transition is one that changes the crystal lattice. The appearance of an additional peak in the region of small angles, compared with [13], indicates that α oxygen is antiferromagnetic.

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[1] W. F. Giauque and H. L. Johnston, J. Am. Chem. Soc. **51**, 2300 (1929).

[2] Borovik-Romanov, Orlova, and Strelkov, DAN SSSR **99**, 699 (1954).

[3] Kanda, Haseda, and Otsubo, Physica **20**, 131 (1954).

[4] J. L. McLennan and J. O. Wilhelm, Phil. Mag. 7/3, 383 (1927).

[5] M. Ruhemann, Z. Physik **76**, 368 (1932).

[6] H. H. Mooy, Leiden, Comm. No. 233a (1932).

[7] L. Vegard, Z. Physik **98**, 1 (1935).

[8] W. H. Keesom and K. W. Taconis, Leiden Comm. No. 240d (1936).

[9] E. M. Hörl, Acta Cryst. **15**, 845 (1962).

[10] R. A. Alikhanov, JETP **36**, 1690 (1959), Soviet Phys. JETP **9**, 1204 (1959).

[11] R. A. Alikhanov, JETP **38**, 806 (1960), Soviet Phys. JETP **11**, 585 (1960).

[12] P. Kapitza and P. Cockroft, Nature **129**, 224 (1932).

[13] Black, Bolz, Brooks, Mauer, and Peiser, J. Res. NBS **61**, 367 (1958).

Translated by J. G. Adashko
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IONIZATION OF POSITIVE IONS BY ELECTRONS

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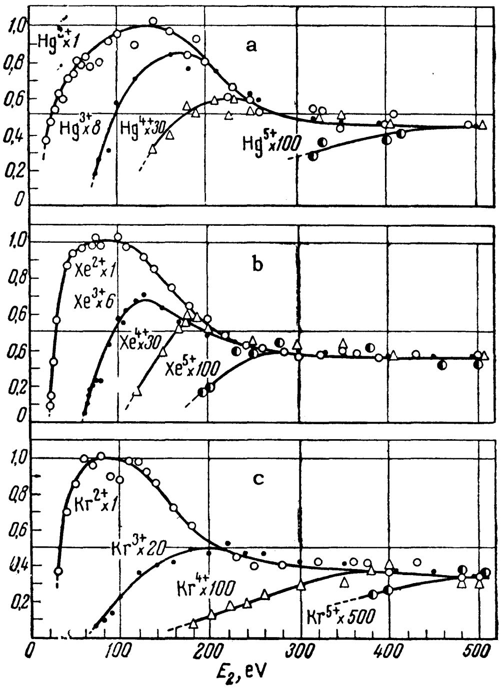
IN connection with phenomena in plasma, it is important at present to study the excitation and ionization of ions in collisions with electrons. These processes have been theoretically treated in several papers, but there is merely one investigation[1] devoted to an experimental study of the ionization of He^+ ions by electrons.

We studied experimentally the ionization of singly-charged ions Hg^+, Xe^+, Kr^+, Ar^+, Ne^+ and the doubly charged ions Hg^{2+}, Xe^{2+}, Kr^{2+}. The method of crossing electron and ion beams was used. The investigation was made with a double mass spectrometer[2] in which the collision chamber, located between two magnetic mass analyzers, was replaced by an electron gun. The electron current was varied from 1 to 20 mA, and the electron energy E_2 was varied from 10 to 500 eV. The ions were accelerated to 2800 eV. The energy E_1 of the electrons ionizing the gas in the ion source was varied from 10 to 180 eV. The working pressure in the ion source was approximately 5×10^{-5} mm Hg and in all other parts of the mass spectrometer it was $(1-3) \times 10^{-6}$ mm Hg. The background pressure was 5×10^{-8}—3×10^{-7} mm Hg.

The figure shows the relative cross sections of the different degrees of ionization of Hg^+, Xe^+, Kr^+, as a function on the electron energy E_2.1) It can be seen that they are similar to the ionization curves of neutral atoms[3,4]. As follows from the figure, the yield curves for differently charged ions become approximately the same for energies $E_2 \geq 3E_i$, where E_i is the potential for the appearance of the next ion. The curves for the yield of Xe^{2+} and Kr^{2+} are quite similar, but differ from the



Relative cross sections for the ionization of ions as functions of energy E_2 of the electrons: a – ionization of Hg^+ (E_1 = 160 eV), b – ionization of Xe^+ (E_1 = 160 eV), c – ionization Kr^+ (E_1 = 90 eV). The numbers on the curves denote the coefficients by which the corresponding cross sections have been increased. Unity corresponds to the cross section for the production of doubly-charged ions at the maximum.

corresponding curve for Hg^{2+}. However, the relative yields of differently charged ions are closer in case of Xe^+ and Hg^+ than for Kr^+. Starting with the production of triply charged ions, the ionization cross sections for large E_2 decrease by a factor of approximately 4—5 with detachment of each succeeding electron from the singly-charged ion. The curves have been plotted with account of the background observed for masses corresponding to the detachment of one electron with the electron gun turned off, amounting to approximately 10—15 percent of the peak produced by the ionization of the ions with the electrons at $E_2 = 250$ eV.

The cross sections for single ionization of singly-charged ions increase sharply when the energy E_1 of the electrons in the ion source is increased by 15 eV starting with 1—3 eV above the potential for the appearance of the corresponding doubly-charged ions. These results lead to the assumption that the ion beam contains several groups of ions with large metastable excitation. Such ions can appear as a result of the ionization of the atoms from the internal orbits. A value of $\sim 10^{-15}$ cm² for the effective cross section of single ionization of Kr^+ at the maximum of the ionization curve, estimated in our experiments accurate to within a factor of 1.5, is therefore not unexpected. The cross section for the production of doubly charged ions upon ionization of singly charged ions is 5—10 times larger than for ionization of the corresponding atoms. The cross sections for the production of ions of equal charge multiplicity but more than doubly charged, by collision between high-energy electrons and Hg^+, Xe^+, and Kr^+ ions agree with those obtained by collision with the corresponding atoms, accurate to within a factor of 1.5—2.

We present the relative effective cross sections σ_{max} for single ionization of different ions in the region of the maximum for the ions investigated by us (the energy E_1 of the electrons was 150 eV):

	Hg^+	Xe^+	Kr^+	Ar^+	Ne^+	Hg^{2+}	Xe^{2+}	Kr^{2+}
σ_{max} :	1.0	1.4	1.8	0.3	0.1	1.3	1.5	0.4

The error in the determination of the relative cross sections is ±30 percent, with the exception of the ionization Ar^+ and Ne^+, for which the error can reach ±50 percent. It is seen from these data that in the case of ionization of ions with many electrons the value of the effective cross section for single ionization depends little on the charge multiplicity of the initial ion. The cross section for the ionization of singly charged ions is larger for ions with a large number of electrons.

We are grateful to Prof. N. N. Tunitskiĭ for a discussion of the results.

[1)] Smooth curves have been drawn through the experimental points although in some cases kinks can be seen, for example for the production of Hg^{2+} ions with $E_2 \sim 60$ eV.

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[1] Dolder, Harrison, and Thoneman, Proc. Roy. Soc. **264A**, 83 (1961).

[2] S. E. Kupriyanov and A. A. Perov, ZhTF **33**, 823 (1963), Soviet Phys. Tech. Phys. **8**, 618 (1963).

[3] R. E. Fox, J. Chem. Phys. **33**, 200 (1960).

[4] H. S. W. Massey and E. H. S. Burhop, Electronic and Ionic Impact Phenomena, Oxford Univ. Press, 1952.

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ONE POSSIBILITY OF PLASMA INSTABILITY

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KINETIC instability of a plasma occurs when the higher-energy levels are more probable. For the Cerenkov and cyclotron buildup of the field oscillations, inversion in the population of levels is actually necessary for the particles whose velocity is close to the field oscillation phase velocities. In the present paper we wish to indicate another possibility for the instability of plasma. This possibility is also connected with inversion in population of the particle levels, but for velocities which can differ substantially from the phase velocities of the field oscillations.

As is well known, the rate of change in the number of quanta $N_{\mathbf{k}}$, caused by their scattering on the particles, is given by the formula:

$$\begin{aligned}\frac{dN_{\mathbf{k}}}{dt} = 2\pi\hbar \sum_{l,\, p} |V(\mathbf{k}, \mathbf{l})|^2 \{ & [(N_{\mathbf{k}} + 1) f(\mathbf{p} + \hbar\mathbf{q})(1 - f(\mathbf{p})) \\ & \times N_{\mathbf{l}} N_{\mathbf{k}} (N_{\mathbf{l}} + 1) f(\mathbf{p})(1 - f(\mathbf{p} + \hbar\mathbf{q}))] \\ & \times \delta(E_{\mathbf{p}+\hbar\mathbf{q}} - E_{\mathbf{p}} - \hbar\omega_{\mathbf{k}} + \hbar\omega_{\mathbf{l}}) + [(N_{\mathbf{k}} + 1)(N_{\mathbf{l}} + 1) \\ & \times f(\mathbf{p} + \hbar\mathbf{q}')(1 - f(\mathbf{p})) - N_{\mathbf{k}} N_{\mathbf{l}} f(\mathbf{p})(1 - f(\mathbf{p} + \hbar\mathbf{q}'))] \\ & \times \delta(E_{\mathbf{p}+\hbar\mathbf{q}'} - E_{\mathbf{p}} - \hbar\omega_{\mathbf{k}} - \hbar\omega_{\mathbf{l}})\}, \qquad (1)\end{aligned}$$