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# Experimental Stark Widths and Shifts for Spectral Lines of Positive Ions
## (A Critical Review and Tabulation of Selected Data for the Period 1976 to 1982)

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A new critical review of the available experimental data on the Stark widths and shifts for lines of non-hydrogenic ionized spectra has been carried out which covers the period from 1976 to the present and represents a continuation of an earlier critical review. The relevant literature, compiled by the NBS Data Center on Atomic Lines Shapes and Shifts as well as by the present authors, was critically evaluated, and data tables containing the selected experimental Stark broadening parameters have been assembled. The data are arranged according to spectra and elements and these are presented in alphabetical order. The accuracy of the experimental data is estimated on the basis of guidelines developed during the previous review. Comparisons with theoretical results are made whenever possible since the comparison with theory has often been a principal motivation for the experiments.

Key words: critically evaluated data; experimental; ionized spectra; Stark broadening parameters; Stark shifts; Stark widths.

## Contents



[a]Part of this work was performed while the author was a guest scientist at the National Bureau of Standards.



## 1. Introduction

A first critical review and tabulation of *experimental* Stark width and shift data for spectral lines of non-hydrogenic positive ions[1] was carried out by two of the present authors in 1976. This new critical data tabulation represents a continuation and extension of the earlier tables for the period from 1976 to the present (generally, mid 1982 is the cut-off date). Many new papers have been published during these last 6 years, often with significantly improved techniques, and the higher ions have received increasing attention.

To maintain consistency, we have closely adhered to the format of the previous tables and to our earlier established evaluation criteria. Our principal sources for literature references have been (a) the NBS "Bibliography on Atomic Line Shapes and Shifts", Supplement 3,[2] which covers the period 1975 to 1978, and (b) the master file of the NBS "Data Center on Atomic Line Shapes and Shifts" from 1978 to the present time.[3] In addition, during this whole period the authors of this review have maintained an independent literature search.

Stark broadening experiments provide valuable checks on theoretical Stark width and shift data, and the comparison with theory has often been a principal motivation for the measurements. Therefore, we have listed comparisons with the available theoretical data throughout the tables and we have particularly utilized two theoretical approximations: for singly ionized atoms, the extensive tables by Griem,[4] based on the semiclassical method; and for multiply ionized species, the extensive tables by Dimitrijević and Konjević,[5] based on a modified semiempirical approach. The respective experiment/theory ratios are listed throughout the tables and they are supplemented by additional (average) ratios for other theoretical approaches in the introductory comments to the various ions when available.

## 2. General Discussion

For the critical evaluation of all experiments we followed the evaluation criteria discussed in the general introduction of our 1976 critical review.[1] Since a detailed discussion of the critical factors in plasma line broadening experiments was presented there, this does not need to be repeated. To summarize, the principal factors in our assessment of the experiments are:

(a) *the characteristics of the plasma source*, specifically such properties as its homogeneity, quasi-stationary behavior during observation time, reproducibility, etc.

(b) *the reliability of the plasma diagnostic method*, especially the determination of the electron density from such techniques as interferometry, hydrogen Stark profiles, and line and continuum intensity measurements, as well as the applicability of the assumed LTE plasma model.

(c) *the determination of the Stark widths and shifts*. Here specifically the detailed consideration of competing broadening mechanisms (Doppler, Van der Waals and instrumental broadening), the distortion of line shapes by self-absorption, and the utilization of appropriate wavelength standards for the shift measurements are considered.

Similar to our earlier review, we found the description of plasma source properties and diagnostic techniques generally to be quite complete in the papers, but discussions of Stark width and shift measurements were often deficient in the sense that authors did not report on the contributions of Doppler or apparatus broadening or did not discuss self-absorption problems (see, e.g., the Mg II case discussed below).

In arriving at our uncertainty estimates, we took into account occasional disagreements between authors outside their mutually estimated error limits. Furthermore, we tested the data—when appropriate—by their adherence to predicted regularities.[6] We looked specifically for similarities within transition arrays and multiplets, and for regularities in homologous ions, or along isoelectronic sequences. For example, line widths within multiplets should normally be nearly identical, but for Ar II some interesting and explainable deviations from this rule were found.

Of the material tabulated here, the resonance lines of Mg II are of special interest because of major inconsistencies in the presumably reliable experimental data.[7–12] Therefore, we are using these data as an example for a detailed case discussion. The unsatisfactory situation is summarized in Fig. 1, which has been taken from the recent paper by Goldbach *et al.*[7] The experimental points, shown with error flags, clearly fall into two groups separated by more than a factor two. The data by Goldbach *et al.*[7] and Roberts and Barnard[8] closely follow the results of the quantum mechanical calculations by Barnes,[13] while the other experiments[9–12] agree closely with the semiclassical calculations of Jones *et al.*[14] The experiment labeled "H", by Hadziomerspahic *et al.*,[12] is a somewhat special situation, since it was performed at much higher temperatures.

Stark broadening measurements for the Mg II resonance lines are particularly difficult for two reasons:

(a) Like most resonance lines, these transitions are very sensitive to self-absorption, which distorts their line shapes. Nearly optically thin conditions may be achieved by keeping the Mg concentration in the plasma very small, and the optical thickness must be accurately determined and monitored.

(b) The Stark widths for the resonance lines are very small. Therefore, high spectral resolution is required to minimize instrumental broadening and a careful (Voigt) profile analysis is necessary to separate the appreciable Doppler broadening contribution (a Gaussian profile) from the Stark profile (a Lorentzian profile). Also, the possible presence of other broadening mechanisms needs to be checked.

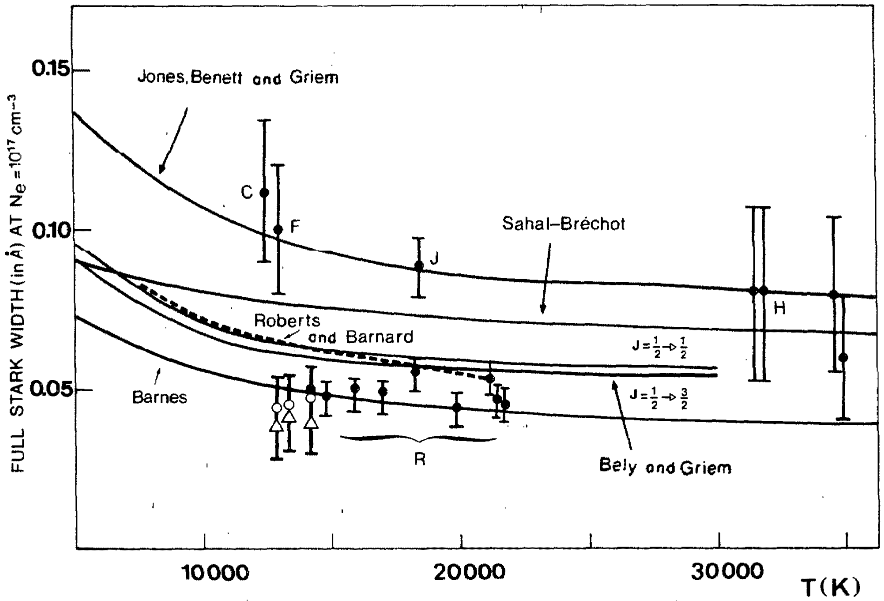


FIGURE 1. Comparison of Stark width data for the Mg II resonance lines (reproduced from Goldbach *et al.*[7]). Experimental results: C, Chapelle and Sahal-Brechot[9]; F, Fleurier *et al.*[10]; J, Jones *et al.*[11]; H, Hadziomerspahic *et al.*[12]; R, Roberts and Barnard.[8] The open circles and triangles are the results of the experiment by Goldbach *et al.*[7] for the $J = 1/2 \rightarrow 3/2$ and the $J = 1/2 \rightarrow 1/2$ lines, respectively. The theoretical results, given as the solid and broken lines, are from the quantum mechanical calculations by Barnes,[13] and Bely and Griem[22]; and the semiclassical calculations of Jones *et al.*,[14] Roberts and Barnard,[8] and Sahal-Brechot.[10]

The two points above address only the last of the three earlier mentioned critical factors in line broadening measurements, the "determination of the Stark profiles." For the overall assessment of the experiments the properties of the plasma sources as well as the diagnostic techniques applied must be critically evaluated, too.

Table 1 provides some key data and comments on the critical factors for the recent Mg II experiments. With respect to the plasma sources (column 2), the electromagnetic shock tube used by Jones *et al.*[11] appears to be of lower quality than the other sources because of its extremely short quasi-stationary state, and its appreciable inhomogeneity across the tube diameter. The diagnostic techniques applied for the electron density ($N_e$) and temperature ($T$) measurements are indicated in columns 3 and 4 and the actual $N_e$ and $T$ ranges are given. The techniques applied are reliable, often-tested methods. The information given in the remaining columns of the table concerns principally the Stark profile determinations. Columns 5 and 6 contain information on the Mg concentration and on optical depth checks, to allow an assessment of the self-absorption problem. Self-absorption cannot be ruled out in the experiments by Jones *et al.*,[11] where no checks are reported, and in the experiment by Chapelle and Sahal-Brechot,[9] where the rather indirect check for variations in the line shape is insensitive to self-absorption.[15] The critical influence of the apparatus profile (column 7) in view of the small Stark width was probably not fully recognized in the experiment by Chapelle and Sahal-Brechot,[9] where it was assumed to be negligible, and in the work by Fleurier *et al.*[10] where it was not taken into account (but they reported that it may be significant for the Mg II resonance lines). In the work of Hadziomerspahic *et al.*,[12] Doppler broadening (comments in column 8) becomes very appreciable because of the much higher temperatures, and it is stated there that this causes large uncertainties in the measured Stark widths.

Therefore, the Mg II experiments by Chapelle and Sahal-Brechot,[9] Fleurier *et al.*,[10] and Jones *et al.*[11] are marginal (or deficient) in conforming to one of the critical experimental factors. In all cases, this tends to make the measured Stark widths too large. In addition, the data by Hadziomerspahic *et al.*[12] contain significant uncertainties due to the appreciable Doppler width contributions. We conclude that the results of Goldbach *et al.*[7] and Roberts and Barnard,[8] which adequately account for the critical factors, provide the most reliable data for the Mg II resonance lines.

## 3. Description of the Tables

As in the earlier review, each data table is preceded by special remarks on the utilized papers. Then, in tabular form, the key data on each selected

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TABLE 1. Key data of Mg II experiments

| Author | Plasma source | Electron density ($10^{17}$ cm$^{-3}$) | Temperature ($10^3$ K) | Concentration of Mg | Optical depth ($\tau$) measurement | Apparatus width ($W_A$) | Doppler broad. contribution | General comments |
|---|---|---|---|---|---|---|---|---|
| Goldbach *et al.* (Ref. 7) | Wall stabilized arc, end-on | 1.1–1.6 (Ar line and continuum intensities, LTE) | 13–14.3 | $10^{-6}$ of Ar carrier gases | Doubling of optic path, after 2:1 ratio of doublet lines is reached ($\tau \leqslant 0.1$) | $W_A \approx 0.007$ Å (by Fabry-Perot), deconvolution procedure is used | Taken into account by deconvolution | Some Ar data used for diagnostics are of questionable reliability; however, their overall contribution is reduced due to redundancy of diagnostic data |
| Roberts and Barnard (Ref. 8) | Pulsed wall stabilized arc (90 $\mu$s duration) | 2 (by interferometry) | 14–21 (relative line intensity) | Natural impurity | 2:1 ratio of doublet lines is checked | $W_A \approx 0.06$ Å, subtracted; 3/4 m spectrometer used in 2. order | Taken into account by deconvolution | |
| Chapelle and Sahal-Brechot (Ref. 9) | Plasma jet, side on | 1.3 (*Ar continuum*) | 13.8 | Not reported | Change in line profile is checked, while Mg concentration is varied | 3.8 m spectrograph $W_A \leqslant 0.02$ Å, assumed to be negligible | About 30% of total width, taken into account by deconvolution | Photographic observations to avoid Abel inversion on measured profiles, theoretical profiles to match measured ones are constructed by integration over all radial positions |
| Fleurier *et al.* (Ref. 10) | Plasma jet, side on | 1.3 (hydrogen Stark br., LTE) | 1.3 | $10^{-5}$ of Ar carrier gas | Application of theoretical formula yields $\tau \approx 0.015$ | $W_A \approx 0.01$ Å; 1.7 m spectrometer is used in higher orders; not taken into account | Appreciable; taken into account by deconvolution | Abel inversion process is used; some observations are photographic |
| Jones *et al.* (Ref 11) | Electromagnetic shock tube ($\approx 2$ $\mu$s plasma duration) | 1 (He I line intensities, LTE) | 19 | Not reported | No checks reported | Oscillating Fabry-Perot; $W_A$ presumably very small, but not reported | Taken into account by deconvolution | Mg is introduced as dust on shock tube walls; inhomogeneities of 15% observed across tube diameter |
| Hadziomerspahic *et al.* (Ref 12) | Z-pinch | 0.3–1.0 (laser interferometry) | 32–35 (relative line intensities) | Not reported | 2:1 ratio of doublet lines is checked | Inverse linear dispersion 2.45 Å/mm; $W_A$ not reported | Substantial; taken into account by deconvolution | Doppler broadening at higher temperatures is large and causes significant uncertainty |

experiment—i.e., the plasma source characteristics and the applied diagnostic technique—are described by a short phrase or remark for quick orientation, and the chosen references are listed. "Remarks" usually concern the actual determination of the Stark profiles and shifts, and are of critical rather than descriptive nature.

Aside from a few corrections or additions to earlier material, the tables cover only recent data—from 1976 through mid 1982—which are additional to our earlier review. The data tables basically contain four pieces of information. In the first three columns, the investigated transitions are identified spectroscopically by their transition array, i.e., by quantum numbers and multiplet designations, and also by their wavelengths (given in Angstrom units). The wavelengths are normally taken from the tables by Reader *et al.*,[16] or, if not available there, from the compilation by Striganov and Sventitskii.[17] The multiplet numbers refer to the running numbers in the multiplet tables by Moore,[18] and the transitions are listed in order of increasing lower and upper quantum numbers.

The second part of the table, comprising columns 4 and 5, contains the temperature and electron density values at which the Stark widths and shifts have been determined. Sometimes the authors have not stated the actual experimental conditions, especially the electron density, and, instead, the line shape data have been presented at a reference electron density—usually $10^{17}$ cm$^{-3}$—to facilitate the comparison with the calculated widths and shifts. In such cases we had no choice but to list this reference density to which the experimental data had been reduced by using the theoretical scaling law (i.e., linear dependence of width and shift on electron density).

In the third part of the table the measured Stark halfwidths, $w_m$, and shifts, $d_m$, and the ratios of measured-to-theoretical widths, $w_m/w_{th}$, and shifts, $d_m/d_{th}$, are given. The experimental widths always represent the full widths at half maximum intensity (FWHM) and are the Stark widths which result after corrections for other broadening mechanisms and instrumental broadening have been made. The experimental Stark shifts, however, are usually identical with the observed shifts, i.e., the shift data contain no corrections since it is assumed that no other mechanism causing the line shifts is effective besides Stark broadening.

An exception is the high-pressure arc experiment by Helbig and Kusch[19] for Mg II, where the density of (foreign) neutral atoms is very high (up to $7 \times 10^{19}$ cm$^{-3}$), about 200 times larger than the electron density. Thus, Van-der-Waals shifts are appreciable in this case and are separated from the Stark shifts by applying theoretical density and temperature relationships which are different for the two broadening causes.

We have presented extensive comparisons with theoretical data to provide a measure of the success of the various theoretical approaches. Also, the use of comprehensive sets of theoretical data should provide some check on the consistency of the experimental data for different ions.

The theoretical width and shift values used for the experiment/theory ratios in the tables have been obtained from two comprehensive sources:

(a) For singly ionized atoms, the tables by Griem[4] based on *semiclassical calculations* (SC) are used.

(b) For multiply ionized atoms, the tables by Dimitrijević and Konjević[5] based on a *modified semiempirical approach* (MSE) are used.

Griem's SC tabulation is the only comprehensive set of theoretical data available for singly ionized atoms, and the MSE calculations are the approach preferred by Dimitrijević and Konjević from a set of four comprehensive theoretical tables for multiply ionized atoms calculated by them.

For *multiply* ionized atoms, we also provide additional comparisons with other available theoretical width data in the individual introductions to the respective spectra.

These theoretical data result principally from:

(a) the semiempirical approximation;
(b) the semiclassical approximation;
(c) the semiclassical approximation with Coulomb cutoff or a combination of straight and hyperbolic perturber trajectories;
(d) a simplified semiclassical approximation;
(e) a modification of the preceding simplified semiclassical approximation;
(f) the semiclassical Gaunt factor approximation,

and are discussed in detail in the references cited in the introductions to the individual spectra. A good indication of the success of these methods may be obtained from Tables 2 and 3, where we have assembled the experiment/theory width ratios for each method for some doubly and triply ionized atoms. It is seen that several theoretical methods agree well with the experimental data, considering that the experimental uncertainties are in the range from 30 to 50%. The modified semiempirical approach (chosen by us for the general comparisons in the tables) gives consistently good ratios.

It should be emphasized that the theoretical width data are for the electron impact width only, i.e., the usually very small additional width caused by ion broadening is neglected. Also, shifts contributed by ions are neglected in the theoretical shift data.

In the final part of the tables, our estimated uncertainties in the data are presented, and the references are listed by numbers. When Stark widths as well as shifts are measured, two accuracy estimates are given; the first refers to the halfwidth, while the second pertains to the shift. We have subdivided the uncertainties into four ranges and coded these by

TABLE 2. Experiment/theory width ratios for doubly ionized atoms (references are given in the introductions to the various ion tables)

| | Theoretical Approximations | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Ion | Modified semiempirical (tabulated) | Semiempirical | Semiclassical | Semiclassical (Coulomb cutoff) | Semiclassical (straight and hyperbolic) | Simplified semiclassical | Modification of simplified semiclassical | Semiclassical Gaunt factor | Number of multiplets considered |
| Ar III | 0.99 | 1.57 | | 1.10 | 1.54 | 0.71 | 0.99 | | 4 |
| C III | 1.29 | 1.66 | 0.76 | | | 0.84 | 0.97 | | 7 |
| Cl III | 1.01 | 1.70 | 0.76 | 1.13 | 1.91 | 0.74 | 1.04 | | 7 |
| N III[a] | 0.92 | 1.57 | | | | 0.67 | 0.95 | | 3 |
| O III | 1.05 | 1.89 | 0.73 | | | 0.75 | 1.02 | 0.98 | 4 |
| Si III | 0.67 | 1.08 | | 1.26 | | 0.48 | 0.68 | | 3 |
| S III | 1.17 | 1.65 | 0.73 | | | 0.74 | 0.96 | 0.85 | 8 |
| Average values: | 1.01 | 1.60 | 0.75 | (1.16) | (1.72) | 0.70 | 0.94 | (0.92) | Multiplet sum: 36 |

[a] Comparisons are only with the experimental data of Ref. 1 of N III.

TABLE 3. Experiment/theory width ratios for triply ionized atoms (references to the calculations are found in the introductions to the various ion tables)

| | Theoretical Approximations | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Ion | Modified semiempirical (tabulated) | Semiempirical | Semiclassical (Coulomb) cutoff) | Semiclassical (straight and hyperbolic) | Simplified semiclassical | Modification of simplified semiclassical | Semiclassical Gaunt factor | Number of multiplets covered |
| Ar IV | 0.76 | 1.24 | 1.30 | 1.74 | 0.59 | 0.92 | | 2 |
| C IV | 1.50 | 2.57 | | | 1.20 | 1.67 | | 2 |
| Si IV | 0.66 | 1.15 | 1.59 | | 0.54 | 0.84 | | 2 |
| S IV | 0.80 | 1.65 | | | 0.64 | 1.05 | 0.89 | 1 |
| Average values: | 0.93 | 1.65 | (1.45) | (1.74) | 0.74 | 1.12 | (0.89) | |

letters, and we have made further differentiations in the material by singling out slightly better sets of data among several similar ones by assigning plus signs (+) to indicate our first choices. The letters represent the following:

A = Uncertainties within 15 percent,
B = Uncertainties within 30 percent,
C = Uncertainties within 50 percent, and
D = Uncertainties larger than 50 percent.

The word uncertainty is used here with the connotation "estimated extent of deviation from the true value," and our uncertainty estimates are based on the evaluation of random errors as well as our estimates of the maximum effects of possible systematic errors. Further comments on the choice of our uncertainty estimates are given elsewhere.[1,15]

## 4. Summary

We have critically evaluated the recent experimental Stark broadening data for isolated ionic lines. We have principally assessed (a) the properties of the plasma sources, (b) the diagnostic methods, and (c) the measurement techniques for the line shapes and shifts. While the discussions by the authors on points (a) and (b) were generally found to be sufficiently complete, and the estimated uncertainties appear to be realistic (but often on the optimistic side), some deficiencies were found in the discussions on the Stark width and shift measurements (point (c)). Several papers did not contain any statements on the effects of either Doppler or apparatus broadening or on possible self-absorption for conditions where the influence of these factors is estimated not to be negligible. Since we cannot be sure whether the missing statements are just an oversight in the reporting of the results or a deficiency of the experiments, we have adjusted our accuracy ratings by an amount which we estimate will cover the probable additional uncertainty introduced.

Two additional factors affected our error estimates and caused us to be more conservative than many authors. These are, first, some discrepancies between experimental results outside the mutually estimated error limits, and secondly, the sometimes appreciable differences between the measured Stark widths of different lines within the same multiplet, where practically the same widths are expected on theoretical grounds.[6]

A result of considerable practical value is the finding that the measured widths for singly ionized atoms are generally in fairly good agreement with the extensive semiclassical calculations by Griem,[4] which confirms earlier studies by Jones,[20] Griem,[4] and Konjević and Wiese[1] on this subject. Notable exceptions are the resonance lines of Mg II (Fig. 1), where the atomic structure involving the states of lines and the principal perturber levels seem to be more realistically treated by fully quantum mechanical approaches.[13,22]

Also, the experimental widths for multiply ionized atoms usually agree quite well with most theoretical approaches (considering that the experimental uncertainties are in the range from 30 to 50%).

This review indicates the need for further experimental material, including high accuracy data, as well as the need for more completeness in the measurements and reporting. The presence or absence of data for the various spectra should be a good guide as to where more, and also more accurate, data are needed.

A similar critical review[23] is being prepared by us on the experimental Stark broadening data of *neutral* atoms, and is organized in the same format.

## Acknowledgments

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# 6. Data Tables

## Aluminum

### Al II

Ground State: $1s^22s^22p^63s^2\ ^1S_0$

Ionization Energy: [18.828] eV = [151860.4] $cm^{-1}$

Two recent measurements, by Fleurier *et al.*[1] with a plasma jet and Lakicevic *et al.*[2] with a T-tube, have provided reliable experimental broadening data for Al II. The extensive tables of theoretical data calculated by Griem and co-workers[3,4] on the basis of the semiclassical approximation, which are always used here for comparisons, can only be applied for multiplet No. 3. The agreement with the results of shift and width measurements[3] is within 20%.

For the measured lines reported in Ref. 1, the authors produced theoretical data for comparison, too. Semiclassical calculations were undertaken, and resonances in elastic cross sections were taken into account. The average ratio of measured to calculated line widths is 0.98, but the scatter around the average value of these ratios is rather large (up to 48%). Also, the results of semiempirical calculations agree well with the experiment (average ratio $w_m/w_{th} = 0.92$). However, an exception is the result for the 2631.6 Å ($3s4f$–$3p^2$) line, which involves broadening due to both dipole and quadrupole interactions.

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Key data on experiments

| Ref. | Plasma source | Method of measurement | | Remarks |
|---|---|---|---|---|
| | | Electron density | Temperature | |
| 2 | Plasma jet | $H_\alpha$ and $H_\beta$ Stark widths | Plasma-composition data | |
| 3 | T-tube | Laser interferometer at 6328 Å | Boltzmann plot of Ar II lines and ratio of Si I to Si II line intensities | No discussion on Doppler and instrumental broadening |

Numerical results for Al II

| No. | Transition array | Multiplet (No.) | Wavelength (Å) | Temperature (K) | Electron density ($10^{17}$ cm$^{-3}$) | $w_m$ (Å) | $w_m/w_{th}$ | $d_m$ (Å) | $d_m/d_{th}$ | Acc. | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | $3s3p$–$3p^2$ | $^1P^o$ - $^1D$ (1) | 3900.68 | 14000 | 1.54 | 0.20 | | | | B | 2 |
| 2. | $3s3p$–$3s4s$ | $^1P^o$ - $^1S$ | 2816.19 | 14000 | 1.54 | 0.31 | | | | B | 2 |
| 3. | $3p^2$–$3s4f$ | $^1D$ - $^1F^o$ | 2631.55 | 14000 | 1.55 | 0.97 | | | | B | 2 |
| 4. | $3s3d$–$3s4f$ | $^3D$ - $^3F^o$ | 3587.45 | 14000 | 1.55 | 1.80 | | | | B | 2 |
| 5. | $3s4s$–$3s4p$ | $^3S$ - $^3P^o$ (3) | 7042.06 | 15000-26000 | 0.44-2.2 | 2.00-1.86 | 1.19-1.19 | (−0.73)-(−0.66) | 1.07-1.06 | C,C | |
| | | | 7056.60 | 15000-26000 | 0.44-2.2 | 1.94-1.80 | 1.15-1.15 | (−0.75)-(−0.68) | 1.10-1.10 | C,C | 3 |
| | | | 7063.64 | 15000-26000 | 0.44-2.2 | 1.96-1.82 | 1.17-1.17 | (−0.72)-(−0.65) | 1.06-1.05 | C,C | 3 |

# Argon

## Ar II

Ground State: $1s^22s^22p^63s^23p^5\ ^2P^o_{3/2}$

Ionization Energy: 27.629 eV = 222848.2 cm$^{-1}$

| Wavelength (Å) | No. | Wavelength (Å) | No. | Wavelength (Å) | No. | Wavelength (Å) | No. |
|---|---|---|---|---|---|---|---|
| 919.78 | 1 | 2891.61 | 3 | 3033.51 | 3 | 3236.81 | 5 |
| 932.05 | 1 | 2942.89 | 3 | 3139.02 | 4 | 3243.69 | 4 |
| 2544.68 | 7 | 2955.39 | 6 | 3169.67 | 4 | 3249.80 | 4 |
| 2549.79 | 7 | 2979.05 | 3 | 3181.04 | 4 | 3287.70 | 4 |
| 2847.82 | 2 | 3014.48 | 6 | 3212.52 | 4 | 3307.23 | 5 |

The results of two recent measurements of Ar II Stark broadening parameters by Baker and Burgess[1] and Behringer and Thoma[2] are tabulated. The first experiment[1] was performed with a pulsed plasma source at a rather high electron density, $N_e = 2 \times 10^{18}$ cm$^{-3}$, and Stark shifts for the Ar II resonance lines (multiplet No. 1 UV) were studied. The second experiment[2] concerns the widths of Ar II lines belonging to six UV multiplets, which were measured in a steady-state, wall-stabilized arc operated at atmospheric pressure. The experimental data were compared with semiempirical calculations[3] and the average ratio of measured to calculated Stark widths was found to be 1.08.

In addition, Ghosh Roy[4] performed an experiment with a free-burning, high-current ($\approx$ 300 A) argon arc. Stark shift and width measurements were performed on the Ar II 1435.93 Å line, which was identified for the first time. Measured line shifts and widths exhibit a highly non-linear dependence on the electron concentration in the range $(0.3 - 2.0) \times 10^{17}$ cm$^{-3}$. Since the identity of this transition appears to still be in doubt (it has not been found in extensive analyses of the Ar II spectrum), these results are not included in the Ar II table.

It is interesting to note the large differences of about 50% in the experimental Stark widths for different lines of multiplet No. 19, which in this special case are caused by very close-lying perturber levels.[2] The energy separation between the levels of the upper term of the multiplet is comparable to the differences in energy from these nearest perturbing levels and thus causes different linewidths within the multiplet. Calculations by Hey[3] have qualitatively confirmed the observed differences.

## References

[1]E. A. M. Baker and D. D. Burgess, J. Phys. B **12**, 2097 (1979).
[2]K. Behringer and P. Thoma, J. Quant. Spectrosc. Radiat. Transfer **20**, 615 (1978).
[3]J. D. Hey, private communication, as quoted in Ref. 2.
[4]D. N. Ghosh Roy, J. Quant. Spectrosc. Radiat. Transfer **17**, 701 (1977).

Key data on experiments

| Ref. | Plasma source | Method of measurement: Electron density | Method of measurement: Temperature | Remarks |
|---|---|---|---|---|
| 1 | Z-pinch | Stark width of Ar II 4848 and 4806 Å lines; Mach-Zehnder interferometer at 6328 Å; continuum absorption of plasma at 6328 Å | Resonant absorption measurements at Ar 4880 Å | |
| 2 | Wall-stabilized arc | Plasma composition data | Absolute intensities of Ar II lines | |

Numerical results for Ar II

| No. | Transition array | Multiplet (No.) | Wavelength (Å) | Temperature (K) | Electron density ($10^{17}$ cm$^{-3}$) | $w_m$ (Å) | $w_m/w_{th}$ | $d_m$ (Å) | $d_m/d_{th}$ | Acc. | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | $3s^23p^5$–$3s3p^6$ | $^2P^\circ$ - $^2S$ (1 UV) | 919.78 | 25000 | 20 | | | 0.00±0.05 | | | 1 |
| | | | 932.05 | 25000 | 20 | | | 0.00±0.05 | | | 1 |
| 2. | $3p^4(^3P)4s$–$3p^4(^1D)4p'$ | $^2P$ - $^2D^\circ$ | 2847.82 | 20000 | 1 | 0.138 | | | | C+ | 2 |
| 3. | | $^2P$ - $^2P^\circ$ (19) | 2891.61 | 20000 | 1 | 0.326 | | | | C+ | 2 |
| | | | 2942.89 | 20000 | 1 | 0.202 | | | | C+ | 2 |
| | | | 2979.05 | 20000 | 1 | 0.302 | | | | C+ | 2 |
| | | | 3033.51 | 20000 | 1 | 0.222 | | | | C+ | 2 |
| 4. | $3p^44p$–$3p^4(^3P)4d$ | $^4P^\circ$ - $^4P$ (47) | 3139.02 | 20000 | 1 | 0.356 | 0.75 | | | C+ | 2 |
| | | | 3169.67 | 20000 | 1 | 0.348 | 0.74 | | | C+ | 2 |
| | | | 3181.04 | 20000 | 1 | 0.350 | 0.74 | | | C+ | 2 |
| | | | 3212.52 | 20000 | 1 | 0.366 | 0.78 | | | C+ | 2 |
| | | | 3243.69 | 20000 | 1 | 0.368 | 0.78 | | | C+ | 2 |
| | | | 3249.80 | 20000 | 1 | 0.362 | 0.77 | | | C+ | 2 |
| | | | 3287.70 | 20000 | 1 | 0.418 | 0.89 | | | C+ | 2 |
| 5. | | $^2P^\circ$ - $^2P$ (83) | 3236.81 | 20000 | 1 | 0.756 | 0.57 | | | C+ | 2 |
| | | | 3307.23 | 20000 | 1 | 0.768 | 0.58 | | | C+ | 2 |
| 6. | | $^2D^\circ$ - $^2D$ | 2955.39 | 20000 | 1 | 0.606 | | | | C+ | 2 |
| | | | 3014.48 | 20000 | 1 | 0.698 | | | | C+ | 2 |
| 7. | $3p^4(^3P)4p$–$3p^4(^1D)4d'$ | $^2P^\circ$ - $^2P$ | 2544.68 | 20000 | 1 | 0.426 | | | | C+ | 2 |
| | | | 2549.79 | 20000 | 1 | 0.430 | | | | C+ | 2 |

## Ar III

Ground State: $1s^2 2s^2 2p^6 3s^2 3p^4\ ^3P_2$

Ionization Energy: 40.74 eV = 328600 $cm^{-1}$

Several line profiles and shifts have been measured recently by Baker and Burgess[1,2] at high electron densities, $N_e > 10^{18}$ $cm^{-3}$, and relatively low electron temperatures, $T_e \approx 26000$ K. Shifts have been determined for the resonance lines and the polarization shift was found to be negligible.[2] Also, line-wing asymmetries have been studied in detail,[1] and they appear to be induced by quantum-mechanical interference effects predicted earlier.[3] The strongly asymmetric profile of the Ar III 875.5 Å line at $N_e = 1.3 \times 10^{18}$ $cm^{-3}$ and $T_e = 27000$ K, as well as its percentage asymmetry as a function of wavelength distance from the line center, is given in Ref. 1.

Stark widths measured at lower electron densities,[4] which were already listed in our earlier review,[5] are tabulated again, but with slight revisions and new theoretical comparison data. The results for the linewidths at $N_e = 8.0 \times 10^{16}$ $cm^{-3}$ are omitted since additional experimental work showed some plasma instabilities at this experimental condition.[6]

In the table, the experimental data are compared with comprehensive calculations based on a modified semiempirical approximation.[7] This is the usual comparison carried out for all multiply ionized atoms. For this ion, some additional experiment/theory comparisons may be made with other theories and the following ratios $w_m/w_{th}$ are obtained (these are averages over the experimental data):

- for the semiclassical method with Coulomb cutoff,[8] calculations by Platisa *et al.*[4] yield $w_m/w_{th} = 0.96$;
- for the semiclassical method[9] with a combination of straight and hyperbolic perturber trajectories,[10,11] calculations by Platisa *et al.*[4] yield $w_m/w_{th} = 1.54$;
- for the semiempirical method,[12] calculations by Hey[13] yield $w_m/w_{th} = 1.57$;
- for the simplified semiclassical method,[14] calculations by Dimitrijević and Konjević[15] yield $w_m/w_{th} = 0.71$;
- for a modification of the preceding simplified semiclassical method,[15] $w_m/w_{th} = 0.99$.

### References


[1]E. A. M. Baker and D. D. Burgess, J. Phys. B **10**, L 177 (1977).
[2]E. A. M. Baker and D. D. Burgess, J. Phys. B **12**, 2097 (1979).
[3]D. D. Burgess, Phys. Rev. **176**, 150 (1968).
[4]M. Platisa, M. Popovic, M. Dimitrijević, and N. Konjević, Z. Naturforsch., Teil A **30**, 212 (1975).
[5]N. Konjević and W. L. Wiese, J. Phys. Chem. Ref. Data **5**, 259 (1976).
[6]M. Platisa and N. Konjević, unpublished results.
[7]M. Dimitrijević and N. Konjević, in *Spectral Line Shapes*, Ed. B. Wende, W. de Gruyter, Berlin (1981), p. 211.
[8]M. Baranger, in *Atomic and Molecular Processes*, Ed. D. R. Bates, Academic Press, New York (1962).
[9]H. R. Griem, M. Baranger, A. C. Kolb, and G. K. Oertel, Phys. Rev. **125**, 177 (1962).
[10]J. Cooper and G. K. Oertel, Phys. Rev. Lett. **18**, 985 (1967).
[11]J. Cooper and G. K. Oertel, Phys. Rev. **180**, 286 (1969).
[12]H. R. Griem, Phys. Rev. **165**, 258 (1968).
[13]J. D. Hey, J. Quant. Spectrosc. Radiat. Transfer **17**, 729 (1977).
[14]H. R. Griem, *Spectral Line Broadening by Plasmas*, Academic Press, New York (1974), Eq. (526).
[15]M. S. Dimitrijević and N. Konjević, J. Quant. Spectrosc. Radiat. Transfer **24**, 451 (1980).


Key data on experiments

| Ref. | Plasma source | Method of measurement: Electron density | Method of measurement: Temperature | Remarks |
|---|---|---|---|---|
| 2 | Z-pinch | Stark width of Ar II 4848 and 4806 Å lines; Mach-Zehnder interferometer at 6328 Å; continuum absorption plasma at 6328 Å | Resonant absorption measurements at Ar II 4880 Å | |
| 4 | Low-pressure pulsed arc | Laser interferometry at 6328 Å | Boltzmann plot of Ar II line intensities | |

Numerical results for Ar III

| No. | Transition array | Multiplet (No.) | Wavelength (Å) | Temperature (K) | Electron density ($10^{17}$ cm$^{-3}$) | $w_m$ (Å) | $w_m/w_{th}$ | $d_m$ (Å) | $d_m/d_{th}$ | Acc. | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | $3s^23p^4$–$3s3p^5$ | $^3$P – $^3$P° (1 UV) | 871.10 | 25000 | 20 | | | 0.16 | | D | 2 |
| | | | 875.53 | 25000 | 20 | | | 0.28 | | D | 2 |
| | | | 878.73 | 25000 | 20 | | | 0.00 | | D | 2 |
| | | | 879.62 | 25000 | 20 | | | -0.19 | | D | 2 |
| | | | 883.18 | 25000 | 20 | | | 0.19 | | D | 2 |
| | | | 887.40 | 25000 | 20 | | | 0.25 | | D | 2 |
| 2. | $3p^33d''$– $3p^3(^2P^\circ)4p''$ | $^3$P° – $^3$P (6) | 3391.85 | 21100 | 0.44 | 0.058 | 1.18 | | | C+ | 4 |
| 3. | $3p^34s$– $3p^3(^4S^\circ)4p$ | $^5$S° – $^5$P (1) | 3285.85 | 21100 | 0.44 | 0.064 | 1.02 | | | C+ | 4 |
| | | | 3301.88 | 21100 | 0.44 | 0.064 | 0.97 | | | C+ | 4 |
| 4. | $3p^34s'$– $3p^3(^2D^\circ)4p'$ | $^3$D° – $^3$D (2) | 3480.55 | 21100 | 0.44 | 0.058 | 0.81 | | | C+ | 4 |
| 5. | | $^3$D° – $^3$F (3) | 3336.13 | 21100 | 0.44 | 0.063 | 0.94 | | | C+ | 4 |

## Ar IV

Ground State: $1s^22s^22p^63s^23p^3\ ^4S^\circ_{3/2}$

Ionization Energy: 59.81 eV = 482400 cm$^{-1}$

The Stark widths measured with a low pressure pulsed arc,[1] presented already in our earlier review,[2] are listed with new theoretical comparison data. These are obtained from the modified semiempirical approximation (see general introduction), which we always apply for the higher ions. In addition, several other comparisons with existing theoretical data may be carried out. Experiment/theory ratios are cited below in the same order as for Ar III, where all references are given. The specific average ratios are:

- for the semiclassical method with Coulomb cutoff, $w_m/w_{th}$ = 1.30;
- for the semiclassical method with a combination of straight and hyperbolic perturber trajectories, $w_m/w_{th}$ = 1.74;
- for the semiempirical method, $w_m/w_{th}$ = 1.24;
- for the simplified semiclassical approach, $w_m/w_{th}$ = 0.59;
- for a modification of the preceding simplified semiclassical method, $w_m/w_{th}$ = 0.92.

### References

[1]M. Platisa, M. Popovic, M. S. Dimitrijević, and N. Konjević, Z. Naturforsch., Teil A 30, 212 (1975).
[2]N. Konjević and W. L. Wiese, J. Phys. Chem. Ref. Data 5, 259 (1976).

Key data on experiments

| Ref. | Plasma source | Method of measurement: Electron density | Method of measurement: Temperature | Remarks |
|---|---|---|---|---|
| 1 | Low-pressure pulsed arc | Laser interferometry at 6328 Å | Boltzmann plot of Ar II line intensities | |

Numerical results for Ar IV

| No. | Transition array | Multiplet (No.) | Wavelength (Å) | Temperature (K) | Electron density ($10^{17}$ cm$^{-3}$) | $w_m$ (Å) | $w_m/w_{th}$ | $d_m$ (Å) | $d_m/d_{th}$ | Acc. | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | $3p^24s$–$3p^2(^3P)4p$ | $^4P$ - $^4D°$ (4 UV) | 2809.44 | 20750–22200 | 0.38–0.56 | 0.023–0.033 | 0.74–0.74 | | | C | 1 |
| 2. | | $^4P$ - $^4P°$ (5 UV) | 2640.34 | 20750–22200 | 0.38–0.56 | 0.021–0.031 | 0.76–0.79 | | | C | 1 |

# Barium

## Ba II

Ground State: $1s^22s^22p^63s^23p^63d^{10}4s^24p^64d^{10}5s^25p^66s\ ^2S_{1/2}$

Ionization Energy: 10.004 eV = 80686.87 cm$^{-1}$

New data have been obtained by Fleurier *et al.*[1] with a plasma jet. We list the same Stark widths for both resonance lines in the table since according to one of the authors[2] these data did not differ by more than 5%.

Theoretical data were calculated by Jones[3] on the basis of the semiclassical theory,[4,5] which we always apply for comparison in these tables. Fleurier *et al.*[1] also performed semiclassical calculations, and took into account resonances of elastic cross sections. With ion broadening included, these calculations give average ratios of measured to calculated values $w_m/w_{th} = 0.95$ and $d_m/d_{th} = 0.67$. Using the semiempirical formula,[6] the same authors calculated an average ratio $w_m/w_{th} =$ 1.03.

The previous Ba II table[7] contains a small error. No results exist for the width and shift of the 4554.0 Å line at 31700 K, so that the listed data should be deleted.

### References


[1]C. Fleurier, S. Sahal-Brechot, and J. Chapelle, J. Quant. Spectrosc. Radiat. Transfer **17**, 595 (1977).
[2]C. Fleurier, private communication (1980).
[3]W. W. Jones, private communication (1975).
[4]W. W. Jones, S. M. Benett, and H. R. Griem, Tech. Report No. 71-128, University of Maryland, College Park, MD (1971).
[5]H. R. Griem, *Spectral Line Broadening by Plasmas*, Academic Press, New York (1974).
[6]H. R. Griem, Phys. Rev. **165**, 258 (1968).
[7]N. Konjević and W. L. Wiese, J. Phys. Chem. Ref. Data **5**, 259 (1976).


Key data on experiments

| Ref. | Plasma source | Method of measurement: Electron density | Method of measurement: Temperature | Remarks |
|---|---|---|---|---|
| 1 | Plasma jet | $H_\alpha$ and $H_\beta$ Stark widths | Plasma–composition data | |

Numerical results for Ba II

| No. | Transition array | Multiplet (No.) | Wavelength (Å) | Temperature (K) | Electron density ($10^{17}$ cm$^{-3}$) | $w_m$ (Å) | $w_m/w_{th}$ | $d_m$ (Å) | $d_m/d_{th}$ | Acc. | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | $5d$–$6p$ | $^2D$ - $^2P°$ (2) | 6141.72 | 13000 | 1.13 | 0.50 | 0.61 | | | B | 1 |
| 2. | $6s$–$6p$ | $^2S$ - $^2P°$ (1) | 4554.03 | 13000 | 1.13 | 0.49 | 0.99 | -0.050 | 0.25 | B,C | 1 |
| | | | 4934.09 | 13000 | 1.13 | 0.49 | 0.99 | -0.050 | 0.25 | B,C | 1 |

# Bismuth

## Bi II

Ground State: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 4f^{14} 5s^2 5p^6 5d^{10} 6s^2 6p^2\ ^3P_0$

Ionization Energy: 16.69 eV = 134600 $cm^{-1}$

The Stark widths of three singly ionized bismuth lines have been measured with a conventional shock tube by Miller and Bengtson.[1] These authors have made comparisons with a semiempirical formula[2] which yields Stark widths that are about 10 to 30% larger than the experimental results.[1]

### References

[1]M. H. Miller and R. D. Bengtson, J. Quant. Spectrosc. Radiat. Transfer **23**, 411 (1980).
[2]H. R. Griem, Phys. Rev. **165**, 258 (1968).

Key data on experiments

| Ref. | Plasma source | Method of measurement: Electron density | Method of measurement: Temperature | Remarks |
|---|---|---|---|---|
| 1 | Gas-driven shock tube | $H_\beta$ Stark width | Line-reversal technique applied to $H_\alpha$ line; absolute intensity of Ne I 5852 Å line | Photographic technique |

Numerical results for Bi II

| No. | Transition array | Multiplet (No.) | Wavelength (Å) | Temperature (K) | Electron density ($10^{17}$ $cm^{-3}$) | $w_m$ (Å) | $w_m/w_{th}$ | $d_m$ (Å) | $d_m/d_{th}$ | Acc. | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | $6p7p$–$6p7d$ | $^3D$ - $^3D°$ | 4705.3 | 11000 | 1 | 2.50* | | | | C | 1 |
| 2. | $6p7s$–$6p7p$ | $^3P°$ - $^1P$ | 5144.3 | 11000 | 1 | 0.98* | | | | C | 1 |
| 3. | | $^3P°$ - $^3P$ | 5719.2 | 11000 | 1 | 1.42* | | | | C | 1 |

*Measurements were taken in the electron-density range $(0.4–1.2)\times 10^{17}$ $cm^{-3}$, but results were given only for $1\times 10^{17}$ $cm^{-3}$.

# Boron

## B II

Ground State: $1s^22s^2\ ^1S_0$

Ionization Energy: 25.154 eV = 202887.4 $cm^{-1}$

The only experimental data available are for the Stark shift of the B II 3451.29 Å line, a $2s2p\ ^1P_1^\circ - 2p^2\ ^1D_2$ transition. A shock-tube experiment by Miller *et al.*,[1] performed at a temperature of about 11600 K and at electron densities from $0.4 \times 10^{17}$ to $2.1 \times 10^{17}$ $cm^{-3}$ (determined from Stark width measurements of the hydrogen $H_\beta$ line), has produced shifts from −0.03 Å to −0.157 Å, respectively, with an estimated uncertainty of ±25%. This measurement happens to agree exactly with semiclassical theory, i.e., $d_m/d_{th} = 1.00$, where the calculated shift $d_{th}$ has been obtained from the computer code of Ref. 2. The experimental results may also be compared with semiclassical calculations,[3] which yield a ratio $d_m/d_{th} = 1.79$, and semiempirical calculations,[1] which yield $d_m/d_{th} = 1.56$. All these ratios are given for $1 \times 10^{17}$ $cm^{-3}$ without taking into account any polarization shift.[1]

### References


[1]M. H. Miller, R. D. Bengtson, and R. A. Roig, Phys. Rev. A **15**, 675 (1977).

[2]W. W. Jones, S. M. Benett, and H. R. Griem, Tech. Report No. 71-128, University of Maryland, College Park, MD (1971).

[3]S. Sahal-Brechot, private communication as quoted in Ref. 1.


# Calcium

## Ca II

Ground State: $1s^22s^22p^63s^23p^64s\ ^2S_{1/2}$

Ionization Energy: 11.871 eV = 95751.87 $cm^{-1}$

New experimental Stark widths and shifts of singly ionized calcium lines have been determined by Fleurier *et al.*[1] with a plasma jet. Since the linewidths within the multiplets did not differ by more than 5%, only average wavelengths for the multiplets were presented. The actual wavelengths of the lines whose Stark broadening parameters were measured were communicated to us by one of the authors.[2]

Our previous Ca II table contained an error in the data by Baur and Cooper[3] for the 3968.47 Å line; thus these data have been tabulated again.

The Stark width tabulated for the 8542.09 Å line[1] supersedes the data for the same line obtained in similar earlier work[4]; the new value eliminates a case of a previously large discrepancy with theory.

In addition to their measurements, Fleurier *et al.*[1] performed semiclassical calculations in which they took into account resonances of elastic cross sections. With ion broadening included, average ratios of experimental to theoretical Stark shifts and widths of 0.99 and 1.23, respectively, have been obtained. The semiempirical approach yields a ratio of 1.72 with the width measurements of Ref. 1, and listed in the table are, as usual, comparisons with the semiclassical approximation (see general introduction).

### References


[1]C. Fleurier, S. Sahal-Brechot, and J. Chapelle, J. Quant. Spectrosc. Radiat. Transfer **17**, 595 (1977).

[2]C. Fleurier, private communication (1980).

[3]J. F. Baur and J. Cooper, J. Quant. Spectrosc. Radiat. Transfer **17**, 311 (1977).

[4]J. Chapelle and S. Sahal-Brechot, Astron. Astrophys. **6**, 415 (1970).

Key data on experiments

| Ref. | Plasma source | Method of measurement: Electron density | Method of measurement: Temperature | Remarks |
|---|---|---|---|---|
| 1 | Plasma jet | $H_\alpha$ and $H_\beta$ Stark widths | Plasma-composition data | |
| 3 | Gas-driven shock tube | Laser interferometry at 6328 Å and 1.15 μm; Stark width of $H_\alpha$ | Line-reversal technique | |

Numerical results for Ca II

| No. | Transition array | Multiplet (No.) | Wavelength (Å) | Temperature (K) | Electron density ($10^{17}$ cm$^{-3}$) | $w_m$ (Å) | $w_m/w_{th}$ | $d_m$ (Å) | $d_m/d_{th}$ | Acc. | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | 3d-4p | $^2$D - $^2$P° | 8542.09 | 13000 | 1.08 | 0.95 | 0.64 | | | B | 1 |
| | | (2) | 8662.14 | 13000 | 1.08 | 0.95 | 0.64 | | | B | 1 |
| 2. | 4s-4p | $^2$S - $^2$P° | 3933.66 | 13000 | 1.08 | 0.235 | 0.78 | -0.048 | 0.38 | B,C | 1 |
| | | (1) | 3968.47 | 13000 | 1.08 | 0.235 | 0.78 | -0.048 | 0.38 | B,C | 1 |
| | | | | 7450 | 1.0 | 0.210 | 0.67 | | | B+ | 3 |
| 3. | 4p-5s | $^2$P° - $^2$S | 3736.20 | 13000 | 1.12 | 0.79 | 0.94 | 0.390 | 1.03 | B,C | 1 |
| | | (3) | 3706.03 | 13000 | 1.12 | 0.79 | 0.94 | 0.390 | 1.03 | B,C | 1 |
| 4. | 4p-4d | $^2$P° - $^2$D | 3179.33 | 13000 | 1.13 | 0.66 | 1.03 | 0.295 | 1.05 | B,C | 1 |
| | | (4) | 3158.87 | 13000 | 1.13 | 0.66 | 1.03 | 0.295 | 1.05 | B,C | 1 |
| | | | 3181.28 | 13000 | 1.13 | 0.66 | 1.03 | 0.295 | 1.05 | B,C | 1 |

# Carbon

## C II

Ground State: $1s^22s^22p\ ^2P^\circ_{1/2}$

Ionization Energy: 24.383 eV = 196664.7 cm$^{-1}$

The earlier data on experimental C II Stark-broadening parameters, which were critically reviewed by us in 1976,[1] were estimated to be of rather low accuracy. New results for these lines have been obtained recently in a low-pressure pulsed arc by Platisa *et al.*[2] and in a wall-stabilized arc by Goly and Weniger[3] and give satisfactory agreement with theory.

### References

[1]N. Konjević and W. L. Wiese, J. Phys. Chem. Ref. Data **5**, 259 (1976).
[2]M. Platisa, M. Popovic, and N. Konjević, J. Quant. Spectrosc. Radiat. Transfer **20**, 477 (1978).
[3]A. Goly and S. Weniger, J. Quant. Spectrosc. Radiat. Transfer **27**, 657 (1982).

Key data on experiments

| Ref. | Plasma source | Method of measurement: Electron density | Method of measurement: Temperature | Remarks |
|---|---|---|---|---|
| 2 | Low-pressure pulsed arc | Laser interferometry at 6328 Å | Boltzmann plot of O II line intensities | |
| 3 | Wall-stabilized arc | $H_\beta$ Stark width | Ratio of line intensities and plasma-composition data | Doppler and instrumental broadening not taken into account |

Numerical results for C II

| No. | Transition array | Multiplet (No.) | Wavelength (Å) | Temperature (K) | Electron density ($10^{17}$ cm$^{-3}$) | $w_m$ (Å) | $w_m/w_{th}$ | $d_m$ (Å) | $d_m/d_{th}$ | Acc. | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | $2s2p^2$–$2s^23p$ | $^2S$ - $^2P^\circ$ (13 UV) | 2836.71 | 26300 | 0.49 | 0.082 | 1.17 | | | C+ | 2 |
| | | | | 11430 | 0.50 | 0.125 | 1.39 | 0.032 | 0.71 | C+,D+ | 3 |
| | | | | 12080 | 0.68 | 0.165 | 1.36 | 0.064 | 1.05 | C+,D+ | 3 |
| | | | 2837.60 | 26300 | 0.49 | 0.083 | 1.17 | | | C+ | 2 |
| | | | | 11430 | 0.50 | 0.135 | 1.50 | 0.057 | 1.27 | D+,C | 3 |
| | | | | 12080 | 0.68 | 0.164 | 1.36 | 0.088 | 1.44 | C+,C+ | 3 |

## C III

Ground State: $1s^22s^2\ ^1S_0$

Ionization Energy: 47.887 eV = 386241.0 cm$^{-1}$

Several calculations have recently been performed which provide theoretical comparison data for the experimental results[1,2] listed in our earlier review. The data are thus presented again and compared with the modified semiempirical approximation which we always apply for the higher ions (see general introduction). Other theoretical methods yield the following experiment/theory width ratios (averaged over the experimental data):

- the semiclassical method,[3,4] $w_m/w_{th} = 0.76$;
- the simplified semiclassical method [Ref. 3, Eq. (526)]; calculations by Dimitrijević and Konjević give $w_m/w_{th} = 0.84$;
- a modification of the preceding simplified semiclassical method,[5] $w_m/w_{th} = 0.97$.

In addition, semiempirical calculations were performed by Bogen[2]; these produced a ratio of experimental[2] to theoretical width $w_m/w_{th} = 1.66$.

It should be noted that none of these calculations deals with the $2s2p$–$2p^2$ transition (multiplet No. 8 UV).

### References


[1] H. J. Kusch, Z. Astrophys. **67**, 64 (1967).
[2] P. Bogen, Z. Naturforsch. Teil A **27**, 210 (1972).
[3] H. R. Griem, *Spectral Line Broadening by Plasmas*, Academic Press, New York (1974).
[4] M. S. Dimitrijević, Proceed. IV Eur. Sect. Conf. At. Mol. Process. Ion. Gases, Dubrovnik (1980), p. 90.
[5] M. S. Dimitrijević and N. Konjević, J. Quant. Spectrosc. Radiat. Transfer **24**, 451 (1980).

Key data on experiments

| Ref. | Plasma source | Method of measurement: Electron density | Method of measurement: Temperature | Remarks |
|---|---|---|---|---|
| 1 | Pulsed discharge | Stark width of $H_\beta$ | Plasma-composition data | Photographic technique; no check for self-absorption reported |
| 2 | Theta-pinch | Stark width of He II 3203 Å | Absolute line intensities and Fowler-Milne method | No corrections for instrumental and Doppler broadening reported |

Numerical results for C III

| No. | Transition array | Multiplet (No.) | Wavelength (Å) | Temperature (K) | Electron density ($10^{17}$ cm$^{-3}$) | $w_m$ (Å) | $w_m/w_{th}$ | $d_m$ (Å) | $d_m/d_{th}$ | Acc. | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | $2s2p-2p^2$ | $^1P^o-^1D$ (8 UV) | 2296.87 | 12800 | 1.0 | 0.34 | | | | D | 1 |
| 2. | $2s3s-2s3p$ | $^3S-^3P^o$ (1) | 4647.42 | 60000 | 4 | 0.95 | 0.98 | | | D | 2 |
| 3. | $2p3s-2p3p$ | $^1P^o-^1D$ (7) | 4325.56 | 60000 | 4 | 2.1 | 2.02 | | | D | 2 |
| 4. | $2s3p-2s3d$ | $^1P^o-^1D$ (2) | 5695.92 | 60000 | 4 | 1.9 | 1.39 | | | D | 2 |
| 5. | $2s3p-2s4d$ | $^1P^o-^1D$ | 1531.8 | 60000 | 4 | 0.43 | 1.02 | | | D | 2 |
| 6. | $2s3d-2s4f$ | $^1D-^1F^o$ (15 UV) | 2162.94 | 60000 | 4 | 0.46 | 1.71 | | | D | 2 |
| 7. | $2s4p-2s5d$ | $^3P^o-^3D$ (10) | 3609 | 60000 | 4 | 6.2 | 0.66 | | | D | 2 |
| 8. | $2s4f-2s5g$ | $^1F^o-^1G$ (18) | 4186.90 | 60000 | 4 | 4.1 | 1.28 | | | D | 2 |

# C IV

Ground State: $1s^2 2s\ ^2S_{1/2}$

Ionization Energy: 64.492 eV = 520178.4 cm$^{-1}$

The available measurements, which are from a theta-pinch experiment,[1] are listed with new theoretical comparison data, obtained by the modified semi-empirical approximation (see general introduction) which we have always applied for higher ions. Furthermore, for the same experimental data, other calculated widths are available for comparison, yielding the following average ratios:

- with a simplified semiclassical method,[3] $w_m/w_{th}$ = 1.20;
- with a modification of the preceding simplified semiclassical method,[4] $w_m/w_{th}$ = 1.67.

Additional comparisons may be made with the results of semiempirical calculations by Bogen,[1] who obtained an average ratio $w_m/w_{th} = 1.82$, while with an effective Gaunt factor $g = 1$ at threshold, one obtains[2] $w_m/w_{th} = 0.71$. Bogen[1] took each perturbing level into account separately; if one treats these levels lumped together, a ratio $w_m/w_{th} = 2.57$ is obtained.[4]

## References

[1]P. Bogen, Z. Naturforsch., Teil A **27**, 210 (1972).
[2]G. S. Romanov, K. L. Stepanov, and M. I. Sirkin, Opt. Spectrosc. (USSR) **47**, 476 (1979).
[3]H. R. Griem, *Spectral Line Broadening by Plasmas*, Academic Press, New York (1974), Eq. (526).
[4]M. S. Dimitrijević and N. Konjević, J. Quant. Spectrosc. Radiat. Transfer **24**, 451 (1980).

Key data on experiments

| Ref. | Plasma source | Method of measurement: Electron density | Method of measurement: Temperature | Remarks |
|---|---|---|---|---|
| 1 | Theta–pinch | Stark width of He II 3203 Å | Absolute line intensities and Fowler–Milne method | No correction for instrumental and Doppler broadening reported |

Numerical results for C IV

| No. | Transition array | Multiplet (No.) | Wavelength (Å) | Temperature (K) | Electron density ($10^{17}$ cm$^{-3}$) | $w_m$ (Å) | $w_m/w_{th}$ | $d_m$ (Å) | $d_m/d_{th}$ | Acc. | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | $2s$–$2p$ | $^2S - {}^2P^\circ$ | 1548.20 | 60000 | 4 | 0.024 | 1.99 | | | D | 1 |
| | | (1 UV) | 1550.77 | 60000 | 4 | 0.024 | 1.99 | | | D | 1 |
| 2. | $3s$–$3p$ | $^2S - {}^2P^\circ$ | 5801.33 | 60000 | 4 | 1.6 | 1.01 | | | D | 1 |
| | | (1) | 5811.98 | 60000 | 4 | 1.6 | 1.01 | | | D | 1 |

# C V

Ground State: $1s^2\ {}^1S_0$

Ionization Energy: 392.077 eV = 3162395 cm$^{-1}$

Stark widths of two quasi hydrogen-like C V lines[1] have been measured by Irons with a high-density plasma produced by laser irradiation of polyethylene foil in vacuum. The results were obtained in a plasma which was both spatially and temporally rather inhomogeneous; therefore, the accuracy of the data is estimated to be low.

A theoretical analysis performed by Irons[1] concludes that ion broadening is dominant under the experimental conditions in which the Stark-broadening data were measured.

## Reference

[1]F. E. Irons, J. Phys. B **6**, 1562 (1973).

Key data on experiments

| Ref. | Plasma source | Method of measurement: Electron density | Method of measurement: Temperature | Remarks |
|---|---|---|---|---|
| 1 | Laser produced plasma | Line intensity | Free–bound continuum analysis | Plasma is very inhomogeneous both temporally and spatially |

Numerical results for C v

| No. | Transition array | Multiplet (No.) | Wavelength (Å) | Temperature (K) | Electron density ($10^{17}$ cm$^{-3}$) | $w_m$ (Å) | $w_m/w_{th}$ | $d_m$ (Å) | $d_m/d_{th}$ | Acc. | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | 5–6* | — | 2982 | 210000 | 7 | 6.6 | | | | D | 1 |
| | | | | 390000 | 26 | 10.6 | | | | D | 1 |
| 2. | 6–7 | — | 4945 | 210000 | 7 | 18 | | | | D | 1 |
| | | | | 390000 | 26 | 38 | | | | D | 1 |

*Quasi hydrogen-like transitions; states of all possible angular momenta contribute.

# Chlorine

## Cl III

Ground State: $1s^22s^22p^63s^23p^3\ ^4S^\circ_{3/2}$

Ionization Energy: 39.61 eV = 319500 cm$^{-1}$

| Wavelength (Å) | No. | Wavelength (Å) | No. | Wavelength (Å) | No. | Wavelength (Å) | No. |
|---|---|---|---|---|---|---|---|
| 3191.45 | 4 | 3392.89 | 7 | 3612.85 | 2 | 4018.50 | 1 |
| 3283.41 | 3 | 3393.45 | 7 | 3656.95 | 2 | 4059.07 | 1 |
| 3289.80 | 3 | 3530.03 | 6 | 3705.45 | 2 | 4106.83 | 1 |
| 3340.42 | 3 | 3602.10 | 2 | 3748.81 | 5 | | |

Stark widths of several Cl III multiplets were measured with a low pressure pulsed arc by Platisa *et al.*[1] As usual, we compare these data in the tables with the modified semiempirical approximation which we always apply for higher ions (see general introduction). In addition, comparisons may be made with several other theoretical approaches, and the following average experiment/theory ratios arc obtained:

- with the semiclassical method,[2] $w_m/w_{th} = 0.76$;
- with the semiclassical method with Coulomb cutoff,[3] as calculated by Platisa *et al.*,[1] $w_m/w_{th} = 1.13$;
- with the semiclassical method,[4] assuming a combination of straight and hyperbolic perturber trajectories,[5,6] $w_m/w_{th} = 1.91$;
- with a simplified semiclassical method,[7] $w_m/w_{th} = 0.74$;
- with a modification of the preceding simplified semiclassical method,[7] $w_m/w_{th} = 1.04$;
- with the semiempirical method,[6] $w_m/w_{th} = 1.70$.

### References

[1]M. Platisa, M. Dimitrijević, M. Popovic, and N. Konjević, Astron. Astrophys. **54**, 837 (1977).
[2]M. S. Dimitrijević and N. Konjević, J. Quant. Spectrosc. Radiat. Transfer **27**, 203 (1982).
[3]M. Baranger, in *Atomic and Molecular Processes*, Ed. D. R. Bates, Academic Press, New York (1962).
[4]H. R. Griem, M. Baranger, A. C. Kolb, and G. K. Oertel, Phys. Rev. **125**, 177 (1962).
[5]J. Cooper and G. K. Oertel, Phys. Rev. Lett. **18**, 985 (1967).
[6]J. Cooper and G. K. Oertel, Phys. Rev. **180**, 286 (1969).
[7]M. S. Dimitrijević and N. Konjević, J. Quant. Spectrosc. Radiat. Transfer **24**, 451 (1980).
[8]J. D. Hey, J. Quant. Spectrosc. Radiat. Transfer **18**, 649 (1977).

Key data on experiments

| Ref. | Plasma source | Method of measurement: Electron density | Method of measurement: Temperature | Remarks |
|---|---|---|---|---|
| 1 | Low-pressure pulsed arc | Laser interferometry at 6328 Å | Boltzmann plot of Cl III line intensities | |

Numerical results for Cl III

| No. | Transition array | Multiplet (No.) | Wavelength (Å) | Temperature (K) | Electron density ($10^{17}$ cm$^{-3}$) | $w_m$ (Å) | $w_m/w_{th}$ | $d_m$ (Å) | $d_m/d_{th}$ | Acc. | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | $3p^23d$–$3p^2(^3P)4p$ | $^4P$ - $^4P^\circ$ (7) | 4018.50 | 24200 | 0.58 | 0.111 | 1.03 | | | C+ | 1 |
| | | | 4059.07 | 24200 | 0.58 | 0.109 | 1.01 | | | C+ | 1 |
| | | | 4106.83 | 24200 | 0.58 | 0.115 | 1.07 | | | C+ | 1 |
| 2. | $3p^24s$–$3p^2(^3P)4p$ | $^4P$ - $^4D^\circ$ (1) | 3602.10 | 24200 | 0.58 | 0.106 | 1.03 | | | C+ | 1 |
| | | | 3612.85 | 24200 | 0.58 | 0.103 | 1.00 | | | C+ | 1 |
| | | | 3656.95 | 24000 | 0.58 | 0.103 | 1.00 | | | C+ | 1 |
| | | | 3705.45 | 24000 | 0.58 | 0.099 | 0.96 | | | C+ | 1 |
| 3. | | $^4P$ - $^4P^\circ$ (2) | 3283.41 | 24200 | 0.58 | 0.097 | 1.07 | | | C+ | 1 |
| | | | 3289.80 | 24200 | 0.58 | 0.097 | 1.07 | | | C+ | 1 |
| | | | 3340.42 | 24200 | 0.58 | 0.100 | 1.10 | | | C+ | 1 |
| 4. | | $^4P$ - $^4S^\circ$ (3) | 3191.45 | 24200 | 0.58 | 0.096 | 1.10 | | | C+ | 1 |
| 5. | | $^2P$ - $^2D^\circ$ (5) | 3748.81 | 24200 | 0.58 | 0.108 | 0.92 | | | C+ | 1 |
| 6. | $3p^24s'$–$3p^2(^1D)4p'$ | $^2D$ - $^2F^\circ$ (10) | 3530.03 | 24200 | 0.58 | 0.105 | 1.05 | | | C+ | 1 |
| 7. | | $^2D$ - $^2D^\circ$ (11) | 3392.89 | 24200 | 0.58 | 0.085 | 0.92 | | | C+ | 1 |
| | | | 3393.45 | 24200 | 0.58 | 0.081 | 0.88 | | | C+ | 1 |

# Fluorine

## F II

Ground State: $1s^22s^22p^4\ ^3P_2$

Ionization Energy: 34.970 eV = 282058.6 cm$^{-1}$

The available data are the result of a recent experiment with a low-pressure pulsed arc by Platisa *et al.*[1] Because of the lack of theoretical data, the usual comparison with the semiclassical theory can be performed only for multiplet No. 1; as seen from the table, the agreement is excellent. For the same experimental data additional comparisons may be made with the semiclassical approximation assuming hyperbolic perturber trajectories,[2] which yields $w_m/w_{th} = 0.64$, and with the semiclassical method assuming a combination of straight and hyperbolic perturber trajectories,[3] which results in $w_m/w_{th} = 1.12$. Semiempirical calculations[4] produce a ratio of $w_m/w_{th} = 1.54$.

### References


[1]M. Platisa, M. S. Dimitrijević, M. Popovic, and N. Konjević, Astron. Astrophys. **54**, 837 (1977).

[2]M. Baranger, in *Atomic and Molecular Processes*, Ed. D. R. Bates, Academic Press, New York (1962).

[3]J. Cooper and G. K. Oertel, Phys. Rev. **180**, 286 (1969).

[4]J. D. Hey, J. Quant. Spectrosc. Radiat. Transfer **18**, 649 (1977).


Key data on experiments

| Ref. | Plasma source | Method of measurement: Electron density | Method of measurement: Temperature | Remarks |
|---|---|---|---|---|
| 1 | Low-pressure pulsed arc | Laser interferometry at 6328 Å | Boltzmann plot of Cl III line intensities | |

Numerical results for F II

| No. | Transition array | Multiplet (No.) | Wavelength (Å) | Temperature (K) | Electron density ($10^{17}$ cm$^{-3}$) | $w_m$ (Å) | $w_m/w_{th}$ | $d_m$ (Å) | $d_m/d_{th}$ | Acc. | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | $2p^33s$–$2p^3(^4S^o)3p$ | $^5S^o$ - $^5P$ (1) | 3847.09 | 24200 | 0.58 | 0.118 | 1.04 | | | C+ | 1 |
| | | | 3849.99 | 24200 | 0.58 | 0.117 | 1.04 | | | C+ | 1 |
| 2. | $2p^33s'$–$2p^3(^2D^o)3p'$ | $^3D^o$ - $^3D$ (5) | 4109.16 | 24200 | 0.58 | 0.112 | — | | | C+ | 1 |
| | | | 4119.21 | 24200 | 0.58 | 0.110 | — | | | C+ | 1 |
| 3. | | $^1D^o$ - $^1F$ (7) | 4299.17 | 24200 | 0.58 | 0.118 | — | | | C+ | 1 |
| | | | | | | | | | | C+ | 1 |

# Krypton

## Kr II

Ground State: $1s^22s^22p^63s^23p^63d^{10}4s^24p^5\ ^2P^o_{3/2}$

Ionization Energy: 24.359 eV = 196474.8 cm$^{-1}$

Stark-width measurements were carried out by Brandt *et al.*[1] with a wall-stabilized-arc source at electron densities from $0.5 \times 10^{17}$ to $1.5 \times 10^{17}$ cm$^{-3}$ and the widths were found to depend linearly on the electron density. The data are therefore tabulated only for $N_e = 1 \times 10^{17}$ cm$^{-3}$. For two multiplets, measurements were carried out for more than one line and the Stark-width variations within the multiplets were found to be quite large, up to 35%.

### References


[1]T. Brandt, V. Helbig, and K. P. Nick, in *Spectral Line Shapes*, Ed. B. Wende, W. de Gruyter, Berlin (1981), p. 265.

[2]T. Brandt, V. Helbig, and K. P. Nick, in *The Physics of Ionized Gases SPIG 1980 (Contributions)*, Boris Kidric Institute of Nuclear Sciences, Beograd, Yugoslavia (1980), p. 208.


Key data on experiments

| Ref. | Plasma source | Method of measurement: Electron density | Method of measurement: Temperature | Remarks |
|---|---|---|---|---|
| 1 | Wall-stabilized arc | Michelson interferometer at 6328 Å and 1.152 μm | No results are reported; numerical data are given in an earlier paper[2] | |

Numerical results for Kr II

| No. | Transition array | Multiplet (No.) | Wavelength (Å) | Temperature (K) | Electron density ($10^{17}$ cm$^{-3}$) | $w_m$ (Å) | $w_m/w_{th}$ | $d_m$ (Å) | $d_m/d_{th}$ | Acc. | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | $4p^45s$–$4p^4(^3P)5p$ | $^4P$ - $^4P^o$ | 5208.32 | 11100–12300 | 1.0 | 0.38 | | | | B | 1 |
| 2. | | $^4P$ - $^4D^o$ | 4765.74 | 11100–12300 | 1.0 | 0.39 | | | | C+ | 1 |
| | | | 4739.00 | 11100–12300 | 1.0 | 0.29 | | | | C+ | 1 |
| 3. | | $^2P$ - $^2P^o$ | 4846.61 | 11100–12300 | 1.0 | 0.34 | | | | B | 1 |
| | | | 4762.44 | 11100–12300 | 1.0 | 0.39 | | | | B | 1 |
| | | | 4615.29 | 11100–12300 | 1.0 | 0.30 | | | | B | 1 |

Numerical results for Kr II—continued

| No. | Transition array | Multiplet (No.) | Wavelength (Å) | Temperature (K) | Electron density ($10^{17}$ cm$^{-3}$) | $w_m$ (Å) | $w_m/w_{th}$ | $d_m$ (Å) | $d_m/d_{th}$ | Acc. | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 4. | | $^2$P - $^2$D° | 4619.17 | 11100-12300 | 1.0 | 0.34 | | | | B | 1 |
| 5. | $4p^45s'$–$4p^4(^1$D$)5p'$ | $^2$D - $^2$F° | 4633.89 | 11100-12300 | 1.0 | 0.32 | | | | B | 1 |

# Lead

## Pb II

Ground State: $1s^22s^22p^63s^23p^63d^{10}4s^24p^64d^{10}4f^{14}5s^25p^65d^{10}6s^26p$ $^2$P$^\circ_{1/2}$

Ionization Energy: 15.032 eV = 121243 cm$^{-1}$

The data obtained by Miller *et al.*[1] with a gas driven shock tube are the only available experimental results, and no semiclassical calculations exist for the usual comparison. Semiempirical calculations[1] were found to agree with the experimental data within ±40%.

### Reference

[1]M. H. Miller, R. D. Bengtson, and J. M. Lindsay, Phys. Rev. A **20**, 1997 (1979).

Key data on experiments

| Ref. | Plasma source | Method of measurement: Electron density | Method of measurement: Temperature | Remarks |
|---|---|---|---|---|
| 1 | Gas-driven shock tube | $H_\beta$ Stark width | Line-reversal technique applied to $H_\alpha$ line; absolute intensity of Ne I 5852 Å line and $H_\beta$ | Photographic technique |

Numerical results for Pb II

| No. | Transition array | Multiplet (No.) | Wavelength (Å) | Temperature (K) | Electron density ($10^{17}$ cm$^{-3}$) | $w_m$ (Å) | $w_m/w_{th}$ | $d_m$ (Å) | $d_m/d_{th}$ | Acc. | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | $6s^27s$–$6s^27p$ | $^2$S - $^2$P° | 5608.85 | 11600 | 1.0 | 1.96* | | | | C | 1 |
| 2. | $6s^26d$–$6s^25f$ | $^2$D - $^2$F° | 4244.92 | 11600 | 1.0 | 1.69** | | | | C+ | 1 |
| | | | 4386.46 | 11600 | 1.0 | 1.72** | | | | C+ | 1 |
| 3. | $6s^27p$–$6s^27d$ | $^2$P° - $^2$D | 5544.25 | 11600 | 1.0 | 3.60* | | | | C+ | 1 |
| | | | 5042.58 | 11600 | 1.0 | 3.84* | | | | C+ | 1 |
| 4. | $6s^27p$–$6s^29s$ | $^2$P° - $^2$S | 4152.82 | 11600 | 1.0 | 2.34*** | | | | C | 1 |
| 5. | $6s6p^2$–$6s^25f$ | $^4$P - $^2$F° | 5372.10 | 11600 | 1.0 | 2.27* | | | | C+ | 1 |

*Measurements were made over a range of electron densities from $0.8\times10^{17}$ cm$^{-3}$ to $1.15\times10^{17}$ cm$^{-3}$, but results were given only for $1\times10^{17}$ cm$^{-3}$.

**Measurements were made over the range $(0.5–1.3)\times10^{17}$ cm$^{-3}$.

***Measurements were made over the range $(1.0–1.15)\times10^{17}$ cm$^{-3}$.

# Magnesium

## Mg II

Ground State: $1s^2 2s^2 2p^6 3s\ ^2S_{1/2}$

Ionization Energy: 15.035 eV = 121267.61 $cm^{-1}$

Stark-broadening measurements for several Mg II lines in the near ultraviolet and visible region have been carried out in three recent experiments.[1-3] Goldbach *et al.*[1] have investigated the Stark broadening of the resonance lines with a wall-stabilized arc and high-resolution instrumentation. Their results agree well with the earlier pulsed-arc work of Roberts and Barnard,[4] but they are in strong disagreement with the data of Fleurier *et al.*[2] obtained with a plasma jet, as well as with earlier results by Chapelle and Sahal-Brechot[5] with a plasma jet and Jones *et al.*[6] with an electromagnetic shock tube. Also, earlier work by Hadziomerspahic *et al.*[7] with a Z-pinch at much higher temperatures tends to be more consistent with the latter set of experiments than with the work of Goldbach *et al.*, or of Roberts and Barnard. A detailed analysis of these experiments is presented in the general introduction, since this is a case of particular interest. Some possible causes for the serious discrepancies are identified which significantly exceed the limits of the mutually estimated uncertainties. On the basis of this analysis, the results of Goldbach *et al.*[1] and Roberts and Barnard[4] are estimated to be the most reliable. However, for the high-temperature region (> 30,000 K), an additional high-precision experiment would be highly desirable.

Fleurier *et al.*[2] have reported multiplet values rather than data for individual lines. However, the line wavelengths were also supplied to us by Fleurier,[8] who noted that the measured linewidths within multiplets did not differ by more than ±5%.

The measurements by Kusch and Schwiecker[3] with a pressurized arc yield a large difference of almost a factor of two between the two Stark linewidths in multiplet No. 2 UV. Differences between Stark-broadening parameters of lines within multiplets may be appreciable in cases where the energy separation for the upper or lower levels of a multiplet cannot be disregarded in comparison with the difference in energy from the nearest perturbing levels or in cases where higher order (e.g., quadrupole) interactions and interference terms are important.[9,10] However, since this is not the case for the lines belonging to Mg II multiplet No. 2 UV one should expect that the linewidths would be approximately equal, as is also borne out by other experiments.[2,11] The results of Ref. 3 thus seem to point to some undetected systematic error.

The data of Helbig and Kusch[11] were misinterpreted in our earlier Mg II table[5]; therefore, the corrected results for these Mg II lines have been included in this tabulation, too.

Finally, it should be noted that Fleurier *et al.*[3] performed semiclassical calculations in which resonances of elastic cross sections were taken into account. With the inclusion of contributions from ion broadening they obtained an average ratio $w_m/w_{th}$ = 1.16 for their experimental width and shift data.

### References

[1]C. Goldbach, G. Nollez, P. Plomdeur, and J. P. Zimmermann, Phys. Rev. A **25**, 2596 (1982).
[2]C. Fleurier, S. Sahal-Brechot, and J. Chapelle, J. Quant. Spectrosc. Radiat. Transfer **17**, 595 (1977).
[3]H. J. Kusch and H. Schwiecker, Astron. Astrophys. **53**, 59 (1976).
[4]D. E. Roberts and A. J. Barnard, J. Quant. Spectrosc. Radiat. Transfer **12**, 1205 (1972).
[5]J. Chapelle and S. Sahal-Brechot, Astron. Astrophys. **6**, 415 (1970).
[6]W. W. Jones, A. Sanchez, J. R. Greig, and H. R. Griem, Phys. Rev. A **5**, 2318 (1972).
[7]D. Hadziomerspahic, M. Platisa, N. Konjević, and M. Popovic, Z. Phys. **262**, 169 (1973).
[8]C. Fleurier, private communication (1980).
[9]W. L. Wiese and N. Konjević, in *Physics of Ionized Gases 1976 (Contributions)*, J. Stefan Institute, Ljubljana, Yugoslavia (1976), p. 416.
[10]N. Konjević and M. S. Dimitrijević, in *Spectral Line Shapes*, Ed. B. Wende, W. de Gruyter, Berlin (1981), p. 241.
[11]V. Helbig and H. J. Kusch, Astron. Astrophys. **20**, 299 (1972).

Key data on experiments

| Ref. | Plasma source | Method of measurement: Electron density | Method of measurement: Temperature | Remarks |
|---|---|---|---|---|
| 1 | Wall-stabilized arc | Plasma-composition data and absolute intensity of continuum at 4000 Å | Absolute intensity of Ar I 4300 Å and Ar II 4806 Å lines | |
| 2 | Plasma jet | $H_\alpha$ and $H_\beta$ Stark widths | Plasma-composition data | |
| 3 | Gas-stabilized high-pressure arc | $H_\beta$ Stark width and H continuum at 4400 Å | Absolute intensity of $H_\beta$ and intensity ratio of Mg I 4703 Å/Mg II 4481 Å lines | Photographic technique |
| 11 | Gas-stabilized high-pressure arc | Shift of Ar I 4158.6 Å line, absolute intensities of Mg I and Mg II lines and of Ar I continuum at 3600 Å | Absolute intensity of Ar I 4158.6 Å line and Mg I/Mg II line intensity ratios | Photographic technique; no self-absorption check reported |

Numerical results for Mg II

| No. | Transition array | Multiplet (No.) | Wavelength (Å) | Temperature (K) | Electron density ($10^{17}$ cm$^{-3}$) | $w_m$ (Å) | $w_m/w_{th}$ | $d_m$ (Å) | $d_m/d_{th}$ | Acc. | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | $3s$–$3p$ | $^2S$ - $^2P^\circ$ (1 UV) | 2795.53 | 13000 | 1.18 | 0.12 | 0.92 | -0.017 | 0.57 | D,C | 2 |
| | | | | 12970–14260 | 1.10–1.64 | 0.048–0.077 | 0.45–0.51 | | | B | 1 |
| | | | 2802.70 | 13000 | 1.18 | 0.12 | 0.92 | -0.017 | 0.57 | D,C | 2 |
| | | | | 12970–14260 | 1.10–1.64 | 0.043–0.065 | 0.39–0.42 | | | B | 1 |
| 2. | $3p$–$3d$ | $^2P^\circ$ - $^2D$ (3 UV) | 2790.79 | 14300 | 1.23 | 0.22 | 0.96 | 0.075 | 0.82 | D,C | 2 |
| 3. | $3p$–$4s$ | $^2P^\circ$ - $^2S$ (2 UV) | 2928.75 | 10000 | 1.0 | 0.70 | 2.20 | 0.06 | 0.36 | D,D | 11 |
| | | | | 10000 | 1.0 | 1.10 | 3.46 | 0.28 | 1.68 | D,D | 3 |
| | | | | 14400 | 1.25 | 0.39 | 1.00 | 0.175 | 0.95 | D,C | 2 |
| | | | 2936.54 | 10000 | 1.0 | 0.72 | 2.26 | 0.08 | 0.49 | D,D | 11 |
| | | | | 10000 | 1.0 | 0.56 | 1.76 | 0.49 | 2.98 | D,D | 3 |
| | | | | 14400 | 1.25 | 0.39 | 1.00 | 0.175 | 0.95 | D,C | 2 |
| 4. | $3d$–$4f$ | $^2D$ - $^2F^\circ$ (4) | 4481.16 | 10000 | 1.0 | 4.26 | 1.56 | 0.32 | * | D,D | 11 |
| | | | | 10000 | 1.0 | 10.8 | 3.94 | -1.89 | 1.97 | D,D | 3 |

*Theory predicts negative shift.

# Neon

## Ne II

Ground State: $1s^22s^22p^5\ ^2P^\circ_{3/2}$

Ionization Energy: 40.962 eV = 330391.0 $cm^{-1}$

The data obtained by Platisa *et al.*[1] with a low-pressure pulsed arc are the only available experimental results. The table shows that, with the exception of multiplet No. 2, the agreement with semiclassical theory is very satisfactory, and the widths for different lines within each multiplet are very similar. A comparison of the experimental data with semiempirical theory[1] yields an average ratio of $w_m/w_{th}$ = 1.70.

### Reference

[1]M. Platisa, M. S. Dimitrijević, and N. Konjević, Astron. Astrophys. **67**, 103 (1978).

Key data on experiments

| Ref. | Plasma source | Method of measurement: Electron density | Temperature | Remarks |
|---|---|---|---|---|
| 1 | Low-pressure pulsed arc | Laser interferometry at 6328 Å | Boltzmann plot of Ne II line intensities | |

Numerical results for Ne II

| No. | Transition array | Multiplet (No.) | Wavelength (Å) | Temperature (K) | Electron density ($10^{17}$ $cm^{-3}$) | $w_m$ (Å) | $w_m/w_{th}$ | $d_m$ (Å) | $d_m/d_{th}$ | Acc. | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | $2p^43s-2p^4(^3P)3p$ | $^4P-^4P^\circ$ (1) | 3694.21 | 28300 | 0.51 | 0.072 | 1.06 | | | C+ | 1 |
| | | | 3734.9 | 28300 | 0.51 | 0.072 | 1.06 | | | C+ | 1 |
| | | | 3709.62 | 28300 | 0.51 | 0.071 | 1.04 | | | C+ | 1 |
| | | | 3766.26 | 28300 | 0.51 | 0.068 | 1.00 | | | C+ | 1 |
| | | | 3777.13 | 28300 | 0.51 | 0.072 | 1.06 | | | C+ | 1 |
| 2. | | $^4P-^4D^\circ$ (2) | 3334.84 | 28300 | 0.51 | 0.081 | 1.35 | | | C+ | 1 |
| | | | 3355.02 | 28300 | 0.51 | 0.083 | 1.38 | | | C+ | 1 |
| | | | 3297.73 | 28300 | 0.51 | 0.083 | 1.38 | | | C+ | 1 |
| 3. | | $^2P-^2D^\circ$ (5) | 3713.08 | 28300 | 0.51 | 0.082 | 1.09 | | | C+ | 1 |
| | | | 3727.11 | 28300 | 0.51 | 0.080 | 1.05 | | | C+ | 1 |
| 4. | $2p^43p-2p^4(^3P)3d$ | $^4D^\circ-^4F$ (13) | 3218.19 | 28300 | 0.51 | 0.088 | 1.22 | | | C+ | 1 |
| 5. | | $^4S^\circ-^4P$ (34) | 3542.85 | 28300 | 0.51 | 0.095 | 0.98 | | | C+ | 1 |

# Nitrogen

## N II

Ground State: $1s^2 2s^2 2p^2\ ^3P_0$

Ionization Energy: 29.601 eV = 238750.5 $cm^{-1}$

Two experiments with pulsed plasma sources by Baker and Burgess[1] and Källne *et al.*[2] are selected; both measurements have been performed at high electron densities ($N_e \approx 1 \times 10^{18}$ $cm^{-3}$). The paper by Baker and Burgess[1] reports shift measurements, while the paper by Källne *et al.*[2] gives line widths. Low accuracies are estimated for all shift and width data, mainly because of source problems.[3]

### References

[1]E. A. M. Baker and D. D. Burgess, J. Phys. B **12**, 2097 (1979).
[2]E. Källne, L. A. Jones, and A. J. Barnard, J. Quant. Spectrosc. Radiat. Transfer **22**, 589 (1979).
[3]M. S. Dimitrijević and N. Konjević, J. Quant. Spectrosc. Radiat. Transfer **25**, 387 (1981); E. Källne and L. A. Jones, J. Quant. Spectrosc. Radiat. Transfer **25**, 393 (1981).

Key data on experiments

| Ref. | Plasma source | Method of measurement: Electron density | Method of measurement: Temperature | Remarks |
|---|---|---|---|---|
| 1 | Z-pinch | Stark width of Ar II 4848 and 4806 Å lines; Mach-Zehnder interferometer at 6328 Å; continuum absorption of plasma at 6328 Å | Resonant absorption measurements at Ar II 4880 Å | |
| 2 | Theta-pinch | Stark widths of He II 4686 Å line | Ratio of intensity of He II 4686 Å line to continuum | Only theoretical estimate of self-absorption reported |

Numerical results for N II

| No. | Transition array | Multiplet (No.) | Wavelength (Å) | Temperature (K) | Electron density ($10^{17}$ $cm^{-3}$) | $w_m$ (Å) | $w_m/w_{th}$ | $d_m$ (Å) | $d_m/d_{th}$ | Acc. | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | $2s^2 2p^2$-$2s2p^3$ | $^3P$ - $^3P°$ (2 UV) | 915.61 | 25000 | 20 | | | 0.3 | | D | 1 |
| | | | 916.01 | 25000 | 20 | | | 0.0 | | — | 1 |
| | | | 916.70 | 25000 | 20 | | | 0.15 | | D | 1 |
| 2. | $2p3s$-$2p3p$ | $^1P°$ - $^1D$ (12) | 3995.00 | 58000 | 14 | 10.8 | | | | D | 2 |
| 3. | $2p3p$-$2p3d$ | $^1P$ - $^1D°$ (15) | 4447.03 | 58000 | 14 | 8.1 | | | | D | 2 |
| 4. | | $^3D$ - $^3D°$ (20) | 4803.29 | 58000 | 14 | 8.7 | | | | D | 2 |
| | | | 4790.4 | 58000 | 14 | 6.2 | | | | D | 2 |

Numerical results for N II—continued

| No. | Transition array | Multiplet (No.) | Wavelength (Å) | Temperature (K) | Electron density ($10^{17}$ cm$^{-3}$) | $w_m$ (Å) | $w_m/w_{th}$ | $d_m$ (Å) | $d_m/d_{th}$ | Acc. | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 5. | $2p3d$-$2p4f$ | $^3F^\circ - ^3G$ (39) | 4040.9 | 58000 | 14 | 26.5 | 1.64* | | | D+ | 2 |
| 6. | | $^3D^\circ - ^3F$ (48) | 4239.4 | 58000 | 14 | 21.5 | 1.03* | | | D+ | 2 |

*The comparison data from the semiclassical theory were taken for a temperature of 40000 K.

## N III

Ground State: $1s^22s^22p\ ^2P^\circ_{1/2}$

Ionization Energy: 47.448 eV = 382704 cm$^{-1}$

Stark-broadening parameters of N III lines were recently measured with two different pulsed plasma sources by Popovic *et al.*[1] and Källne *et al.*[2] Low accuracies are estimated for the width data of Ref. 2 because of indications of source problems.[3]

In addition to the usual comparison with the modified semiempirical theory in the table, the experimental results of Ref. 1 may be compared with several other theoretical approximations, which yield the following (average) experiment/theory width ratios:

- with the semiempirical method,[4] $w_m/w_{th} = 1.67$;
- with the simplified semiclassical method,[5] $w_m/w_{th} = 0.67$;
- with a modification of the preceding simplified semiclassical method,[5] $w_m/w_{th} = 0.95$.

### References


[1]M. Popovic, M. Platisa, and N. Konjević, Astron. Astrophys. **41**, 463 (1975).

[2]E. Källne, L. A. Jones, and A. J. Barnard, J. Quant. Spectrosc. Radiat. Transfer **22**, 589 (1979).

[3]M. S. Dimitrijević and N. Konjević, J. Quant. Spectrosc. Radiat. Transfer **25**, 387 (1981); E. Källne and L. A. Jones, J. Quant. Spectrosc. Radiat. Transfer **25**, 393 (1981).

[4]J. D. Hey, J. Quant. Spectrosc. Radiat. Transfer **16**, 575 (1976); J. D. Hey and R. J. Bryan, J. Quant. Spectrosc. Radiat. Transfer **17**, 221 (1977).

[5]M. S. Dimitrijević and N. Konjević, J. Quant. Spectrosc. Radiat. Transfer **24**, 451 (1980).


Key data on experiments

| Ref. | Plasma source | Method of measurement: Electron density | Method of measurement: Temperature | Remarks |
|---|---|---|---|---|
| 1 | Low-pressure pulsed arc | Laser interferometry at 6328 Å | Boltzmann plot of relative N II line intensities | |
| 2 | Theta-pinch | Stark width of He II 4686 Å line | Ratio of intensity of He II 4686 Å line to continuum | Only theoretical estimate of self-absorption reported |

Numerical results for N III

| No. | Transition array | Multiplet (No.) | Wavelength (Å) | Temperature (K) | Electron density ($10^{17}$ cm$^{-3}$) | $w_m$ (Å) | $w_m/w_{th}$ | $d_m$ (Å) | $d_m/d_{th}$ | Acc. | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | $3s$-$3p$ | $^2$S - $^2$P° (1) | 4097.33 | 24300 | 0.55 | 0.096 | 0.82 | | | C+ | 1 |
| | | | | 58000 | 14 | 7.6 | 3.80 | | | D | 2 |
| | | | 4103.43 | 58000 | 14 | 5.8 | 2.89 | | | D | 2 |
| 2. | $3p$-$3d$ | $^2$P° - $^2$D (2) | 4634.14 | 24300 | 0.55 | 0.112 | 0.76 | | | C+ | 1 |
| | | | 4640.64 | 24300 | 0.55 | 0.115 | 0.78 | | | C+ | 1 |
| 3. | $2s2p3s$-$2s2p(^3$P°$)3p$ | $^4$P° - $^4$D (3) | 4510.91 | 58000 | 14 | 5.3 | 2.44 | | | D | 2 |
| 4. | | $^4$P° - $^4$P (5) | 3367.34 | 24300 | 0.55 | 0.098 | 1.18 | | | C+ | 1 |
| 5. | | $^2$P° - $^2$D (6) | 4200.10 | 58000 | 14 | 7.4 | 2.98 | | | D | 2 |
| | | | 4195.76 | 58000 | 14 | 8.2 | 3.31 | | | D | 2 |
| 6. | $2s2p3p'$-$2s2p(^3$P°$)3d'$ | $^4$D - $^4$F° (9) | 4858.82 | 58000 | 14 | 8.5 | 3.67 | | | D | 2 |
| | | | 4865.8* | 58000 | 14 | 6.4 | 2.77 | | | D | 2 |

*This wavelength does not match any given in the N III Multiplet Tables by C. E. Moore, NSRDS-NBS 3, Sect. 5, U.S. Government Printing Office, Washington, D.C. (1975).

## N IV

Ground State: $1s^2 2s^2\ ^1S_0$

Ionization Energy: 77.472 eV = 624866 cm$^{-1}$

The only piece of experimental information available is for the Stark width of the $2s3p\ ^1$P° - $2s3d\ ^1$D transition at 4057.76 Å. Theta-pinch measurements performed at a temperature of 58000 K and at an electron density of $1.4 \times 10^{18}$ cm$^{-3}$ by Källne *et al.*[1] yielded a width of 7.4 Å, which is exactly 5.00 times larger than the result of the modified semiempirical approximation which is always used in these tables in the theory comparisons for the higher ions. Various other theoretical approaches have also been applied to calculations of the width of this line and poor agreement with the experimental result was found,[2] always in the direction that the calculated widths are substantially smaller. An accuracy rating of D is indicated for the experimental width because of indications of source problems.[2]

### References


[1]E. Källne, L. A. Jones, and A. J. Barnard, J. Quant. Spectrosc. Radiat. Transfer 22, 589 (1979).

[2]M. S. Dimitrijević and N. Konjević, J. Quant. Spectrosc. Radiat. Transfer 25, 387 (1981); E. Källne and L. A. Jones, J. Quant. Spectrosc. Radiat. Transfer 25, 393 (1981).

# Oxygen

## O III

Ground State: $1s^2 2s^2 2p^2\ {}^3P_0$

Ionization Energy: 54.934 eV = 443086 cm$^{-1}$

The Stark widths measured with a low pressure pulsed arc,[1] presented already in our earlier review,[2] are listed again with new theoretical comparison data. These are obtained from the modified semiempirical approximation (see general introduction), which is always utilized in these tables for the higher ions. In addition, several other theoretical approaches are available for comparisons and have produced the following average ratios:

- the semiclassical method,[3] which yields $w_m/w_{th}$ = 0.73;
- the semiclassical Gaunt factor method,[4] $w_m/w_{th}$ = 0.98;
- the simplified semiclassical method,[5] $w_m/w_{th}$ = 0.75;
- a modification of the preceding simplified semiclassical method,[5] $w_m/w_{th}$ = 1.02;
- a semiempirical approach,[6] $w_m/w_{th}$ = 1.89.

### References


[1]M. Platisa, M. Popovic, and N. Konjević, Astron. Astrophys. **45**, 325 (1975).
[2]N. Konjević and W. L. Wiese, J. Phys. Chem. Ref. Data **5**, 259 (1976).
[3]M. S. Dimitrijević, Publ. of Astr. Obs., No. 1, Sarajevo, (1981), p. 215.
[4]J. D. Hey and P. Breger, J. Quant. Spectrosc. Radiat. Transfer **24**, 349 (1980).
[5]M. S. Dimitrijević and N. Konjević, J. Quant. Spectrosc. Radiat. Transfer **24**, 451 (1980).
[6]J. D. Hey and R. J. Bryan, J. Quant. Spectrosc. Radiat. Transfer **17**, 221 (1977).


Key data on experiments

| Ref. | Plasma source | Method of measurement: Electron density | Method of measurement: Temperature | Remarks |
|---|---|---|---|---|
| 1 | Low-pressure pulsed arc | Laser interferometry at 6328 Å | Boltzmann plot of O III line intensities | |

Numerical results for O III

| No. | Transition array | Multiplet (No.) | Wavelength (Å) | Temperature (K) | Electron density ($10^{17}$ cm$^{-3}$) | $w_m$ (Å) | $w_m/w_{th}$ | $d_m$ (Å) | $d_m/d_{th}$ | Acc. | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | $2p3s-2p(^2P^\circ)3p$ | $^3P^\circ-{}^3D$ (2) | 3754.67 | 25900 | 0.52 | 0.076 | 1.06 | | | C+ | 1 |
| | | | 3759.87 | 25900 | 0.52 | 0.072 | 1.00 | | | C+ | 1 |
| 2. | | $^3P^\circ-{}^3P$ (4) | 3047.13 | 25900 | 0.52 | 0.056 | 1.09 | | | C+ | 1 |
| 3. | $2p3p-2p(^2P^\circ)3d$ | $^3D-{}^3F^\circ$ (8) | 3260.98 | 25900 | 0.52 | 0.066 | 1.18 | | | C+ | 1 |
| | | | 3265.46 | 25900 | 0.52 | 0.063 | 1.12 | | | C+ | 1 |
| 4. | | $^3P-{}^3D^\circ$ (14) | 3715.08 | 25900 | 0.52 | 0.074 | 0.93 | | | C+ | 1 |

# Silicon

## Si II

Ground State: $1s^22s^22p^63s^23p\ ^2P^\circ_{1/2}$

Ionization Energy: 16.345 eV = 121838.4 cm$^{-1}$

The results of three experiments on Si II Stark broadening parameters are selected which have been performed with shock tubes, i.e., either gas driven tubes[1,2] or an electromagnetically driven T-tube.[3] The strong interest in the Stark broadening of Si II lines is partly due to the fact that ionized silicon is often present in plasmas as an impurity and therefore Stark broadening parameters of Si II lines are useful for diagnostic purposes; but a disagreement of a factor of two between an earlier experiment[4,5] and semiclassical calculations has also contributed renewed interest.

The agreement between the more recent experiments[2,3] and Griem's semiclassical calculations—as seen in the table—is now quite close. However, the situation is still not satisfactory, since the new measurements differ sharply from the earlier experiments of Puric *et al.*[4,5]

### References


[1] A. Lesage and M. Miller, C. R. Acad. Sci., Ser. B **280**, 645 (1975).
[2] A. Lesage, S. Sahal-Brechot, and M. H. Miller, Phys. Rev. A **16**, 1617 (1977).
[3] W. T. Chiang and H. R. Griem, Phys. Rev. A **18**, 1169 (1978).
[4] J. Puric, S. Djenize, J. Labat, and Lj. Cirkovic, Phys. Lett. **45A**, 97 (1973).
[5] J. Puric, S. Djenize, J. Labat, and Lj. Cirkovic, Z. Phys. **267**, 71 (1974).


Key data on experiments

| Ref. | Plasma source | Method of measurement: Electron density | Method of measurement: Temperature | Remarks |
|---|---|---|---|---|
| 1 | Gas–driven shock tube | $H_\beta$ Stark width | Line reversal technique applied to $H_\alpha$ line; absolute intensity of Ne I 5852 Å line and $H_\beta$ | Photographic technique |
| 2 | Gas–driven shock tube | $H_\beta$ Stark width | Line reversal technique applied to $H_\alpha$ line; absolute intensity of Ne I 5852 Å line and $H_\beta$ | Photographic technique |
| 3 | T–tube | He I 3889 Å and 5016 Å widths | Ratio of intensities of He I 3889 and 5016 Å to continuum | |

Numerical results for Si II

| No. | Transition array | Multiplet (No.) | Wavelength (Å) | Temperature (K) | Electron density ($10^{17}$ cm$^{-3}$) | $w_m$ (Å) | $w_m/w_{th}$ | $d_m$ (Å) | $d_m/d_{th}$ | Acc. | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | $3s3p^2$–$3s^2(^1S)4p$ | $^2P$ - $^2P^\circ$ (1) | 3856.02 | 10000 | 1.0 | 1.07 | 0.92 | 0.20 | 0.41 | C+,D | 2 |
| | | | | 18000 | 1.0 | 1.00 | 0.98 | | | B | 3 |
| | | | 3862.60 | 10000 | 1.0 | 1.05 | 0.91 | 0.20 | 0.41 | C+,D | 2 |
| | | | | 18000 | 1.0 | 0.98 | 0.96 | | | B | 3 |
| 2. | $3s^23d$–$3s^2(^1S)4f$ | $^2D$ - $^2F^\circ$ (3) | 4128.07 | 10000 | 1.0 | 1.58 | 1.15 | −0.32 | 0.65 | C,C | 2 |
| | | | 4130.89 | 10000 | 1.0 | 1.60 | 1.17 | −0.32 | 0.65 | C,C | 2 |

Numerical results for Si II—continued

| No. | Transition array | Multiplet (No.) | Wavelength (Å) | Temperature (K) | Electron density ($10^{17}$ cm$^{-3}$) | $w_m$ (Å) | $w_m/w_{th}$ | $d_m$ (Å) | $d_m/d_{th}$ | Acc. | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 3. | $3s^24s$-$3s^2(^1S)4p$ | $^2S$ - $^2P^\circ$ (2) | 6347.10 | 10000 | 1.0 | 1.96 | 0.84 | -0.31 | 0.31 | C+,C | 2 |
| | | | | 18000 | 1.0 | 2.14 | 1.06 | | | B | 3 |
| | | | 6371.36 | 10000 | 1.0 | 1.93 | 0.82 | -0.25 | 0.25 | C+,C | 2 |
| | | | | 18000 | 1.0 | 2.22 | 1.10 | | | B | 3 |
| 4. | $3s^24p$-$3s^2(^1S)4d$ | $^2P^\circ$ - $^2D$ (5) | 5041.03 | 10000 | 1.0 | 3.5* | 1.21 | 1.15* | 0.75 | D,C | 1 |
| | | | | 10000 | 1.0 | 2.53 | 0.87 | 1.10 | 0.72 | C+,C | 2 |
| | | | 5055.98 | 10000 | 1.0 | 3.5* | 1.21 | 1.15* | 0.75 | D,C | 1 |
| | | | | 10000 | 1.0 | 2.69 | 0.93 | 1.15 | 0.75 | C+,C | 2 |
| 5. | $3s^24p$-$3s^2(^1S)5s$ | $^2P^\circ$ - $^2S$ (4) | 5957.56 | 10000 | 1.0 | 3.3* | 1.30 | 1.2* | 0.86 | D,C | 1 |
| | | | | 10000 | 1.0 | 2.78 | 1.08 | 1.32 | 0.94 | C+,C | 2 |
| | | | 5978.93 | 10000 | 1.0 | 3.3* | 1.30 | 1.2* | 0.86 | D,C | 1 |
| | | | | 10000 | 1.0 | 2.75 | 1.07 | 1.35 | 0.96 | C+,C | 2 |

*It is assumed that the two lines in the multiplets have the same width and shift since the results of Ref. 1 are given for an averaged multiplet wavelength.

## Si III

Ground State: $1s^22s^22p^63s^2\ ^1S_0$

Ionization Energy: 33.492 eV = 270139.3 cm$^{-1}$

The Stark broadening of Si III lines has been investigated experimentally with two different pulsed sources by Puric *et al.*[1] and Platisa *et al.*[2] The table includes, as usual, a comparison with the modified semiempirical approximation. Additional comparisons with other calculations may be performed and yield the following average ratios[2] (for Ref. 1, only the results at 16400 K are used):

- with the semiclassical method with Coulomb cutoff,[3] as calculated by Platisa *et al.*,[2] $w_m/w_{th} = 1.26$;
- with the simplified semiclassical method,[4] $w_m/w_{th} = 0.48$;
- with a modification of the preceding simplified semiclassical method,[4] $w_m/w_{th} = 0.68$;
- with the semiempirical method,[4] $w_m/w_{th} = 1.08$.

Some experimental data for multiplet No. 2, for electron temperatures from 10600 K to 16400 K, may also be compared with semiclassical calculations[5] and yield an average ratio $w_m/w_{th} = 0.90$.

### References


[1]J. Puric, S. Djenize, J. Labat, and Lj. Cirkovic, Z. Phys. **267**, 71 (1974).
[2]M. Platisa, M. S. Dimitrijević, M. Popovic, and N. Konjević, J. Phys. B **10**, 2997 (1977).
[3]M. Baranger, in *Atomic and Molecular Processes*, Ed. D. R. Bates, Academic Press, New York (1962).
[4]M. S. Dimitrijević and N. Konjević, J. Quant. Spectrosc. Radiat. Transfer **24**, 451 (1980).
[5]S. Sahal Brechot, Astron. Astrophys. **2**, 322 (1969).


Key data on experiments

| Ref. | Plasma source | Method of measurement: Electron density | Method of measurement: Temperature | Remarks |
|---|---|---|---|---|
| 1 | T-tube | Laser interferometry at 6328 Å | Boltzmann plot of Ar II line intensities | |
| 2 | Low-pressure pulsed arc | Laser interferometry at 6328 Å | Boltzmann plot of Cl III line intensities | |

Numerical results for Si III

| No. | Transition array | Multiplet (No.) | Wavelength (Å) | Temperature (K) | Electron density ($10^{17}$ cm$^{-3}$) | $w_m$ (Å) | $w_m/w_{th}$ | $d_m$ (Å) | $d_m/d_{th}$ | Acc. | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | $3s4s$–$3s(^2S)4p$ | $^3S$ - $^3P°$ (2) | 4552.62 | 8700–16400 | 1.0 | 0.48–0.38 | 0.61**–0.67 | 0.05–0.05 | | C,C | 1 |
| | | | | 25600 | 0.58 | 0.180 | 0.68 | | | C+ | 2 |
| | | | 4567.82 | 8700 | 1.0 | 0.56 | 0.62 | 0.04 | | C,C | 1 |
| | | | | 10600–16400 | 1.0 | 0.60–0.67 | 0.84–1.17 | 0.04–0.07 | | C,C | 1 |
| | | | | 25600 | 0.58 | 0.181 | 0.69 | | | C+ | 2 |
| | | | 4574.76 | 25600 | 0.58 | 0.176 | 0.67 | | | C+ | 2 |
| 2. | $3s4p$–$3s(^2S)4d$ | $^3P°$ - $^3D$ (5) | 3791.41 | 25600 | 0.58 | 0.204 | 0.72 | | | C+ | 2 |
| 3. | | $^3P°$ - $^3S$ (6) | 3241.62 | 25600 | 0.58 | 0.186 | 0.61 | | | C+ | 2 |
| | | | 3233.95 | 25600 | 0.58 | 0.186 | 0.61 | | | C+ | 2 |
| | | | 3230.50 | 25600 | 0.58 | 0.182 | 0.60 | | | C+ | 2 |
| 4. | $3s4d$–$3s(^2S)5f$ | $^3D$ - $^3F°$ (8.06) | 3486.21 | 8700–16400 | 1.0 | 0.52* | | 0.04–0.06 | | C,C | 1 |

*The Stark width was measured only at 12800 K.
**This result was obtained at 10600 K.

## Si IV

Ground State: $1s^22s^22p^63s\ ^2S_{1/2}$

Ionization Energy: 45.141 eV = 364093.1 cm$^{-1}$

The only set of experimental data was obtained by Platisa *et al.*[1] with a low pressure arc. In addition to the usual comparisons with the modified semiempirical approximation listed in the table (see general introduction), several other comparisons may be made which yield the following average experiment/theory width ratios:

- with the semiempirical method,[3] $w_m/w_{th} = 1.15$;
- with the semiclassical theory with Coulomb cutoff, $w_m/w_{th} = 1.59$;
- with a simplified semiclassical method,[3] $w_m/w_{th} = 0.54$;
- with a modification of the preceding simplified semiclassical method,[3] $w_m/w_{th} = 0.84$.

### References


[1]M. Platisa, M. Dimitrijević, M. Popovic, and N. Konjević, J. Phys. B **10**, 2997 (1977).
[2]M. Baranger, in *Atomic and Molecular Processes*, Ed. D. R. Bates, Academic Press, New York (1962).
[3]M. S. Dimitrijević and N. Konjević, J. Quant. Spectrosc. Radiat. Transfer **24**, 451 (1980).


Key data on experiments

| Ref. | Plasma source | Method of measurement: Electron density | Method of measurement: Temperature | Remarks |
|---|---|---|---|---|
| 1 | Low-pressure pulsed arc | Laser interferometry at 6328 Å | Boltzmann plot of Cl III line intensities | |

Numerical results for Si IV

| No. | Transition array | Multiplet (No.) | Wavelength (Å) | Temperature (K) | Electron density ($10^{17}$ cm$^{-3}$) | $w_m$ (Å) | $w_m/w_{th}$ | $d_m$ (Å) | $d_m/d_{th}$ | Acc. | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | $4s$–$4p$ | $^2$S - $^2$P° (1) | 4088.85 | 25600 | 0.58 | 0.125 | 0.57 | | | C+ | 1 |
| | | | 4116.10 | 25600 | 0.58 | 0.123 | 0.57 | | | C+ | 1 |
| 2. | $4p$–$4d$ | $^2$P° - $^2$D (2) | 3165.71 | 25600 | 0.58 | 0.138 | 0.75 | | | C+ | 1 |
| | | | 3149.56 | 25600 | 0.58 | 0.137 | 0.75 | | | C+ | 1 |

# Strontium

## Sr II

Ground State: $1s^22s^22p^63s^23p^63d^{10}4s^24p^65s\ ^2S_{1/2}$

Ionization Energy: 11.030 eV = 88964.0 cm$^{-1}$

The plasma-jet experiment by Fleurier *et al.*[1] has produced new data for the Sr II resonance doublet. While the authors did not explicitly state that both lines of the doublet were investigated, identical results for the two lines were introduced in our table since, according to Fleurier,[2] these data did not differ by more than 5%.

Jones *et al.*[3] did not calculate theoretical data for Sr II lines, but their computer code was used by us to calculate the Stark width of the resonance doublet and the ratios $w_m/w_{th}$ were included in the table together with older experimental results.[4,5] It should be noted that Fleurier *et al.*[2] performed semiclassical calculations, too, and obtained for the resonance multiplet average ratios of $w_m/w_{th} = 0.99$ and $d_m/d_{th} = 1.02$.

### References

[1]C. Fleurier, S. Sahal-Brechot, and J. Chapelle, J. Quant. Spectrosc. Radiat. Transfer 17, 595 (1977).
[2]C. Fleurier, private communication (1980).
[3]W. W. Jones, S. M. Benett, and H. R. Griem, Tech. Report No. 71-128, University of Maryland, College Park, MD (1971).
[4]J. Puric and N. Konjević, Z. Phys. 249, 440 (1972).
[5]D. Hadziomerspahic, M. Platisa, N. Konjević, and M. Popović, Z. Phys. 262, 169 (1973).

Key data on experiments

| Ref. | Plasma source | Method of measurement: Electron density | Method of measurement: Temperature | Remarks |
|---|---|---|---|---|
| 1 | Plasma jet | $H_\alpha$ and $H_\beta$ Stark width | Plasma composition data | |
| 4 | T-tube | Laser interferometry at 6328 Å | Boltzmann plot of Ar II line intensities | |
| 5 | Z-pinch | Laser interferometry at 6328 Å | Boltzmann plot of Ar II line intensities | |

Numerical results for Sr II

| No. | Transition array | Multiplet (No.) | Wavelength (Å) | Temperature (K) | Electron density ($10^{17}$ cm$^{-3}$) | $w_m$ (Å) | $w_m/w_{th}$ | $d_m$ (Å) | $d_m/d_{th}$ | Acc. | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | 5s–5p | $^2S-^2P^o$ (1) | 4077.71 | 13000 | 1.0 | 0.32 | 0.89 | -0.067 | 0.43 | B,C | 1 |
| | | | | 14200 | 1.0 | | | -0.09 | 0.65 | C | 4 |
| | | | | 31700 | 1.0 | 0.22 | 0.79 | | | C+ | 5 |
| | | | 4215.52 | 13000 | 1.0 | 0.32 | 0.89 | -0.067 | 0.43 | B,C | 1 |
| | | | | 14200 | 1.0 | | | -0.09 | 0.65 | C | 4 |
| | | | | 31700 | 1.0 | 0.24 | 0.86 | | | C+ | 5 |

# Sulfur

## S III

Ground State: $1s^22s^22p^63s^23p^2\ ^3P_0$

Ionization Energy: 34.83 eV = 280900 cm$^{-1}$

| Wavelength (Å) | No. | Wavelength (Å) | No. | Wavelength (Å) | No. | Wavelength (Å) | No. |
|---|---|---|---|---|---|---|---|
| 2718.88 | 7 | 2872.00 | 6 | 3387.13 | 1 | 3928.62 | 2 |
| 2756.89 | 7 | 2950.23 | 8 | 3662.01 | 5 | 3983.77 | 2 |
| 2856.02 | 6 | 2964.80 | 8 | 3831.95 | 4 | 4332.71 | 3 |
| 2863.53 | 6 | 3370.38 | 1 | 3899.09 | 4 | 4361.53 | 3 |

The pulsed arc experiment by Platisa *et al.*[1] has produced Stark broadening data for a fairly large number of S III lines. In addition to the usual comparison with the modified semiempirical approximation, which we list in the tables (see general introduction), comparisons with several other theoretical approaches may be made. These yield the following experiment/theory width ratios (averaged over all experimental data):

- with the semiempirical method,[2] $w_m/w_{th} = 1.65$;
- with the semiclassical method,[3] $w_m/w_{th} = 0.73$;
- with the semiclassical Gaunt factor method,[4] $w_m/w_{th} = 1.03$;
- with the simplified semiclassical method,[2] $w_m/w_{th} = 0.74$;
- with a modification of the preceding simplified semiclassical method,[2] $w_m/w_{th} = 0.96$.

### References


[1] M. Platisa, M. Popovic, M. Dimitrijević, and N. Konjević, J. Quant. Spectrosc. Radiat. Transfer **22**, 333 (1979).

[2] M. S. Dimitrijević and N. Konjević, J. Quant. Spectrosc. Radiat. Transfer **24**, 451 (1980).

[3] M. S. Dimitrijević and N. Konjević, J. Quant. Spectrosc. Radiat. Transfer **27**, 203 (1982).

[4] J. D. Hey and P. Breger, J. Quant. Spectrosc. Radiat. Transfer **24**, 427 (1980).


Key data on experiments

| Ref. | Plasma source | Method of measurement: Electron density | Method of measurement: Temperature | Remarks |
|---|---|---|---|---|
| 1 | Low-pressure pulsed arc | Laser interferometry at 6328 Å | Boltzmann plot of S III line intensities | |

Numerical results for S III

| No. | Transition array | Multiplet (No.) | Wavelength (Å) | Temperature (K) | Electron density ($10^{17}$ cm$^{-3}$) | $w_m$ (Å) | $w_m/w_{th}$ | $d_m$ (Å) | $d_m/d_{th}$ | Acc. | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | $3p3d-3p(^2P^\circ)4p$ | $^3P^\circ-^3P$ (2) | 3370.38 | 28500 | 0.51 | 0.076 | 1.16 | | | C+ | 1 |
| | | | 3387.13 | 28500 | 0.51 | 0.077 | 1.16 | | | C+ | 1 |
| 2. | | $^3D^\circ-^3P$ (8) | 3928.62 | 28500 | 0.51 | 0.088 | 0.96 | | | C+ | 1 |
| | | | 3983.77 | 28500 | 0.51 | 0.086 | 0.95 | | | C+ | 1 |
| 3. | $3p4s-3p(^2P^\circ)4p$ | $^3P^\circ-^3D$ (4) | 4332.71 | 28500 | 0.51 | 0.125 | 0.88 | | | C+ | 1 |
| | | | 4361.53 | 28500 | 0.51 | 0.126 | 0.88 | | | C+ | 1 |
| 4. | | $^3P^\circ-^3P$ (5) | 3831.95 | 28500 | 0.51 | 0.101 | 0.86 | | | C+ | 1 |
| | | | 3899.09 | 28500 | 0.51 | 0.098 | 0.85 | | | C+ | 1 |
| 5. | | $^3P^\circ-^3S$ (6) | 3662.01 | 28500 | 0.51 | 0.093 | 0.84 | | | C+ | 1 |
| 6. | $3p4p-3p(^2P^\circ)4d$ | $^3D-^3F^\circ$ (15 UV) | 2856.02 | 28500 | 0.51 | 0.105 | 1.56 | | | C+ | 1 |
| | | | 2863.53 | 28500 | 0.51 | 0.103 | 1.53 | | | C+ | 1 |
| | | | 2872.00 | 28500 | 0.51 | 0.102 | 1.52 | | | C+ | 1 |
| 7. | | $^3D-^3D^\circ$ (16 UV) | 2718.88 | 28500 | 0.51 | 0.103 | 1.64 | | | C+ | 1 |
| | | | 2756.89 | 28500 | 0.51 | 0.105 | 1.67 | | | C+ | 1 |
| 8. | | $^3P-^3D^\circ$ (18 UV) | 2950.23 | 28500 | 0.51 | 0.107 | 1.43 | | | C+ | 1 |
| | | | 2964.80 | 28500 | 0.51 | 0.108 | 1.44 | | | C+ | 1 |

## S IV

Ground State: $1s^22s^22p^63s^23p\ ^2P^\circ_{1/2}$

Ionization Energy: 47.30 eV = 381541.4 cm$^{-1}$

The Stark width for the $4s\ ^2S-4p\ ^2P^\circ$ line at 3097.46 Å has been measured with a low pressure pulsed arc by Platisa *et al.*[1] The electron density was determined by laser interferometry ($N_e$ = $5.1\times10^{16}$ cm$^{-3}$) and the temperature was derived from a Boltzmann-plot of S III line intensities ($T$ = 28500 K). The full width at half maximum was measured to be $\Delta\lambda_{1/2}$ = 0.059 Å and a "C+" accuracy is estimated. As with other multiply ionized atoms in these tables, we have compared this experimental result with the modified semiempirical approximation, which yields a ratio $w_m/w_{th}$ = 0.80. The measured width may also be compared with several other theoretical approaches, and the following ratios are obtained:

- with the semiempirical approximation,[2] $w_m/w_{th}$ = 1.65;
- with the semiclassical Gaunt factor approach,[3] $w_m/w_{th}$ = 0.89;
- with the simplified semiclassical method,[2] $w_m/w_{th}$ = 0.64;
- with a modification of the preceding simplified semiclassical method,[2] $w_m/w_{th}$ = 1.06.

### References

[1]M. Platisa, M. Popovic, M. Dimitrijević, and N. Konjević, J. Quant. Spectrosc. Radiat. Transfer **22**, 333 (1979).

[2]M. S. Dimitrijević and N. Konjević, J. Quant. Spectrosc. Radiat. Transfer **24**, 451 (1980).

[3]J. D. Hey and P. Breger, J. Quant. Spectrosc. Radiat. Transfer **24**, 427 (1980).

# Tin

## Sn II

Ground State: $1s^22s^22p^63s^23p^63d^{10}4s^24p^64d^{10}5s^25p\ ^2P^\circ_{1/2}$

Ionization Energy: 14.632 eV = 118017.0 cm$^{-1}$

Miller *et al.*[1] studied the Stark widths of seven Sn II multiplets utilizing photographic spectra obtained with a gas driven shock tube. Comparisons were made with the semiempirical formula[2] and the agreement for multiplets No. 2–6 in the following table was found to be satisfactory, yielding an average value[1] $w_m/w_{th} = 0.93$.

### References

[1]M. H. Miller, R. A. Roig, and R. D. Bengtson, Phys. Rev. A **20**, 499 (1979).
[2]H. R. Griem, Phys. Rev. **165**, 258 (1968).

Key data on experiments

| Ref. | Plasma source | Method of measurement: Electron density | Method of measurement: Temperature | Remarks |
|---|---|---|---|---|
| 1 | Gas-driven shock tube | $H_\beta$ Stark width | Line reversal technique applied to $H_\alpha$ line; absolute intensity of Ne I 5852 Å line and $H_\beta$ | Photographic technique |

Numerical results for Sn II

| No. | Transition array | Multiplet (No.) | Wavelength (Å) | Temperature (K) | Electron density ($10^{17}$ cm$^{-3}$) | $w_m$ (Å) | $w_m/w_{th}$ | $d_m$ (Å) | $d_m/d_{th}$ | Acc. | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | $5s5p^2$–$5s^2(^1S)6p$ | $^4P$ - $^2P^\circ$ | 4816 | 11600 | 1.0 | 1.6 | | | | D+ | 1 |
| 2. | $5s^26s$–$5s^2(^1S)6p$ | $^2S$ - $^2P^\circ$ | 6844.05 | 11600 | 1.0 | 4.2 | | | | D+ | 1 |
| 3. | $5s5p^2$–$5s^2(^1S)4f$ | $^2D$ - $^2F^\circ$ | 3351.97 | 11600 | 1.0 | 2.5 | | | | C | 1 |
| | | | 3283.21 | 11600 | 1.0 | 2.3 | | | | C | 1 |
| 4. | $5s^25d$–$5s^2(^1S)4f$ | $^2D$ - $^2F^\circ$ | 5799.18 | 11600 | 1.0 | 4.2 | | | | D+ | 1 |
| | | | 5588.92 | 11600 | 1.0 | 3.8 | | | | C | 1 |
| 5. | $5s^26p$–$5s^2(^1S)6d$ | $^2P^\circ$ - $^2D$ | 5561.95 | 11600 | 1.0 | 5.1 | | | | C | 1 |
| | | | 5332.36 | 11600 | 1.0 | 5.3 | | | | C | 1 |
| 6. | $5s^26p$–$5s^2(^1S)7s$ | $^2P^\circ$ - $^2S$ | 6761.45 | 11600 | 1.0 | 5.5 | | | | C | 1 |
| 7. | $5s^26p$–$5s^2(^1S)7d$ | $^2P^\circ$ - $^2D$ | 3575.45 | 11600 | 1.0 | 3.0 | | | | C | 1 |

# Xenon

## Xe II

Ground State: $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^2 4p^6 4d^{10} 5s^2 5p^5\ ^2P^o_{3/2}$

Ionization Energy: 21.21 eV = 171068.4 cm$^{-1}$

Two recent shock tube experiments by Lesage *et al.*[1] and Miller *et al.*[2] have yielded Stark widths for several Xe II lines. The results of Ref. 1 were obtained with three different gas driven shock tubes. The data in both papers are given normalized to an electron density of $1 \times 10^{17}$ cm$^{-3}$. The experimental data of Ref. 1 have been compared with semiempirical calculations and an excellent average ratio of $w_m/w_{th} = 1.01$ was found.

### References

[1]A. Lesage, M. H. Miller, J. Richou, and T. Bach, in *Spectral Line Shapes*, Ed. B. Wende, W. de Gruyter, Berlin (1981), p. 257.
[2]M. H. Miller, A. Lesage, and D. Abadie, Phys. Rev. A **25**, 2064 (1981).

Key data on experiments

| Ref. | Plasma source | Method of measurement: Electron density | Method of measurement: Temperature | Remarks |
|---|---|---|---|---|
| 1 | Three gas-driven shock tubes | Laser interferometry and $H_\beta$ Stark profile | Line reversal and plasma composition data | Photographic technique |
| 2 | Gas-driven shock tube | $H_\beta$ Stark width | Line reversal technique applied to $H_\alpha$ line; absolute intensity of Ne I 5852 Å line and $H_\beta$ | Photographic technique |

Numerical results for Xe II

| No. | Transition array | Multiplet (No.) | Wavelength (Å) | Temperature (K) | Electron density ($10^{17}$ cm$^{-3}$) | $w_m$ (Å) | $w_m/w_{th}$ | $d_m$ (Å) | $d_m/d_{th}$ | Acc. | Ref. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. | $5p^4 6s$–$5p^4(^3P)6p$ | $^4P$ - $^4P^o$ | 5292.22 | 11000 | 1.0 | 0.88 | | | | C | 1 |
| | | | | 11200** | 1.0 | 0.93$^a$ | | | | C+ | 2 |
| | | | 5372.39 | 11000 | 1.0 | 0.84 | | | | C+ | 1 |
| | | | | 11200 | 1.0 | 0.90$^b$ | | | | C+ | 2 |
| 2. | | $^4P$ - $^4D^o$ | 4603.03* | 11000 | 1.0 | 0.81 | | | | C+ | 1 |
| | | | | 11200 | 1.0 | 0.84$^b$ | | | | C+ | 2 |
| | | | 4844.33* | 11000 | 1.0 | 0.81 | | | | C+ | 1 |
| | | | | 11200 | 1.0 | 0.86$^c$ | | | | C+ | 2 |
| | | | 5419.15 | 11000 | 1.0 | 0.81 | | | | C+ | 1 |
| | | | | 11200 | 1.0 | 0.95$^d$ | | | | C+ | 2 |
| 3. | $5p^4 5d$–$5p^4(^3P)6p$ | $^4D$ - $^4D^o$ | 5472.61 | 11000 | 1.0 | 0.90 | | | | C+ | 1 |
| | | | | 11200 | 1.0 | 0.96$^e$ | | | | C+ | 2 |
| 4. | | $^4D$ - $^4P^o$ | 6051.15 | 11000 | 1.0 | 0.91 | | | | C | 1 |
| | | | | 11200 | 1.0 | 0.96$^f$ | | | | C+ | 2 |

*Wavelengths taken from Striganov and Sventitskii (see general introduction).
**The temperature range for all results from Ref. 2 is 10200–12400 K. Ranges of electron density measurements (in $10^{17}$ cm$^{-3}$) are: a → 0.6–1.8; b → 0.7–1.8; c → 0.7–1.0; d → 0.6–1.8; e → 0.6–1.0; and f → 0.7–1.0.