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EXCITATION OF H (2P) STATE OF HYDROGEN ATOM AT $H3^+$-HE COLLISION

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***Abstract**:*
We have presented results of experimental measurement of the excitation function of hydrogen atomic line Lα (λ= 121.6nm) , which was emitted during of H_3^+-He collision. It was determined, that the intensity of radiation given lines depends on internal (vibrational) excitation of H_3^+ molecular ion in the initial (ground) electronic state.
***Key words**:* Dissociative excitation, *excitation function, H_3^+ molecular ion.*

Introduction

The molecule H_3^+ was detected by Thompson[1]still in 1912, however more or less full understanding of structure and property of this molecule is far from being completed. In experimental research of H_3^+ dissociation on a thin foil was determined that H_3^+ has the structure of an equilateral triangle[2]. The band system in the Infrared range of the absorption spectrum of this ion was detected by Oka at al.[3]. Binding energy of H_3^+ ion was defined experimentally[4,5] on research of a threshold of H_3^+ dissociation at collisions H_3^+ - He. The energy surfaces appropriate to various electronic states H_3^+ were calculated in articles[6-9]. Many parameters of H_3^+ molecular ion (Binding energy, energy of electronic-vibration excitation, symmetry of state, dissociation limit etc..) were defined in experiments. For example, in articles on electronic recombination of a molecule H_3^+ the thresholds of excitation of various electronic state [10,11] were defined, the cross section of formation of dissociation products H, H^+ , H^-, H_2^+ is measured and are determined the excited states of a molecule which at decay give these products[12,16]. The research of processes of H_3^+ dissociation with formation of excited atoms of hydrogen the special interest is represented. It is stipulated by that the appropriate excited electronic state is not investigated enough. For example, the excited H atoms in a state (2p) at dissociation of H_3^+, will be formed at decay[17] of $1À_2^{//}$ molecular state, which till now practically is not investigated experimentally. The definition of polarization degree of Lα emission in coincidence with a dissipated ion H_2^+, at collisions H_3^+ - He, has allowed the authors of article[17] to study the mechanism of H_3^+ dissociation and the role of molecular orientation in the excitation process. The radiation cross section of Lα lines (transition2p-1s) of hydrogen atom was measured by Dunn at al.[18] at collisions of ions H_3^+ with H_2 and He.

The research of H_3^+ molecular ion has independent theoretical and practical interest. There is some theoretical and experimental evidence that H_3^+ is an important catalyst in the stellar medium[19-21]. Large concentrations of H_3^+ in dense stellar clouds provides one of the important mechanism of molecular formation in stellar medium according to the reaction:

$$H_3^+ + X \rightarrow XH^+ + H_2 \qquad (1)$$

Where X may be CO, N_2, H_2O, NH_3, Si, S, H_2S, etc. Seventy-seven reactions involving H_3^+ in stellar clouds were studied with their rate coefficients by Suzuki [21].

The experimental investigations of the dissociation processes showed dependence of the cross section of various inelastic channels on the vibrational excitation of these ions[10,11,16] in the ground electronic state $1À_1^{/}$. The purpose of the present article was studying of a role of vibrational excitation of an initial electronic state of H_3^+ ions in the process of Lα emission at dissociation of these ions.

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2. Experimental technique

The H_3^+ ion beam leaving the Toneman type ion source was accelerated to a predetermined energy, then focused by the quadruple lenses and analyzed by the magnet mass analyzer (with resolution ~30). The emerging ions passed through collimating slits and finally entered at the collision chamber .The radiation emitted as a result of the excitation of Hydrogen atom was observed at the angle 90^0 to the direction of the beam. The spectroscopic analysis of the emission was performed with a Seya-Namioka vacuum monochromator incorporating a toroidal diffraction grating .Radiation was registered by the secondary electronic multiplier in the pulse –counting conditions.

The photon signal was linear with pressure and ion beam current(0.1-0.5ηA), showing the relative unimportance of secondary processes. The experimental set-up and calibration procedures of the light-recording system have been described previously [22].

An estimate of the uncertainty in the absolute values of the cross sections is about ~30% and in main is defined by an error of calibration.

The used experimental device allows to carry out research of the excitation processes in various conditions of experiment. In particular, by changing the pressure of working gas - hydrogen in an ion source it was possible to vary relative fraction of the output of H^+ , H_2^+, H_3^+ ions depending on the value of pressure and to investigate influence of internal excitation degree of a molecule on efficiency of the process of Lα. line excitation . The relatively high value of a current of H_3^+ ions was obtained, when pressure in the ionic source reached ~ 0.1 Torr. In this case, the H_3^+ ions with inappreciable internal energy was extracted from the source (In main in v = 0 vibrational state) [10,11]. In these conditions, vibrationally - excited ions H_3^+ participate in quenching collisions with molecules H_2 :

$$(H_3)^+ * + H_2 \rightarrow H_3^+ + H_2 *. \qquad (2)$$

The H_3^+ ions in the ionic source will be formed in the following reaction[10]:

$$H_2^+ + H_2 \rightarrow H_3^+ + H \qquad (3)$$

The number of quenching collision is defined from a relative output of H_2^+ and H_3^+ ions. Therefore, it is necessary to measure dependence of a relative output H_2^+ ions on the pressure of hydrogen inside the source, as it was offered in article [10] :

$$R = I(H_2^+) / I(H_2^+) + I(H_3^+) \qquad (4)$$

$I(H_2^+)$ and $I(H_3^+)$ are currents of (H_2^+) and (H_3^+) ions extracted from the source. From this dependence follows, that in the investigated range, the relative fraction of H_3^+ ions was decreased with increasing of pressure in the source (Fig.1). The coefficient R reaches at least value 0.05. This value is comparable with the value 0.06, which was obtained in article [10] in the Penning type source, at the same values of the pressure ~ 0.1 Torr. It is necessary to note, that the coefficient R essentially varies depending on the type of the source. However researches of various types of the source indicated [10], that the minimum value of R in all cases is reached approximately at the same pressure ~ 0.1Torr. Our results are well agreed with results of the authors of ref. [10].

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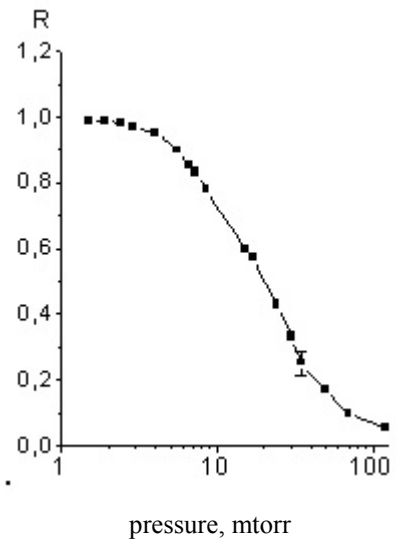
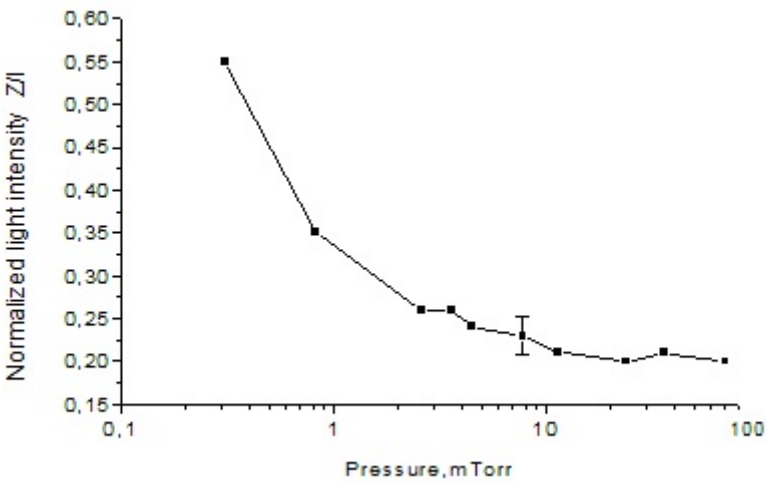


Fig.1 Dependence of a relative output R of
H_2^+ and H_3^+ ions at the pressure(in the ion source

We have presented a result of the measurement of the excitation efficiency (Normalized counting rate on a current of a primary beam) of Lα lines in the collision H_3^+ *-He* (at the energy E =4Kev of ion) at various pressures of a source (Fig. 2). The excitation efficiency decreases (approximately 2 times) with increasing of pressure and achieves saturation at pressure of hydrogen 0.6-0.8 Torr. (Fig. 2). It means, that at rather low pressures ~ 0.001Torr.,the internal (vibrational) excitation of H_3^+ ions essentially influences on the probability of the dissociation process (with excitation).



Dependence of the normalized light intensity Z/I (Z- light intensity, I-ion beam intensity) on the pressure in the ion source.

3.Results and discussion:

The analysis of our experimental results indicates, that excitation efficiency of hydrogen atomic line is less, when H_3^+ ions as a result of quenching collision become de-excited. It can be

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explained on the basis of following fact :the vibrational excitation (~ 0.3-1 eV) in the ground electronic state reduces to the considerable change (a few eV)of inelastic threshold amount of excitation energy of an excited electronic state. In our case this is the electronic state ($^1A_2^{//}$). Such type of investigation was carried out earlier[10,11,16], however they concerned inelastic channels of dissociation, producing the hydrogen atoms in the ground state. Consequently excited states, studied in these articles, differ from those surveyed by us. It is necessary to note, that the research of excitation efficiency of various inelastic channels depending on vibration excitation of H_3^+ ion (in a ground electronic state) contains the important information sort of a surface of potential energy of various excited electronic states. Our results specify that the concrete behavior of energy surfaces in area Franck-Kondon (is meant saving a principle Franck-Kondon) is those, that the energy difference between vibrational level v = 0 (of the ground electronic state $1À_1^{/}$) and vibrational level of excited electronic state $1À_2^{//}$ at vertical transition (in frameworks of principle Franck-Kondon) on some eV is more than for transition from excited v = 1, v = 2 or v = 3 vibrational levels (of the ground electronic state of H_3^+). Investigation of authors of ref.[11] indicated that in various ionic sources at pressures 10^{-3} mTorr there can be a sufficient amount of ions H_3^+ in excited v = 1, v = 2 or 3 vibrational states. Probably, in our conditions when pressure inside a source reaches $P = 8{\cdot}10^{-2}$- 10^{-1}Torr, from a source the ions are extracted in the ground v = 0 vibrational state. In these conditions, the measurements of the emission cross section of λ= 121.6nm (transition 2p-1s) hydrogen atomic line was carried out during dissociation process of H_3^+ ions at collisions with helium atoms in the energy range E=3-9 keV . The results of experimental investigation are presented on Fig. 3 and compared with the same from ref.[18]. It is visible, that the good agreement is observed. It can beat is explained by the following factors: 1.Probably in the indicated case experimental condition of the formation of H_3^+ ions beat, identical with ours 2. Our researches indicated, what excitation efficiency of Lα line is not so significant (~ 2) varies at essential (on two order) changing of pressure inside a source. (from 0.001 to 0.1Torr). In similar condition, the electronic recombination cross section changes on one order with changing of vibrational excitation of H_3^+ (In the ground electronic state) [16]. Naturally, as it was specified above, this difference can beat is stipulated by concrete behavior of potential energy surface of excited electronic state.

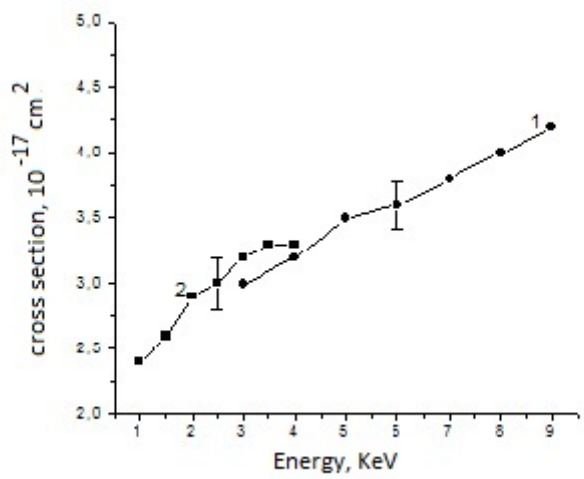

Fig.3 Emission cross section of the hydrogen atomic line HI(121.6nm)
1-Our results, 2- Dunn at al.[18].

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