STARK BROADENING REGULARITIES WITHIN SEVERAL SPECTRAL SERIES OF NEUTRAL POTASSIUM

I. P. Dojčinović, I. Tapalaga and J. Purić

Faculty of Physics, University of Belgrade, POB 44, 11000 Belgrade, Serbia

Abstract

The electron and proton impact contribution to the Stark widths dependences on the upper level ionization potential for different spectral series of neutral potassium have been studied and discussed. Term structure and temperature influences on the found dependence were also studied. The differences between the found dependences within different spectral series were smaller at high temperatures.

1. INTRODUCTION

It is very convenient for studying Stark broadening parameters regularities to express them as the function of the binding energy of the electron undergoing transition. The upper level ionization potential χ conveys the plasma electric micro-field influence on the electron undergoing transition. The effect of plasma electric micro-field on the Stark broadening of particular line is higher if the bounding energy is lower. This dependence was successfully used recently in a series of papers devoted to the study of regularities within spectral series of Mg I /1/, Be I /2/, He I /3/ and Ca I /4/ where coefficients obtained suggested that the upper level ionization potential is an appropriate parameter for studying the Stark broadening behaviour within similar spectra. The aim of this paper is to analyse functional dependence of electron and proton impact contribution to the Stark widths of spectral lines (FWHM) on the upper level ionization potential, within several spectral series of K I. Using the proposed simple model, one can provide Stark broadening data for transitions that have not yet been calculated due to the lack of parameters needed in more complicated models.

Stark broadening data used for the analysis presented in this paper was taken from /5-7/. Most of this data are available online /8/. Data for ionization potential of K I spectral lines were taken from NIST database /9/. A total of 33 spectral lines of K I have been collected and analysed. Within these data the following series have been investigated: 3d-np (2), 3d-nf (2), 4d-np (2), 4p-nd (2), 4p-ns (2), 4s-np (2) and 4d-nf (2). Next to the series notation there is a number in parentheses (2) indicating doublet spectral lines.

2. THEORETICAL BACKGROUND

Similar behaviour of Stark broadening data and χ was found by Purić et al. /10/. This discovery was followed by investigation of analytic relation between Stark widths and χ in paper /11/. The quantum theoretical basics for this relation are given in /12/. The final form of Stark width dependence is given by:

$$\omega = a \cdot \chi^{-b} \tag{1}$$

In this equation, w is Stark width in rad/s, is the upper level ionization potential taken in eV; and a, b are the fitting coefficients independent of χ . In order to investigate this dependence one has to have an accurate database normalised to the same electron density and temperature as it is described elsewhere /1/.

3. RESULTS AND DISCUSSION

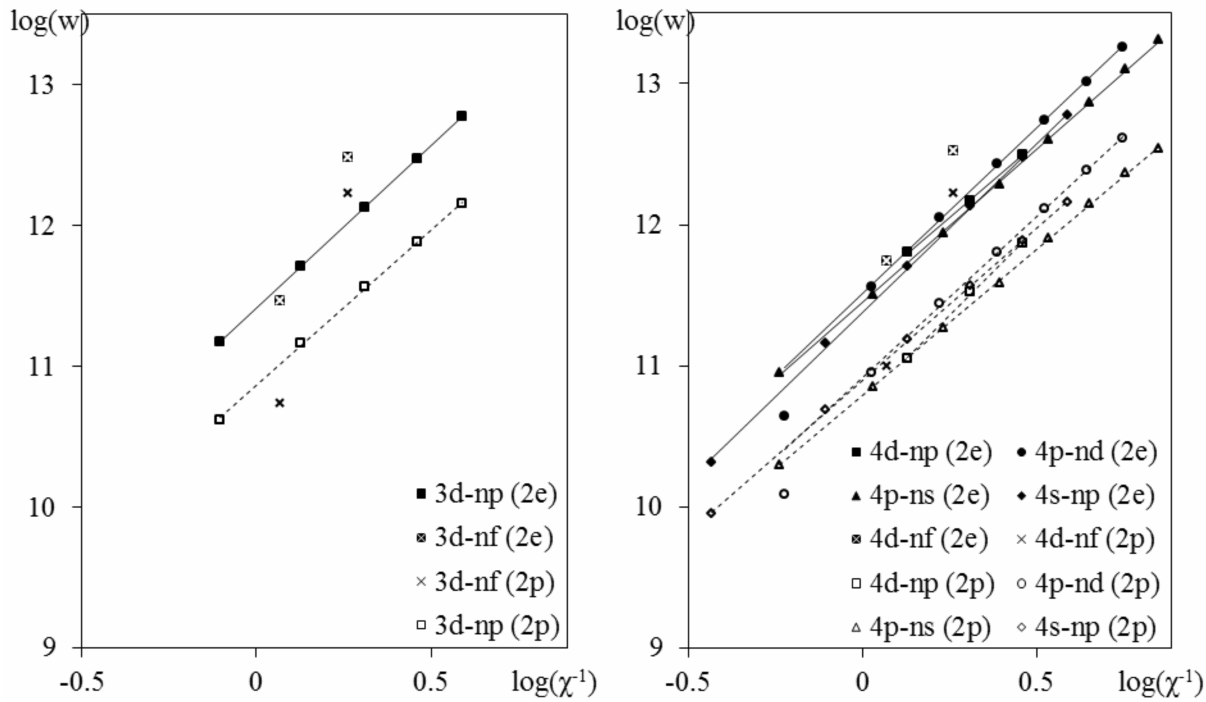

Figure 1 The electron and proton impact contributions to Stark widths (in rad/s) versus inverse upper level ionization potential (in eV) presented in log-log scale for different K I spectral series with principal quantum number of lower level equal to n=3 and n=4 at temperature 10 000 K. The number 2 in brackets indicates doublets, letters e and p indicate electron and proton contribution respectively.

Normalization of source data was done by custom made software according to the above equations. For all the studied series it was found that the relation given by equation 1 is appropriate for all temperatures in range from 5 000 K to 25 000 K in the case of electron and proton impact contributions. Such dependences of the Stark width on the upper level ionization potential were verified for 33 spectral lines belonging to 7 spectral series studied here. The appropriate dependences expressed by equation 1 for all studied series are given graphically by straight lines in Figure 1.

The electron and proton impact contributions to the Stark widths dependences versus inverse value of the upper level ionization potential given for all investigated spectral series for different K I spectral series with principal quantum number of lower level equal to n=3 and n=4 is presented in Fig. 1, for electron temperature of 10 000 K. The average relative contribution of proton impact is 24% of electron contribution at 10 000 K. Similar regularities were noticed in preceding papers /1-4/. When the studied spectral series were treated separately, the majority of the corresponding coefficients of determinations R^2 were better than 0.99, except for series 4p-nd. The reason for low R^2 value for this series lies in low Stark width for transition 4p-3d because 3d state has no close perturbing f or any other state. For series 3d-nf and 4d-nf coefficients of determination R^2 were not available for only two lines per series existing. It was found, as well, that for 3d- 3f and 4d-3f there are no close perturbing states for 3f transition and so lines obtained were narrower than expected. If 4p-3d transition is excluded from trend analysis, obtained R^2 values for electron contribution are much better, namely, 0.9997 instead of 0.9879 for temperature of 10 000 K. Average relative deviation from the obtained trends for all spectral transitions is approximately 3% at T=10 000 K. In addition to trend analysis, the obtained Stark width dependences on the upper level ionization potential can be used for prediction of Stark widths data for the lines of interest, in astrophysics as well as in atomic physics, not investigated until now.

4. CONCLUSION

Searching for different types of regularities and systematic trends which can simplify complicated theoretical calculations is of great interest. In this work the existence of the functional dependences of Stark widths on the upper level ionization potential was shown for the lines originating from the 7 studied series. These dependences were obtained and found to be of the form given by equation 1. Electron and proton impact contribution to Stark width broadening have the same type of behaviour, but the proton contribution is significantly smaller. They can be used to evaluate the results of Stark broadening data that is already measured or calculated or for prediction of the Stark widths values for the lines not measured or theoretically calculated until now but belonging to the investigated series.

The best precision can be obtained using the same equation for any particular series separately. In order to achieve better linear fitting for 3p-nd series, transition 3p-3d has to be neglected in the further analysis.

Acknowledgements

This work is financially supported by the Ministry of Education and Science of the Republic of Serbia within the project 171034.

References

1. Tapalaga I., Dojčinović I. P., Purić J., 2011, Mon. Not. R. Astron. Soc., 415, 503
2. Dojčinović I. P., Tapalaga I., Purić J., 2011, Publ. Astron. Soc. Aust., 28, 281
3. Dojčinović I. P., Tapalaga I., Purić J., 2012, Mon. Not. R. Astron. Soc., 419, 904
4. Tapalaga I., Dojčinović I. P., Milosavljević M. K., Purić J., 2012, Publ. Astron. Soc. Aust., 29, 20
5. Dimitrijević M. S., Sahal-Bréchot S., 1984, A&A, 136, 289
6. Dimitrijević M. S., Sahal-Bréchot S., 1987, JQSRT, 38, 37
7. Dimitrijević M. S., Sahal-Bréchot S., 1990, BOBeo, 142, 29
8. Sahal-Bréchot, S., Dimitrijević, M.S., Moreau N., 2012. Stark-B database, [online]. Available: http://stark-b.obspm.fr [Feb 13, 2012]. Observatory of Paris, LERMA and Astronomical Observatory of Belgrade
9. Ralchenko Yu., Kramida A. E., Reader J., and NIST ASD Team (2012). NIST Atomic Spectra Database (ver. 4.1.0), [Online]. Available: http://physics.nist.gov/asd [2012, January 17]. National Institute of Standards and Technology, Gaithersburg, MD
10. Purić J., Lakićević I., Glavonjić V., 1979, JPhys, 40, 795
11. Purić J., Lakićević I., Glavonjić V., 1980, PhLA, 76, 128
12. Griem H. R., 1968, PhRv, 165, 258