimate of the maximum perturber density for which the line may be treated as isolated and tabulated data may be used.

PERTURBER DENSITY = 1.E+19cm-3

| PERTURBERS ARE: | | ELECTRONS | | PROTONS | |
|---|---|---|---|---|---|
| TRANSITION | T(K) | WIDTH(Å) | SHIFT(Å) | WIDTH(Å) | SHIFT(Å) |
| Cl VII 3S 3P | 100000. | 0.183 | -0.160E-02 | 0.149E-02 | -0.859E-03 |
| 804.8 A | 200000. | 0.131 | -0.211E-02 | 0.350E-02 | -0.180E-02 |
| C=0.80E+22 | 500000. | 0.879E-0 | 1-0.262E-02 | 0.711E-02 | -0.366E-02 |
| | 1000000. | 0.674E-0 | 1-0.236E-02 | 0.997E-02 | -0.510E-02 |
| | 1500000. | 0.586E-0 | 1-0.234E-02 | 0.110E-01 | -0.585E-02 |
| | 2000000. | 0.534E-0 | 1-0.227E-02 | 0.117E-01 | -0.633E-02 |

**Table 2 continued**

PERTURBER DENSITY = 1.E+19cm-3

| PERTURBERS ARE: | | ELECTRONS | | PROTONS | |
|---|---|---|---|---|---|
| TRANSITION | T(K) | WIDTH(Å) | SHIFT(Å) | WIDTH(Å) | SHIFT(Å) |
| Cl VII 3S 4P | 100000. | 0.277E-01 | 0.264E-03 | 0.102E-02 | 0.129E-03 |
| 196.2 A | 200000. | 0.204E-01 | 0.211E-03 | 0.165E-02 | 0.256E-03 |
| C=0.18E+21 | 500000. | 0.143E-01 | 0.297E-03 | 0.235E-02 | 0.455E-03 |
| | 1000000. | 0.114E-01 | 0.280E-03 | 0.267E-02 | 0.608E-03 |
| | 1500000. | 0.102E-01 | 0.268E-03 | 0.286E-02 | 0.678E-03 |
| | 2000000. | 0.942E-02 | 0.271E-03 | 0.299E-02 | 0.727E-03 |
| Cl VII 4S 4P | 100000. | 4.35 | -0.842E-01 | 0.132 | -0.643E-01 |
| 2190.4 A | 200000. | 3.24 | -0.983E-01 | 0.217 | -0.112 |
| C=0.22E+23 | 500000. | 2.33 | -0.966E-01 | 0.320 | -0.176 |
| | 1000000. | 1.88 | -0.949E-01 | 0.377 | -0.211 |
| | 1500000. | 1.68 | -0.938E-01 | 0.413 | -0.234 |
| | 2000000. | 1.56 | -0.861E-01 | 0.441 | -0.251 |
| Cl VII 3P 4S | 100000. | 0.416E-01 | 0.236E-02 | 0.637E-03 | 0.149E-02 |
| 294.3 A | 200000. | 0.308E-01 | 0.255E-02 | 0.170E-02 | 0.252E-02 |
| C=0.40E+21 | 500000. | 0.218E-01 | 0.277E-02 | 0.352E-02 | 0.387E-02 |
| | 1000000. | 0.174E-01 | 0.266E-02 | 0.466E-02 | 0.463E-02 |
| | 1500000. | 0.154E-01 | 0.261E-02 | 0.536E-02 | 0.515E-02 |
| | 2000000. | 0.141E-01 | 0.247E-02 | 0.598E-02 | 0.549E-02 |
| Cl VII 3P 3D | 100000. | 0.114 | -0.447E-03 | 0.171E-02 | -0.147E-03 |
| 602.6 A | 200000. | 0.814E-0 | 1-0.418E-03 | 0.359E-02 | -0.317E-03 |
| C=0.45E+22 | 500000. | 0.543E-0 | 1-0.484E-03 | 0.641E-02 | -0.731E-03 |
| | 1000000. | 0.416E-0 | 1-0.380E-03 | 0.807E-02 | -0.111E-02 |
| | 1500000. | 0.363E-0 | 1-0.405E-03 | 0.872E-02 | -0.136E-02 |
| | 2000000. | 0.332E-0 | 1-0.395E-03 | 0.915E-02 | -0.153E-02 |
| Cl VII 3P 4D | 100000. | 0.403E-01 | 0.685E-03 | 0.158E-02 | 0.112E-02 |
| 224.8 A | 200000. | 0.302E-01 | 0.870E-03 | 0.262E-02 | 0.182E-02 |
| C=0.75E+20 | 500000. | 0.214E-01 | 0.809E-03 | 0.402E-02 | 0.275E-02 |
| | 1000000. | 0.172E-01 | 0.750E-03 | 0.499E-02 | 0.332E-02 |
| | 1500000. | 0.153E-01 | 0.660E-03 | 0.564E-02 | 0.369E-02 |
| | 2000000. | 0.141E-01 | 0.576E-03 | 0.620E-02 | 0.395E-02 |
| Cl VII 4P 4D | 100000. | 3.11 | 0.119E-01 | 0.143 | 0.525E-01 |
| 1680.4 A | 200000. | 2.34 | 0.239E-01 | 0.217 | 0.875E-01 |
| C=0.42E+22 | 500000. | 1.69 | 0.120E-01 | 0.293 | 0.134 |
| | 1000000. | 1.37 | 0.111E-01 | 0.345 | 0.161 |
| | 1500000. | 1.23 | 0.706E-02 | 0.379 | 0.179 |
| | 2000000. | 1.14 | 0.239E-02 | 0.404 | 0.192 |

The complete results of our calculations of electron-, proton-, and He III- impact line widths and shifts for 2 fluorine VI and 10 chlorine VII multiplets, for perturber densities $10^{17}$– $10^{22}$ $cm^{-3}$ and temperatures T = 100,000 – 2,000,000 K, will be published elsewhere (Dimitrijević and Sahal-Bréchot, 1998ab). Here, in Tables 1 and 2, only data for perturber density of $10^{19}$ $cm^{-3}$, as a sample of obtained results are shown for fluorine VI and chlorine VII respectively. We also specify a parameter C (Dimitrijević and S.Sahal-Bréchot, 1984), which gives an estimate for the maximum perturber density for which the line may be treated as isolated when it is divided by the corresponding full width at half maximum.

There is not experimental results concerning F VI and Cl VII. However, predictions on the basis of systematic trends along isoelectronic sequences exist for F VI $3s^1S$ - $3p^1P^o$, 2464.8 Å line for T = 45000 K and the electron density of $10^{17}cm^{-3}$ and for Cl VII $4s^2S$ - $4p^2P^o$, 2178.8 Å line for T = 60000 K and the electron density of $10^{17}cm^{-3}$ (Purić et al., 1988). Electron temperatures in this paper are too low for the comparison with our data.

We hope that the obtained results are of interest for astrophysical and laboratory plasma research, as well as for the theoretical considerations of systematic trends along isoelectronic sequences.

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