UDC 539.182

T. A. Florko, A. V. Glushkov, Yu. M. Lopatkin, S. V. Ambrosov, V. P. Kozlovskaya

1Odessa State Environmental University, L’vovskaya str.15, Odessa-16, 65016, Ukraine
2Sumy State University, 2, Rimsky-Korsakov Street, 40007, Sumy, Ukraine
e-mail: quantflo@mail.ru

ON INTENSITY OF EMISSION OF THE METALS ATOMS IN A HYDROGEN-OXYGEN FLAME IN A PRESENCE OF A MAGNETIC FIELD

An intensity of emission for the alkali atoms (potassium and rubidium) in the hydrogen-oxygen flame under action of a magnetic field is theoretically estimated with using quantum defect approximation in operator perturbation theory for atomic systems in external magnetic field. New estimates for the intensities of emission of the lines for K (D1: $4^2P_{1/2}-4^2S_{1/2}$ and D2: $4^2P_{3/2}-4^2S_{1/2}$) and Rb (1: $5^2P_{3/2}-5^2S_{1/2}$ and 2: $6^2P_{3/2}-5^2S_{1/2}$) are presented. The maximum value of the magnetic effect for D2 line of K atom for σ - polarization is equal 1.65, for π -polarization— 1,24. For Dl line the maximum value is equal 1,36 for both polarizations.

In this paper we present renewed theoretical estimates for intensity of emission of the alkali atoms (potassium and rubidium) in the hydrogen-oxygen flame under action of a magnetic field. To take into account the magnetic field effect we use simplified model based on the operator perturbation theory for atomic systems in external magnetic field. New estimates are listed for the intensities of emission of the lines for K (D1: $4^2P_{1/2}-4^2S_{1/2}$ and D2: $4^2P_{3/2}-4^2S_{1/2}$) and Rb (1: $5^2P_{3/2}-5^2S_{1/2}$ and 2: $6^2P_{3/2}-5^2S_{1/2}$). The maximum value of the magnetic effect for D2 line of K atom for σ - polarization is equal 1.65, for π -polarization— 1,24. For Dl line the maximum value is equal 1,36 for both polarizations. Let us remind that an effect of external field on the spectral parameters for atoms and ions in the flame is of a great interest as in the modern chemical physics and physics of combustion as atomic optics and spectroscopy [1-10].

Among the effects that require further theoretical and experimental research related phenomenon is increasing the intensity of the glow of atoms in a strong magnetic field in the complete absorption at the line center. *The known* example is the excess luminosity of sunspots in the rays Na, Ca^{+}, on the luminosity of the solar disk, which is apparently due to the effects of environmental enlightenment in a magnetic field of about 4.5 kE.

In series of papers by Hayashi et al (look for example, [1]) it has been investigated the fluorescence additives of inorganic salts in flames at atmospheric pressure and was found the effect of external magnetic field H on the intensity of the luminescence of the intermediate particles. For the OH radical in a magnetic field of 18 kE luminescence intensity increased by 14%, and for the sodium atom - by 2.5 times. Sodium salts were introduced into the dispersing aqueous solutions of flame under a stream of nitrogen. The experimentally measured magnetic effect, i.e. the ratio of I(H)/I(0) luminescence intensity in a magnetic field H to the intensity of the glow without a magnetic field. Hayashi et al have shown that such salts $Na\tilde{N}l$ magnetic effect increases with the concentration (s) of the salt in solution, and salts of the type $NaNO2$, on the contrary, the magnetic effect decreases. Sorokin and others [1] concerning the effect of the magnetic field on the intensity of the luminescence of alkali metals sodium and cesium in the flames. Appropriate aerosol stream is saturated nitrogen vapor salts $Na\tilde{N}l$, $\tilde{N}s\tilde{N}l$.

It was studied an influence of the magnetic field strength of 10 kE on the luminescence intensity of the resonance lines of sodium (D1: $3^2P_{1/2}-3^2S_{1/2}$ and D2: $3^2P_{3/2}-3^2S_{1/2}$). The range of variation of pressure sodium $0^{-5}-5.0^{-4}$ Torr. For the line D2 in the case of σ - polarization maximum value of the magnetic effect is equal to 2, and in the case of π- polarization - 1.5. In the case of lines D1 maximum value is 1.6 and is the same for both polarizations. For cesium atom measurements were taken at two wavelengths of transitions (1: $6^2P_{3/2}-6^2S_{1/2}$ and 2: $7^2P_{3/2}-6^2S_{1/2}$). In refs. [2,3] there were presented first theoretical estimates for the effect of a magnetic field on the intensity of the luminescence of alkali metals: sodium and cesium (salts $Na\tilde{N}l$, $\tilde{N}s\tilde{N}l$) in a hydrogen - oxygen flame intensity magnetic field of 10 kE. There were listed preliminary data for the intensity of the luminescence lines of sodium (D1: $3^2P_{1/2}-3^2S_{1/2}$ and D2: $3^2P_{3/2}-3^2S_{1/2}$) and cesium lines (1: $6^2P_{3/2}-6^2S_{1/2}$ and 2: $7^2P_{3/2}-6^2S_{1/2}$). The maximum value of the magnetic effect of the D2 line of the sodium atom in the case of σ - polarization is equal to 1.9, and in the case of π - polarization - 1.45, and for the line D1 maximum value is 1.5.

In order to get more precise data it is necessary to use more consistent model for treating an effect of a magnetic field on the intensity of the luminescence of alkali metals. Here we use such a model and apply it to studying emission intensities for alkali atoms in the hydrogen - oxygen flame under availability of the magnetic field (strength 10 kE) for the lines D1: $4^2P_{1/2}-4^2S_{1/2}$, D2: $4^2P_{3/2}-4^2S_{1/2}$ in potassium and D1: $5^2P_{3/2}-5^2S_{1/2}$ D2: $6^2P_{3/2}-5^2S_{1/2}$)in the caesium.

Naturally, the intensity *I* of the *i-j* transition is connected with the concentration of atoms (standardly determined by the appropriate dissociation constant, see. [2.4]) and correspondingly the line strength S is defined as follows:

$$S = 3\hbar e^2 g_1 f_{i-j} / 2m\omega_0 \ . \qquad (1)$$

Here $\omega_0 = E_i - E_j$ - the frequency of the tran sition, and f_{i-j} -is the radiative transition *i-j* oscillator strength. In approximation of the "length" form *D* transition operator an oscillator strength is defined by the following expresssion:

$$f_{i-j} = 2m/\hbar^2 \left(E_i - E_j\right) \left|\left\langle \Psi_j \middle| D \middle| \Psi_i \right\rangle\right|^2 . \qquad (2)$$

Naturally the intensity σ - component is proportional to the square of the standard *3j*- symbols:

$$\begin{pmatrix} ...J...1.........J' \\ -M.\ 1....M-1 \end{pmatrix}\begin{pmatrix} ...J......1........J' \\ -M.\ -1.....M+1 \end{pmatrix}$$

and for the π – component it has:

$$\begin{pmatrix} ...J......1.....J' \\ -M.\ 0.....M \end{pmatrix}.$$

The key moment of the model is determination of the wave functions. Here the wave functions of the states were found from the numerical solution of the Schrodinger equation for alkali atom in a magnetic field using the simplified quantum defect approximation version of the operator perturbation theory method [11]. Such a model is more correct with the usual H-like approximation, nevertheless it is more simplified in comparison with the model potential approach (look analysis regarding different models in Refs. [6-8,12-14]).

In Table 1 we present our data which illustrate an influence of the magnetic field H in the luminescence intensity of D2 line of the potassium atom in the σ - and π - polarizations depending on the partial pressure of potassium atoms. In the first case, the maximum value of the magnetic effect of I(H)/I(0) is equal to 1.65, and in the second - 1.24.

In the case of line D1 potassium atom calculated value of the maximum magnetic effect - 1,36. Let us not that the preliminary estimate of this value in [3] is 1.4.

For the rubidium atoms the magnetic field increases the intensity of emission line (1) in ~1.5 times. Analysis shows that the obtained renewed estimates are in physically reasonable (at least qualitative) agreement with experimental data.

Table 1

The influence of magnetic field on the intensity of the sodium atom D2 line in the s- and p-polarization as a function of the partial pressure of sodium atoms in flames: I(H)/I(0) - the ratio of the luminescence intensity in the magnetic field strength H of the luminescence intensity without magnetic field; p is the partial pressure (0 $^{-5}$ Torr).

$I(H)/I(O)\backslash p$	6	12	18	24	30
σ - polarization	1,04	1,27	1,65	1,59	1,28
π -polarization	0,98	1,10	1,24	1,22	0,68

References

1. Sorokin N.I., Dultsev E.N., Bazhin N.M. The influence of magnetic field on the intensity of luminescence of alkali metal atoms in a hydrogen-oxygen flame // Chemical Physics. – 1988. – T.7, № 1. – P. 100-103.
2. Kuklin I.V., Kozlovskaya V.P. The calculation of the intensity of luminescence of alkali metal atoms in a hydrogen-oxygen flame in the presence of a magnetic field// Physics aerodisperse systems. – 2001. – Vol38. - P.273-276.
3. Kozlovskaya V.P., The theoretical determination of the intensity of luminescence of alkali metal atoms in a hydrogen-oxygen flame in the presence of a magnetic field// Physics of Aerodisp. Systems. – 2003. – Vol.40 – P.322-326.
4. Kasabov G.A., Eliseev V.V. Spectroscopic tables low-temperature plasma. - M .: Atomizdat, 1973. - P.160.
5. Sobelman I.I. Introduction to the theory of atomic spectra. – M .: Nauka, 1977. – P.213.
6. Kleppner D., Chun-Ho I., Welch G. R. In: Irregular Atomic Systems and Quantum Chaos/ Ed. J.C.Gay (Kluwer,N-Y.,1990).
7. Benvenuto F., Casati G., Shepelyansky D.L. Rydberg Stabilization of atoms in strong fields: “magic” mountain in chaotic sea // Z. Phys. B. – 1994. – Vol.94. – P.481-486.
8. Dupret K., Zakrzewski J., Delande D. Resonances in the Diamagnetic Rydberg Spectrum: Order and Chaos // Europhys. Lett. – 1995. – Vol.31, №5-6. – P.251-256.
9. Glushkov A.V., Ivanov L.N. DC Strong-Field Stark-Effect: consistent quantum-mechanical approach // J.Phys. B: At. Mol. Opt. Phys. – 1993. – Vol. 26, №16. – P.L379-L386.
10. Glushkov A., Malinovskaya S., Ambrosov S., Shpinareva I., Troitskaya O., Resonances in quantum systems in strong external fields: Consistent quantum approach// J. of Techn. Phys.1997.-Vol. 38.-P.215-218.
11. Rusov V.D., Glushkov A.V., Vaschenko V.N., Korchevsky D.A., Ignatenko A.V. Stochastic dynamics of the atomic systems in the crossed electric and magnetic field: the rubidium atom recurrence spectra//Bulleten of Kiev National Univ.Ser. Phys. – Math. – 2004. – № 4. – P.433-438.
12. Fedchuk A.P., Glushkov A.V., Le-pikh Ya.I., Ignatenko A.V., Kvasikova A.S., Atom of hydrogen and wannier-mott exciton in crossed electric and magnetic fieldst// Photoelectronics. – 2014. – Vol.23. – P.176-181.
13. Kuklina I.V., Shevchuk V.G. H-like and He-like Systems in Superstrong magnetic field: Numeral Calculation // Uzhgorod Univ. Scientific Herald. Ser. Phys. – 2000. – Vol.8, №2. – P.361-364.
14. Ambrosov S.V., Ignatenko V.M., Korchevsky D.A., Kozlovskaya V.P., Sensing stochasticity of atomic systems in crossed electric and magnetic fields by analysis of level statistics for continuous energy spectra//Sensor Electronics and Microsyst.Techn. – 2005. – N2. – P.19-23.

15. Mikhailenko V.I., Kuznetsova A.A., Prepelitsa G.P., Ignatenko A.V., Penning and stochastic collisional ionization of atoms in an external magnetic field// Photoelectronics. – 2010. – N19. – P.89-92.

This article has been received within 2015

UDC 539.182

T. A. Florko, A. V. Glushkov, Yu. M. Lopatkin, S. V. Ambrosov, V. P. Kozlovskaya

ON INTENSITY OF EMISSION OF THE METALS ATOMS IN A HYDROGEN-OXYGEN FLAME IN A PRESENCE OF A MAGNETIC FIELD

Abstract.

An intensity of emission for the alkali atoms (potassium and rubidium) in the hydrogen-oxygen flame under action of a magnetic field is theoretically estimated with using quantum defect approximation in operator perturbation theory for atomic systems in external magnetic field 10 кЕ. New estimates for the intensities of emission of the lines for K (D1: $4^2P_{1/2}-4^2S_{1/2}$ and D2: $4^2P_{3/2}-4^2S_{1/2}$) and Rb (1: $5^2P_{3/2}-5^2S_{1/2}$ and 2: $6^2P_{3/2}-5^2S_{1/2}$) are presented. The maximum value of the magnetic effect for D2 line of K atom for σ - polarization is equal 1.65, for π -polarization— 1,24. For Dl line the maximum value is equal 1,36 for both polarizations

Key words: intensity of emission, alkali metals, hydrogen-oxygen flame, magnetic field

УДК 539.182

Т. А. Флорко, А. В. Глушков, Ю. М. Лопаткин, С. В. Амбросов, В. П. Козловская

О ИНТЕНСИВНОСТИ СВЕЧЕНИЯ АТОМОВ ЩЕЛОЧНЫХ МЕТАЛЛОВ В ВОДОРОДНО-КИСЛОРОДНОМ ПЛАМЕНИ В ПРИСУТСТВИИ МАГНИТНОГО ПОЛЯ

Резюме.

Дана теоретическая оценка эффекта влияния магнитного поля (10 кЭ) на интенсивности свечения атомов щелочных металлов: калия и рубидия в водородно- кислородном пламени с использованием приближения квантового дефекта в операторной теории возмущений для атомов во внешнем магнитном поле. Рассчитаны интенсивности свечения линий *K* (Dl: $4^2P_{1/2}-4^2S_{1/2}$ и D2: $4^2P_{3/2}-4^2S_{1/2}$) и линий *Rb* (1: $5^2P_{3/2}-5^2S_{1/2}$ и 2: $6^2P_{3/2}-5^2S_{1/2}$). Максимальная величина магнитного эффекта для линии D2 атома калия в случае σ- поляризации равна 1.65, в случае π- поляризации — 1.24, для линии D1 максимальное значение составляет 1.36 и одинаково для обеих поляризаций.

Ключевые слова: интенсивность излучения, щелочные металлы, водородно-кислородное пламя, магнитное поле

УДК 539.182

Т. О. Флорко, О. В. Глушков, Ю. М. Лопаткін, С. В. Амбросов, В. П. Козловська

ПРО ІНТЕНСИВНІСТЬ СВІЧЕННЯ АТОМІВ ЛУЖНИХ МЕТАЛІВ У ВОДНЄ-КИСЕНЕВОМУ ПЛАМЕНІ У ПРИСУТНОСТІ МАГНІТНОГО ПОЛЯ

Резюме.

Одержана теоретична оцінка ефекту впливу магнітного поля (10 кЕ) на інтенсивності світіння атомів лужних металів: калію і рубідію в водневo кисневому полум'ї з використанням наближення квантового дефекту в операторної теорії збурень для атомів у зовнішньому магнітному полі. Розраховані інтенсивності свічення ліній К (Dl: $4^2P_{1/2}-4^2S_{1/2}$ та D2: $4^2P_{3/2}-4^2S_{1/2}$) і *Rb* (1: $5^2P_{3/2}-5^2S_{1/2}$ і 2: $6^2P_{3/2}-5^2S_{1/2}$). Максимальна величина магнітного ефекту для лінії D2 атому *K* у випадку σ - поляризації складає 1.65, а у випадку π- поляризації – 1.24 , а для лінії D1 максимальне значення складає 1.36 і є однаковим для обох поляризацій.

Ключові слова: інтенсивність випромінювання, лужні метали, водне-кисневе полум'я, магнітне поле