THE DISSOCIATIVE EXCITATION PROCESSES IN COLLISIONS OF ELECTRONS AND HELIUM IONS WITH OXYGEN MOLECULES.

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ABSTRACT. Absolute cross sections for dissociative excitation processes of oxygen atomic and ionic lines in the collisions of e -O_2 and He^+-O_2 are determined. The high intense oxygen ionic line OII (83.4 nm) has been observed. In case of electrons impact a doubly charged oxygen ionic line OIII (70.5 nm) has been observed too. For He^+-O_2 collisions the experimental results are interpreted qualitatively in terms of quasidiatomic approximation.

In the present work, the values for absolute cross sections of dissociative excitation processes at collisions of electrons and helium ions with oxygen molecules in 200-500 eV and 2-11 keV energy range are given respectively. The measurements were carried out by optical spectroscopy method. The experimental set-up and calibration procedure for the determination of absolute value of cross sections of excitation processes has been described in details [1,2]. An estimation of uncertainties of the absolute value of all cross sections given here did not exceed 20-25% and the accuracy of relative measurements was 4 -5%.

The ion beam extracted from the discharge ion source is focused, accelerated and mass selected in a 60^0 magnetic sector field. The formed He^+ ion beam was passed through collimating slits and finally entered into the collision chamber. To ensure single collision condition a working gas pressure was an order of 1-2 $x10^{-3}$ Torr.

The radiation emitted in the collision was observed at angle 90^0 with respect to the direction of the primary ion beam. The spectral analysis of this radiation was performed in the vacuum ultraviolet (VUV) spectral region by a Saya-Namioka monochromator incorporating a toroidal diffraction grating. The intensity of the

radiation was detected by secondary electron multipliers under integrating or pulse-counting conditions.

Particular attention was devoted to the reliable determination and control of the relative and absolute spectral sensitivity of the light recording system. This was done by measuring the signal due to the emission of the molecular bands and atomic lines excited by electrons in collisions with H_2, N_2, O_2 molecules and Ar atoms. For this an electron gun was located directly in front of the entrance slit of the collision chamber .The relative spectral sensitivity and the values of the absolute cross sections were obtained by comparison with cross sections for the same lines and molecular bands reported in 3-8].

RESULTS

In Figs.1 and 2 the review spectrum for He^+ -O_2 pair in the 80 - 150 nm spectral region at a fixed helium ion energy (E = 10 keV) and for e - O_2 in the 55 - 90 nm spectral region at a fixed energy (E = 0.44 keV) are presented accordingly. In Fig.3 the dependencies of absolute cross sections from the collision energy for the dissociative excitation of oxygen atomic OI (97.4, 99.0 nm, 102.6 nm, 115.2 nm) and ionic OII (83.4nm) lines at He^+ -O_2 collision are presented**.** Here for the sake of comparison the excitation cross-section of helium resonance atomic lines HeI (53.7 nm, 58.4 nm) are presented as well. As it seems main inelastic channel responsible for the dissociative excitation processes is an oxygen ionic line OII (83.4nm), due to its intensity. At the collision of electron with oxygen molecules the most intense ionic line OII (83.4 nm) is observed. The emission spectrum (in an area of 83.4 nm) includes also relatively intensive ionic line OIII (83.3 nm, $2p^2\ ^3P$ - $2p^3\ ^3D^0$) (not shown in Fig.). Besides, it is interesting to mention that the weak ionic line of doubly charged ion OIII (70.6 nm) is observed too. The absolute value of excitation cross section of OIII (70.6 nm, $2p^2\ ^3P$-$2p^3\ ^3P^0$) line at an electron energy E=200 eV is equal to the $3.4x10^{-20}cm^2$ and at an energy E = 440 eV to the $3.8 \times 10^{-20}\ cm^2$.

DISCUSSION

The dissociation of molecules and hence the formation of excited atomic or ionic products proceede via decay of intermediate core-excited oxygen molecular ions.

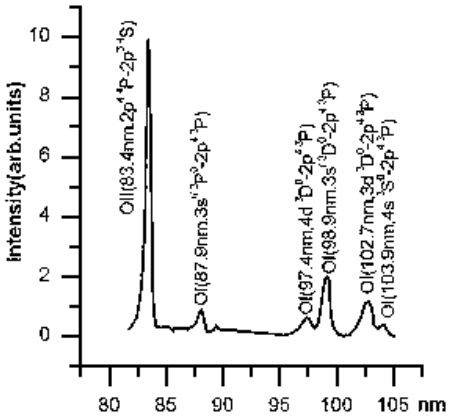


Fig.1. Spectrum of O_2 at 10 keV helium ion impact energy from 80 to 105 nm

Fig.2. Spectrum of O_2 at 440 eV electron impact energy from 55 to 90

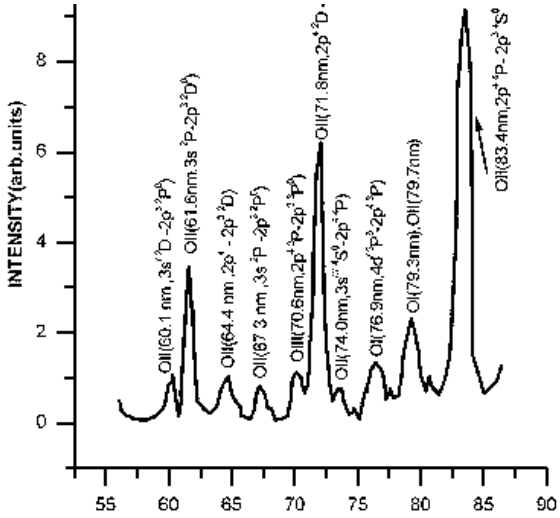
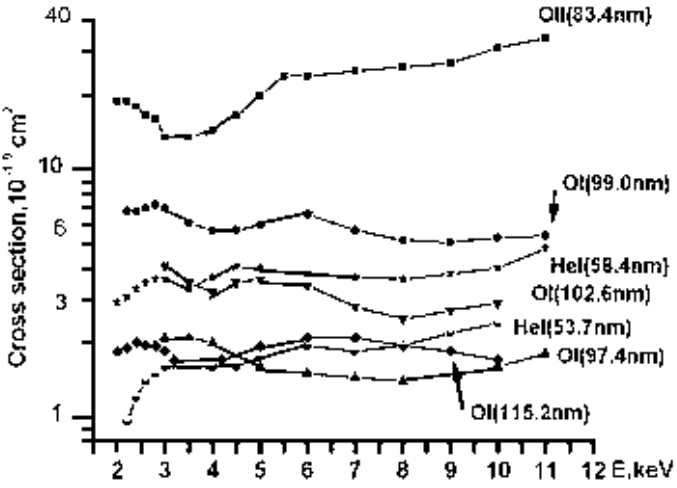


Fig.3. Energy dependence of the excitation cross section of helium and oxygen lines in $He^+ - O_2$ collisions



At the collisions of helium ions with molecules the intense atomic and ionic lines of oxygen is formed in the charge exchange process mainly [9], whereas for electronic collisions the same lines are formed in the ionization process. In both cases the formation of excited products of dissociation is connected with decay of the same high excited molecular states of O_2^{+*}. This is the reason for comparison of the results in the case of He^+ and electron impact with O_2 molecule.

To discuss the results of the formation of inner shell vacancy the quasidiatomic approach has been used. In terms of this approximation the excitation of inelastic channels is induced by transitions of electrons at crossings between an initially occupied and promoted molecular orbital (MO) with empty MO's [9,10]. In our case initial vacancy in He (1s) orbital becomes an inner vacancy of the quasimolecule, hence core-excited, one–hole molecular states can be formed. In particular, the decay of one -hole $2\sigma_g^{-1}$ high excited molecular states $^2\sum_g^-$ or $^4\sum_g^-$ of oxygen cause the excitation of intense oxygen ionic line OII (83.4 nm) [11]. The removal of a $2s\sigma_g$ electron from O_2 molecules requires about 40eV [11,12] . Therefore excitation

of the inelastic channel in the charge exchange process He ($1s^2$) + O_2^+ ($2\sigma_g^{-1}$) requires changing the internal energy of the quasimolecular $(He, O_2)^+$ system by 15 eV. This statement is confirmed from [9] too. In fact, the observed broad energy loss spectra around 22 eV might contain the above excited inelastic channel.

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დისოციაციის პროდუქტების აღგზნების გამოკვლევა ელექტრონებისა და He^+ იონების ჟანგბადის მოლეკულებთან დაჯახების პროცესში

დასკვნა

e $-O_2$ და He^+ - O_2 წყვილებისათვის დისოციატიური აღგზნების პროცესებში გაზომილია ჟანგბადის იონური და ატომური სპექტრალური ხაზების გამოსხივების აბსოლუტური კვეთი. დაკვირვებულ იქნა მაღალი ინტენსიობის იონური ხაზი OII (83.4 ნმ). ელექტრონებით დაჯახების პროცესში გაზომილ იქნა ორჯერად იონიზირებული ჟანგბადის იონის ოპტიკური ხაზის -OIII (70.5 ნმ) აღგზნების კვეთი. He^+ -O_2 წყვილისათვის ექსპერიმენტული მონაცემები თვისობრივად აღწერილია კვაზიდიატომურ მიახლოებაში.