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REGULARITIES IN STARK BROADENING PARAMETERS*

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Abstract: Existence of regularities and systematic trends of Stark broadening parameters has been indicated using semiempirical formulae of Griem[5] for width and shift of spectral lines. The relationship between Stark broadening parameters and nuclear charge was found and these regularities were illustrated by the experimental results for elements belonging to second group of periodic system.

1. Introduction

Systematic trends and some regularities in atomic oscillator strengths detected by Wiese[1-4] have already found numerous applications. The three major regularities in atomic f — values were indicated:

— systematic trends for the f — values for a fixed transition along an isoelectronic sequence,

— systematic trends for the f — values of corresponding lines of chemically similar families of elements (homologous atoms); and

— systematic trends of f — values within the spectral series.

Since the physical analogue exists, we have used similar procedure, and found some regularities also for the Stark broadening parameters of the lines originating from homologous atoms, and for the lines from isoelectronic sequences.

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2. *Theoretical principles*

Griem has derived semiempirical expressions for half-half width and shift of an isolated ion line

$$w_{se} \cong 8\left(\frac{\pi}{3}\right)^{\frac{3}{2}}\frac{h}{ma_0}N\left(\frac{E_H}{k_T}\right)^{\frac{1}{2}}\sum_{i'f}\left[|<i'|r|i>|^2\bar{g}_{se}\left(\frac{\bar{E}}{|\Delta E_{i'i}|}\right)+\right.$$

$$\left.+|<f'|r|f>|^2\bar{g}_{se}\left(\frac{\bar{E}}{|\Delta E_{f'f}|}\right)\right], \tag{1}$$

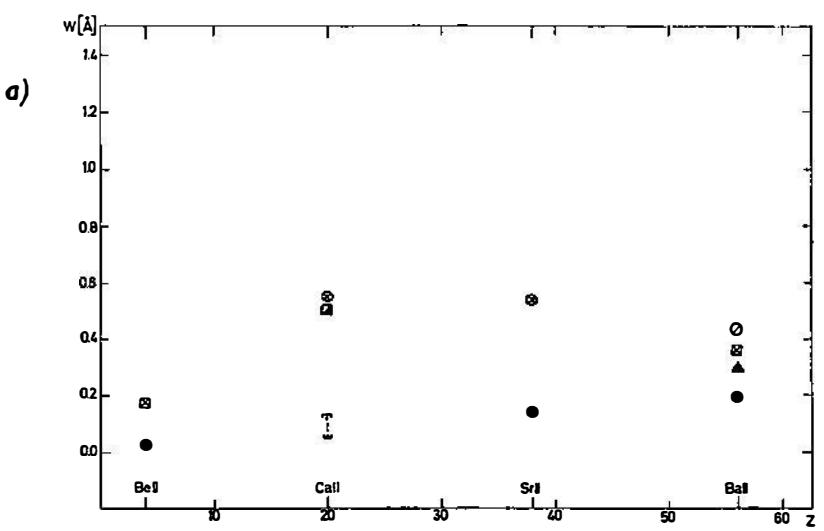
$$d \cong -8\left(\frac{\pi}{3}\right)^{\frac{3}{2}}\frac{h}{ma_0}N\left(\frac{E_H}{k_T}\right)^{\frac{1}{2}}\sum_{i'f}\left[\frac{\Delta E_{i'i}}{|<E_{i'i}|}|<i'|r|i>|^2\bar{g}_{sh}\left(\frac{\bar{E}}{|\Delta E_{i'i}|}\right)-\right.$$

$$\left.-\frac{\Delta E_{f'f}}{|\Delta E_{f'f}|}|<f'|r|f>|^2\bar{g}_{sh}\left(\frac{\bar{E}}{|\Delta E_{f'f}|}\right)\right], \tag{2}$$

where $\bar{g}_{se}$ and $\bar{g}_{sh}$ are the effective Gaunt factors for the width and shift respectively.

Both of these expressions contain matrix elements $<i'|r|i>$ which can be calculated treating perturbing levels individually, using Shore and Mentzel[6] tables, from the following relation

$$|<i'|r|i>|^2 = \frac{S_{i'i}}{2\bar{J}+1}, \tag{3}$$



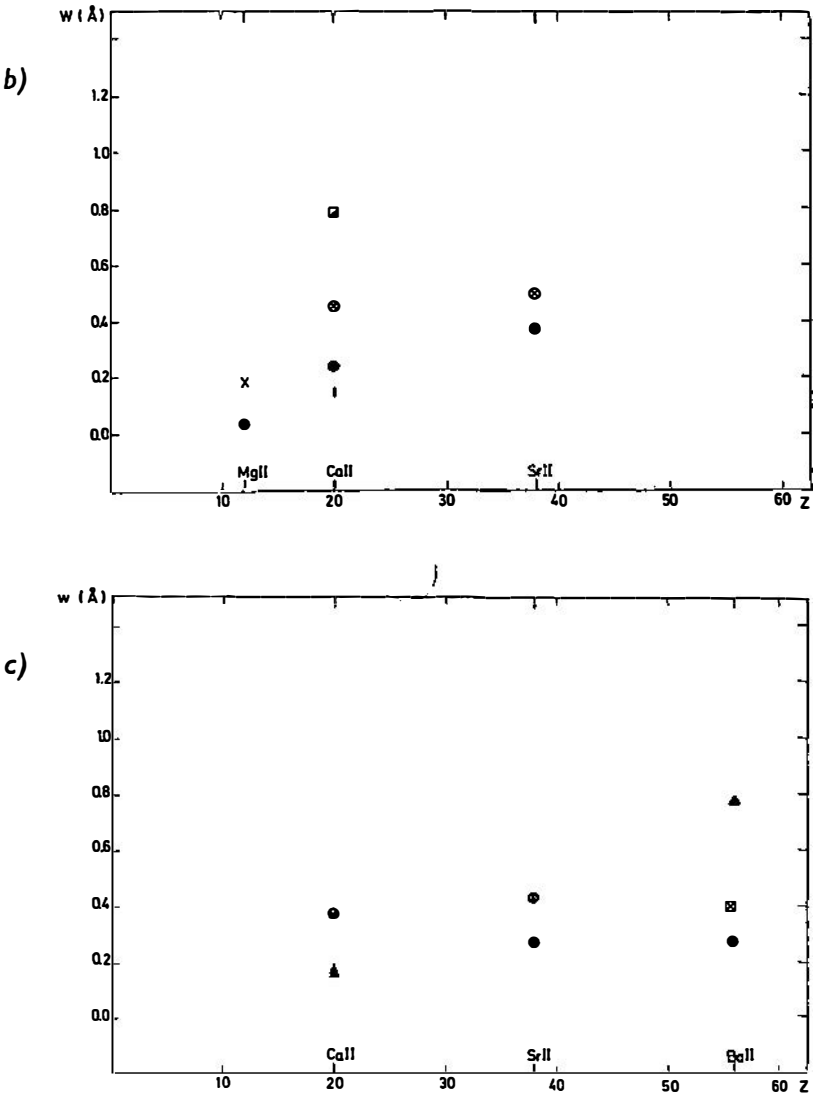


Fig.1. Values of w versus charge of the nucleus Z for the lines originating from various transitions of homologous atoms:

a) $ns - np$,

b) $np - (n + 1)s$,

c) $np - nd$.

$n = 2$ for Be II, $n = 4$ for Ca II, $n = 5$ for Sr II and $n = 6$ for Ba II.

● Griem[5], ⊘ Jäger[7], ⊗ Purić et al.,[8] ⊠ Platiša et al.,[9] ◹ Kush et al.[10] ▲ Cooper et al.,[11] × Purić,[12] | Hadžiomerspahić et al.,[13] — Sahal Brechot[14] ■ Purić et al.[15], □ Yamamoto[16], ⊙ Griem[17], I Platiša et al.[9], Chapell et al.[18], Purić et al.[8], Roberts et al.[19], Griem[5], Hildum et al.[20].

where $S_{i'i}$ is the line strength of a transition $i' \rightarrow i$. Wiese[5] has derived the line strength $S_{i'i}$ for a fixed transition along an isoelectronic sequence in the form of the series

$$S_{i'i} = S_0 Z^{-2} + S_1 Z^{-3} + S_2 Z^{-4} + \ldots, \tag{4}$$

where S_0 is hydrogenic quantity and Z is nuclear charge of the emitters from an isoelectronic array. Since the expressions for width and shift contain this quantity, by substitution of Equ. (3) and Equ. (4) in Equs. (1) and (2) one obtains after simplification the following series expansions for the Z — dependence of w and d

$$w = w_0 Z^{-2} + w_1 Z^{-3} + w_2 Z^{-4} + \ldots, \tag{5}$$

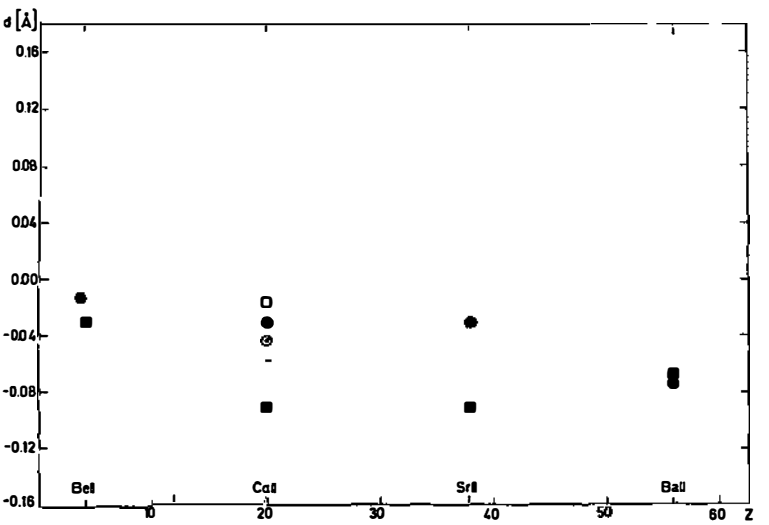
$$d = d_0 Z^{-2} + d_1 Z^{-3} + d_2 Z^{-4} + \ldots . \tag{6}$$

Both of these series expansions begin with leading terms which are also hydrogenic quantities.

From Equs. (5) and (6) one can conclude that for the lines of a fixed transition along an isoelectronic sequence, $Z^2 w$ and $Z^2 d$ should depend linearly on $1/Z$, provided Z is sufficiently large.

For the homologous atoms, according to Wiese, systematic trends in S and f values are to be expected on account of analogous configuration of their outher electrons. Analogous transitions of homologous atoms should exhibit similar values, but these trends are not so clear as in the case of isoelectronic sequence, where the electronic configuration is the same.

a)



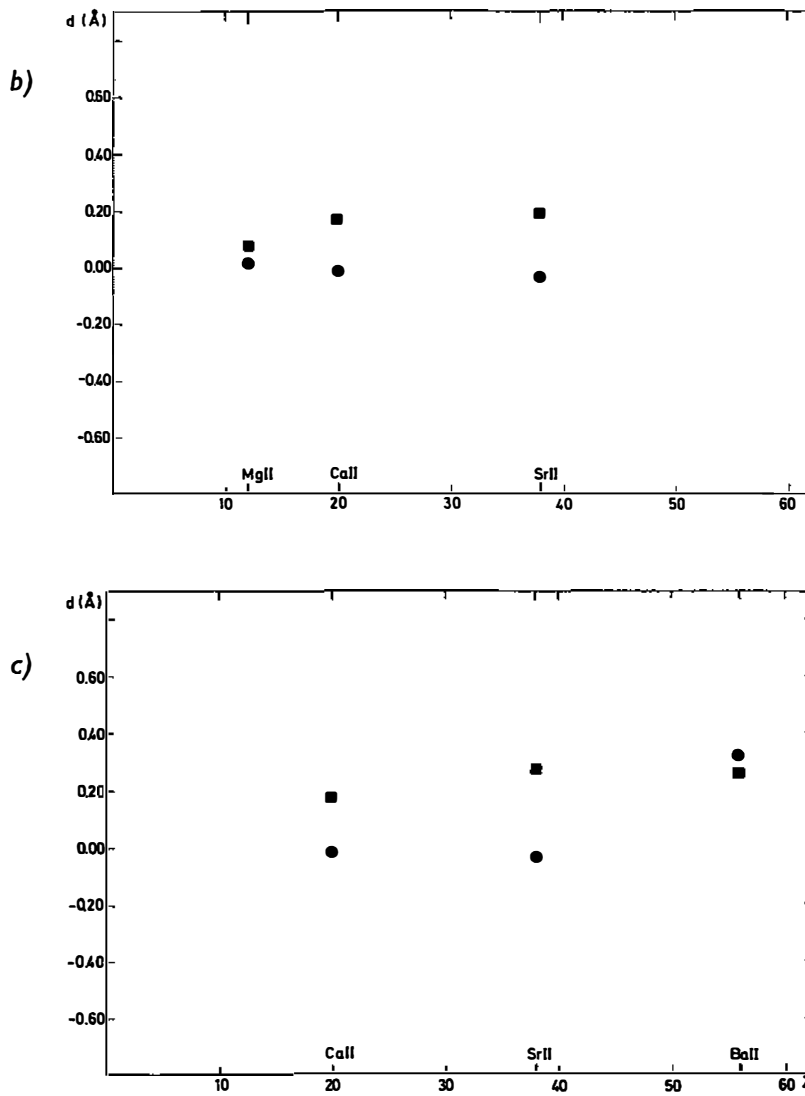


Fig. 2. Values of d versus charge of the nucleus Z for the lines originating from various transition of homologous atoms:

a) $ns - np$
b) $np - (n + 1)s$
c) $np - nd$

Notations same as for Figs. 1 a), 1 b) and 1 c).

Since the physical analogue exists also in this case, one can expect similar trends also in the Stark broadening parameters — the w and d values originating from the same transition of homologous atoms.

3. *Observed trends in experimental w and d - values*

Experimental data for some ion lines of homologous atoms belonging to earth alkaline metals (second column in the periodic table of elements[7, 20]) together with some results for FI[21, 22] and FII[23] lines were graphically and tabularly presented in order to find systematic trends predicted for similar transitions of these elements with similar electron configuration. For the ionized earth alkaline metals the w — and d — values show just a weak dependence on the nuclear charge of the emitters for the following types of transitions

$$ns - np,\ np - (n+1)s \text{ and } np - nd,$$

where $n = 2$ for Be II, 3 for Mg II, 4 for Ca II, 5 for Sr II and 6 for Ba II.

In Figs. 1 and 2 w and d multiplet values are given for the above mentioned transitions of homologous atoms. These figures contain all experimental and theoretical data of Stark broadening parameters for the given multiplets known to the authors, and also theoretical results calculated using Griem' s semiempirical formula. From the figures one may conclude that there exists agreement between w and d — multiplet values (within one order of magnitude), especially if one takes into account large scatter of experimental data for some Ca II and Ba II lines.

Finally, comparing experimental data for the Stark half-half width of the lines originating from the similar transitions of F I[21, 22] and A II[23] atomic species, one can find also a reasonable agreement. Results quoted are presented in the Table.

TABLE

Transition			w-values
	F I (Ref.[21])	(Ref.[22])	A II (Ref.[23])
$ns\ ^4P\text{-}np\ ^4P^0$	—	0.15	0.16
$ns\ ^4P\text{-}np\ ^4D^0$	0.19	0.17	0.17
$ns\ ^4P\text{-}np\ ^4S^0$	0.16	0.16	0.12
$ns\ ^2P\text{-}np\ ^2S^0$	—	0.12	0.22
$ns\ ^2P\text{-}np\ ^2P^0$	—	0.12	0.15

Because of lack of relevant experimental or theoretical data it is at present not possible to give examples supporting Equs. (5) and (6) for isoelectronic sequences.

4. *Conclusions*

Experimental data for Stark broadening and shift of lines originating from the homologous atoms indicate the systematic trends predicted by the theory. Obviously similar broadening effects, under the same plasma conditions, are closely connected with similarity of electron configuration of the outer shells of homologous atoms. Regularities are also expected to be found for isoelectronic sequences, but there is still a lack of experimental and theoretical data.

References

1) W. L. Wiese, and A. W. Wiese, Phys. Rev. **175** (1968) 50;
2) W. L. Wiese, Appl. Opt. **7** (1968) 2361;
3) W. L. Wiese, Beam Foil Spectroscopy, (Gordon and Breach Publ., New York, 1968) 385–406,
4) W. L. Wiese, »Regularities in Atomic Oscillator Strengths« in: Physics of Ionized Gases edited by M. V. Kurepa, (Institute of Physics, Beograd, Yugoslavia, 1972);
5) H. R. Griem, Phys. Rev. **165** (1968) 258;
6) B. W. Shore and D. H. Mentzel, Astrophys. J. Suppl., Ser. 22, No **106** (1965) 197;
7) H. Jäger, Z. Phys. **223** (1969) 19;
8) J. Purić, M. Platiša and N. Konjević, Z. Phys. **247** (1971) 216;
9) M. Platiša, J. Purić, N. Konjević and J. Labat, Astron. Astrophys., **15** (1971) 325
10) H. J. Kush and H. P. Pritschow, Astron. Astrophysci. **4** (1970) 31;
11) J. Cooper and G. K. Oertel, Phys. Rev. Lett., **18** (1967) 985;
12) J. Purić, »Experimental Study of Stark Broadening of Ions in Plasmas« in: Physics of Ionized Gases, edited by M. V. Kurepa (Institute of Physics, Beograd, Yugoslavia, 1972);
13) D. Hadžiomerspahić, N. Konjević, M. Platiša and M. Popović, VI SPIG Constributed Papers, 221, Miljevac by Split (1972);
14) S. Sahal Brechot, Astron. Astrophys. **1** (1969) 322;
15) J. Purić and N. Konjević, Z. Physik, **249** (1972) 440;
16) M. Yamamoto, Phys. Rev. **145** (1966) 137;
17) H. R. Griem, Plasma Spectroscopy (McGraw-Hill, New York 1964);
18) J. Chapelle and S. Sahal Brechot, Astron. Astrophys. **6** (1970) 415;
19) J. R. Roberts and K. L. Eckerle, Phys. Rev. **159** (1967) 104;
20) J. S. Hildum and J. Cooper, Phys. Lett. **36A** (1971) 153;
21) J. Purić, Ph. D. Thesis, University of Beograd (1972);
22) N. Konjević, M. Popović and M. Platiša, Z. Physik, **257** (1972) 235;
23) N. Konjević, J. Labat, Lj. Ćirković and J. Purić, Z. Physik **235** (1970) 35.

PRAVILNOSTI PARAMETARA STARKOVOG ŠIRENJA

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SADRŽAJ

Pokazano je da postoje pravilnosti i sistematski trendovi parametara Štarkovog širenja korišćenjem semi-empirijske formule Greim-a[5] za širinu i pomeraj spektralnih linija. Sledeći ovu teoriju nađena je relacija između parametara Štarkovog širenja i naelektrisanja jezgra a regularnosti su ilustrovane eksperimentalnim rezultatima za elemente druge grupe periodnog sistema.