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INVESTIGATION OF THE SPECTRUM OF ELECTRONS RELEASED UPON COLLISION OF Ar^+ IONS WITH Ar ATOMS

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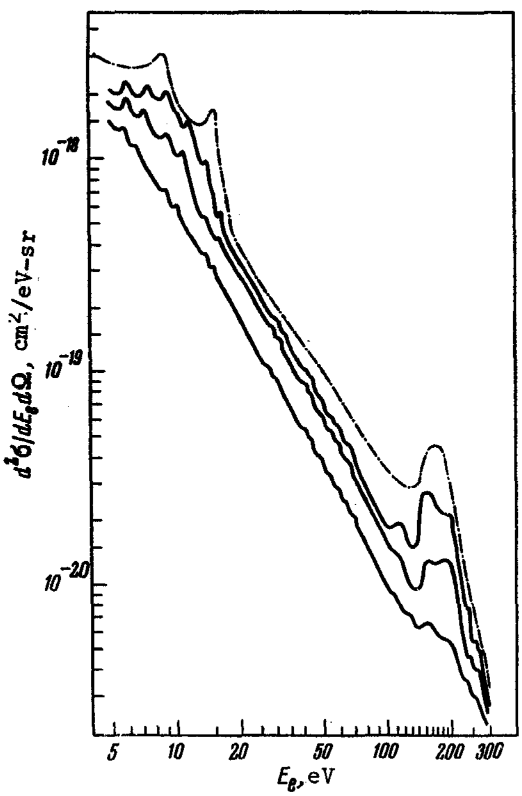
In order to clarify the character of the mechanism of inelastic atomic collisions, particularly the question of the nature of characteristic inelastic energy losses [1,2], great importance attaches to the study of the energy spectrum of the electrons released in ionization processes in which heavy atomic particles take part.

We present in this paper preliminary results of such an investigation for the Ar^+-Ar pair at three values of the collision energy (5, 15, and 25 keV) in the electron energy range 5 - 300 eV. The experimental procedure will be described in detail later. The electrons were analyzed by energy in a cylindrical electrostatic analyzer of the Blauth type [3]. The electron emission angle, determined by the first-order focusing condition, was 54.5° to the beam axis. The high resolving power of the instrument ($\leq$ 1%) in conjunction with high sensitivity and a low relative error of the measurements ($\leq$ ±6%) has made it possible to observe a whole series of structural singularities in the energy distribution of the electrons.

The figure shows the obtained electron energy spectrum. The ordinates show the absolute magnitudes of the differential electron-production cross sections per unit solid angle and per unit energy interval, and the abscissas show the electron energies E_e. The dashed curve represents, for comparison, the data of [4]. As seen from the figure, it is possible to separate in the electron energy spectrum a continuous part that decreases smoothly with increasing electron energy in accordance with a power law (approximately like $E_e^{-5/3}$), and a



Energy distributions of the electrons released in collisions between Ar^+ ions and Ar atoms. The solid lines show the data of the present paper. The upper curve corresponds to a colliding-ion energy 25 keV, the middle curve to 15 keV, and the lower one to 5 keV. The electron emission angle is 54.5°. The dashed curve shows the data of [4] for the same pair of particles at a colliding-ion energy 100 keV and at an electron emission angle 160°.

structure superimposed on it. The absolute values of the cross sections decrease with decreasing collision energy in accordance with the analogous dependence for the values of the total ionization cross sections [5].

A preliminary analysis has shown that the observed spectral lines agree sufficiently well in position with the energies of the auto-ionization transitions of the isolated Ar atom. However, in the case of collisions of heavy atomic particles (unlike, e.g., collisions in which the colliding particle is an electron or a photon), these lines can be strongly smeared as a result of the Doppler broadening connected with the appreciable transfer of kinetic energy to the recoil particle ("hard" radiation [6]). In addition, just as in [4], Doppler twins of the spectral lines of the electrons emitted by the recoil atoms were observed. These twins are connected with the emission of electrons of the same energy from the fast particle, and are shifted relative to the main lines towards the higher energies. As a result of the indicated circumstances (which are particularly significant at large values of E_e), the structure of the spectrum becomes strongly complicated and is smeared out in a rather large energy interval.

It is possible to distinguish in the structure part of the energy spectrum several line groups as follows: 1) a line group in the interval E_e = 5 - 20 eV, connected with the excitation of the M shell of Ar, 2) a line group in the interval E_e = 110 - 220 eV, connected with the excitation of the $L_{2,3}$ subshell of Ar, and 3) line groups not observed in [4], in the intervals E_e = 28 - 70 and 245 - 280 eV, due to the excitation of the L_1 subshell of Ar. The most intense peaks in the region E_e = 5 - 20 eV are concentrated near E_e = 6 eV and are due to the auto-ionization transitions $3s3p^54p \rightarrow 3s^23p^4$ and $3s^3p^54s4p \rightarrow 3p^44p$, and also near E_e = 9.5 eV (transitions $3s3p^54s4p \rightarrow 3p^44s$ and $3s3p^64s,p \rightarrow 3p^5$), and E_e = 14 eV (transitions $3p^44s4p \rightarrow 3p^5$ and $3s^33p^54s4p \rightarrow 3s3p^6$).

The structure of the spectrum in the region E_e = 28 - 70 eV is due to the Koster-Kronig transitions in which both electrons from the M shell of Ar and excited electrons in the state with principal quantum number $n > 3$ take part. The direct transitions to the L_1 vacancy lead to the appearance of a structure in the region E_e = 245 - 280 eV.

The sharply pronounced rise of the spectrum in the vicinity E_e = 110 - 220 eV is due to Auger transitions with filling of the vacancy in the $L_{2,3}$ subshell of Ar. The great length of this section of the spectrum is connected apparently with the fact that the Auger transitions can occur in both the neutral atom Ar and in the multiply-ionized atom. With increasing charge of the ion from which the Auger electrons are emitted, the spectral lines should shift towards smaller energies, because when the electron is removed from the outer shell the sum of the binding energies of the two outer electrons increases much more strongly than the binding energy of the electron at the inner shell of the atom.

The results obtained by us enable to draw the following conclusions concerning the mechanism of inelastic energy transfer upon collision of heavy atomic particles.

When the colliding particles come close together, a strong overlap of the shells takes place in the produced quasimolecule, leading to excitation of the system and formation of vacancies in the inner shells. Lifting of this excitation by means of auto-ionization transitions can occur both after the separation of the atomic particles, when the "individuality" of each atom is sufficiently clearly pronounced, and at the instant of collision, when the system of colliding particles can be characterized by the properties of the quasimolecule. Processes of the former type play a major role in the formation of the structure in the energy spectrum of the electrons, whereas those of the latter type apparently have a much broader energy distribution and can make an appreciable contribution to the formation of the continuous part of the spectrum. It can be assumed that the first two lines of the characteristic losses (R_I^* and R_{II}^* [1]) are connected with auto-ionization transitions occurring when the M shell and the $L_{2,3}$ subshell of Ar are respectively excited. However, an exact identification of the lines of inelastic losses on the basis of data on the electron spectra is difficult, since experiments performed with the aid of the coincidence method are used to investigate processes that occur at a fixed value of the impact parameter, whereas the processes participating in the electron production take place at all values of the impact parameter.

A detailed investigation of the auto-ionization states of Ar and an identification of the lines of the energy spectra of the electrons will be carried out in our subsequent studies.

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ANGULAR ANISOTROPY OF FISSION OF Pu^{238} BY NEUTRONS

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The angular anisotropy of the scattering of nuclear-fission fragments is the consequence of the inhomogeneity of the distributions of the projections K of the angular momentum I on the symmetry axis (the scission direction). The distribution f(K) is formed by the spectrum of the accessible fission channels - the quantum levels of the fissioning nucleus in the intermediate state. According to the Bohr model [1] it is expected that f(K) depends strongly on the excitation energy in the near-threshold region of the excitation, where a small number of channels participate in the fission and the variation of the cross section is determined primarily by the barrier penetrability. This region is characterized by appreciable changes in the form of the angular distribution of the fragments $W(\theta)$, the value of the coefficient of angular anisotropy $A = W(0°)/W(90°) - 1$, and other characteristics of the fission process - the so called-channel effects. They become quite clearly pronounced in the neutron fission of the "light" nuclei Th^{230}, Th^{232}, and U^{234}, but attenuate quite rapidly when the number of the nucleons in the fissioning nucleus increases: the quantity A decreases and the form of $W(\theta)$ becomes stable [2].