which is valid for small concentrations and not too low temperatures. Here ρ is the density of the solution, ρ_s the density of the superfluid component, c the He^3 concentration, and u_1 and u_2 the speeds of the first and second sounds in the solution, respectively. The error in the determination of the velocity does not exceed 2%.

It follows from the figure that the experimental results for helium-isotope solutions are in fully satisfactory agreement with the theory [5]. Tentative measurements of the absorption coefficient indicate that it increases rapidly with temperature. This makes measurements near the λ point difficult.

Work is now continuing in broader temperature and concentration intervals, with an aim at obtaining information on the behavior of the He^3 and He^4 atoms in narrow channels.

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AUTOINIZATION OF FAST LITHIUM-LIKE NITROGEN AND OXYGEN IONS AFTER PASSAGE THROUGH A SOLID

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Passage of fast atomic ion-beam particles through matter should give rise to excited ions with an increased probability of electron loss by collision with the atoms of the medium. In addition, electrons may leave the excited particles spontaneously [1] (Auger effect). The experiments described below were set up to observe the increased probability of electron loss by fast ions passing through a medium.

Beams of nitrogen and oxygen ions accelerated in a 72-cm cyclotron were focused at a distance of 8 meters from the cyclotron (Fig. 1). Targets comprising thin celluloid films ~2 $\mu g/cm^2$ thick (i.e., ~10^{17} atoms/cm^2) were placed at different locations on the path of the beam near the focus. Ions were produced with different charges after the passage of the beam through the target. The ions with a given charge i were directed with the aid of a magnetic mass monochromator into a charge-exchange chamber ~0.5 m long, in which part of the ions with charge i was converted into ions with other charges by collision with the gas atoms and spontaneous ejection of the electrons. A magnetic analyzer with a system of proportional counters, each of which registered ions with a single fixed charge [3], made it possible to determine the charge composition of the beam passing through the charge-exchange chamber, i.e., the relative number Φ_j of ions with different charges j ($\Sigma_j \Phi_j = 1$).

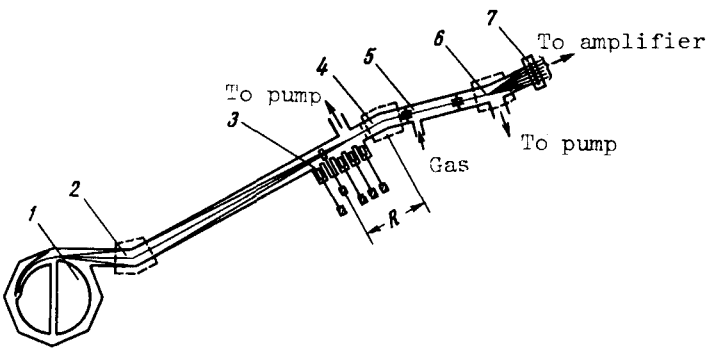

Fig. 1. Diagram of experimental setup: 1 - Cyclotron, 2 - focusing magnet, 3 - targets, 4 - mass monochromator, 5 - charge-exchange chamber, 6 - analyzer, 7 - detectors.

The relative number Φ_{i+1} of ions with charge i + 1 depends on the effective cross sections σ^*_{ij} and σ_{ij} of the processes involving a change of charge for excited and non-excited particles (the first and second indices i and j indicate respectively the initial and final charges of the ions), on the number n of atoms per cm^3 in the charge-exchange chamber, on the length L of the charge-exchange chamber, on the probability a_i of spontaneous loss of an electron by excited ions, on the probability r_i of radiative de-excitation, on the ion velocity v, and on the fraction α_i of the ions with charge i in the excited states. Under the conditions $\sigma_{ij} nL \ll 1$ (for arbitrary i and j) and $K^*_i \gg \Sigma'_j \sigma_{ij} n$, where $K^*_i = \Sigma'_j \sigma^*_{ij} n + (a_i + r_i)/v$, the following relation holds true:

$$\Phi_{i+1} = \sigma_{i,i+1} nL + \beta_i \Delta\sigma^*_{i,i+1} nL + \beta_i a_i L/v, \qquad (1)$$

where

$$\beta_i = \alpha_i [1 - \exp(-K^*_i L)](K^*_i L)^{-1}, \qquad \Delta\sigma^*_{i,i+1} = \sigma^*_{i,i+1} - \sigma_{i,i+1}.$$

The number of excited ions reaching the charge-exchange chamber depends on the distance R between the target and the center of the magnetic field of the mass monochromator: $\alpha_i(R) = \alpha_i(0) \exp(-q^*_i R)$, where $q^*_i = \Sigma'_j \sigma^*_{ij} n' + (a_i + r_i)/v$, and n' is the number of atoms per cm^3 on the path of particles between the target and the monochromator.

The experiment consisted of determining the relative number of ions with charge i + 1, produced in the charge-exchange chamber from the ions with charge i and separated by the mass monochromator, for different distances R between the target and the center of the magnetic field of the mass monochromator. The measurements were made with nitrogen ions with charges i = 2 - 5 and with oxygen ions with i = 3 - 5.

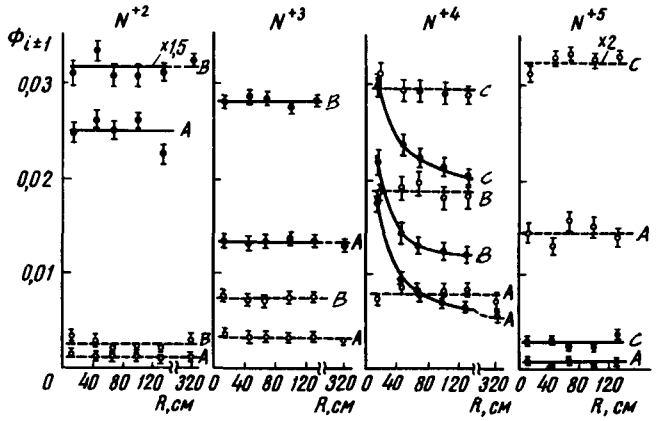

Fig. 2. Relative number $\Phi_{i\pm1}$ of fast ions of nitrogen produced in the charge-exchange chamber, plotted against R. The ions with charge i, separated by the mass monochromator, are indicated in the upper part of the figure. The light and full points give respectively the relative numbers of ions Φ_{i-1} and Φ_{i+1} which capture and lose one electron. Curves A, B, and C correspond to different thicknesses t = nL of the gas target in the charge-exchange chamber; t = 1.4, 3.6, and 6 x 10^{14} atoms/cm^2.

For most ions, the values of Φ_{i+1}, as well as the values of Φ_{i-1} which were determined simultaneously for control purposes, were independent of R (Fig. 2). On the other hand, in experiments with N^{+4} and O^{+5} ions, the relative number Φ_{i+1} of quintuply-charged nitrogen ions and sextuply-charged oxygen ions increased appreciably with decreasing R. During the time of these measurements the pressure was $\sim 10^{-5}$ mm Hg in all parts of the experimental set-up through which the beam passed. With a ten-fold ingrease of pressure on the path of the beam from the target to the mass monochromator, the quantities $\Delta\Phi_{i+1}(R) = \Phi_{i+1}(R) - \Phi_{i+1}(R_{max})$ did not change. This means that collisions with atoms of the residual gas had practically no influence on the processes leading to the reduction in the number of excited ions and responsible for the increase in the values of Φ_{i+1} with decreasing R. i.e., $\Sigma'_j \sigma^*_{ij} n' \ll (a_i + r_i)/v$ and $q_i^* = (q_i + r_i)/v$.

With increasing pressure in the charge-exchange chamber, the values of $\Phi_{i+1}(R)$ increased in accordance with (1), while the values of $\Delta\Phi_{i+1}(R) = \Phi_{i+1}(R) - \Phi_{i+1}(R_{max})$ were independent of the pressure (Fig. 2). According to (1),

$$\Delta\Phi_{i+1}(R) = [\alpha_i(R) - \alpha_i(R_{max})][1 - \exp(-K_i^* L)](K_i^* L)^{-1}(\Delta\sigma^*_{i,i+1} n + a_i/v)L,$$

where $K_i^* = q_i^* = (a_i + r_i)/v$, and therefore the absence of a dependence of $\Delta\Phi_{i+1}(R)$ on $\underline{n}$ means that the observed increase in the number of quintuply-charged nitrogen ions and sixtuply-charged oxygen ions with decreasing distance between the target and the mass monochromator cannot be attributed to an increase in the cross sections for the loss of an electron in collisions of the excited ions with the atoms of the medium ($\Delta\sigma^*_{i,i+1} n \ll a_i/v$). Since control experiments have shown that the values of $\Delta\Phi_{i+1}(R)$ do not depend on the dimensions of the diaphragms through which the beam passed, the observed effect is not connected with the interaction between the ions and the surfaces of the diaphragms. Thus, we are left with the assumption that this phenomenon is the result of spontaneous emission of an electron by the ions N^{+4} and O^{+5}, i.e., as a result of autoionization of these particles.

From the experimental values of q_i^*, characterizing the dependence of $\Delta\Phi_{i+1}$ on R, we determined the average lifetimes $\tau = 1/(a_i + r_i)$ of the autoionization states. Since

$\Sigma'_j \sigma_{ij} n' \ll (a_i + r_i)/v$, we have $\tau = 1/q_i^* v$. The autoionization of the N^{+4} ions was observed at ion velocities v (4 - 12) x 10^8 cm/sec, i.e., at energies from ~1 to 10 MeV. For all these energies $\tau = (5.5 \pm 2) \times 10^{-8}$ sec. Approximately the same value of the lifetime, $\tau = (4 \pm 2) \times 10^{-8}$ sec, was obtained for O^{+5} (at $v = 8 \times 10^8$ cm/sec).

In all cases the quantity $\Delta\Phi_{i+1} \sim \alpha_i a_i/(a_i + r_i)$ was of the order of 1%. From this we get the estimate $\alpha_i \gtrsim 1\%$ for the fraction of the ions which are in autoionized states with the lifetimes indicated above. When the target thickness is increased from ~2 to 20 $\mu g/cm^2$ the number of such ions remains essentially the same, since $\Delta\Phi_{i+1}$ increases in this case by only 20% (for $v = 8 \times 10^8$ cm/sec). Practically no such ions were produced in a gas target ~10^{15} atoms/cm^2 thick, placed along the path of the beam in place of the celluloid film.

The lifetime of the excited states subject to autoionization decay is usually 10^{-13} - 10^{-14} sec [4]. However, for negative helium ions He^- and for lithium atoms there are known metastable autoionization states $(1s2s2p)^4P_{5/2}$ with lifetimes $\tau \approx 10^{-3}$ sec for He^- ions and $\tau \approx 5 \times 10^{-6}$ for lithium atoms [5,6]. The metastable autoionization states of the lithium-like nitrogen and oxygen atoms, observed by us, apparently belong to the same type of states with maximum possible values of the total angular and spin momenta.

Inasmuch as there should be many more excited states of ions with lower lifetimes than metastable states with $\tau \approx 10^{-8}$ sec, it follows from the obtained results that immediately after leaving the solid target an appreciable fraction of the fast multiply-charged ions loses an electron and its charge increases as a result of autoionization.

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DIRECT ATOMIC-MOLECULAR OR IONIC-MOLECULAR REACTIONS

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Several experiments have been recently performed [1-4] on ion-molecular reactions of the type A + BC → AB + C (A = atom or ion, BC = diatomic molecule or ion), and have cast light on the energy dependence of the absolute cross sections of these reactions. These experiments pertain to a relative-motion energy close to 10 eV, for which the theories based on the use of the intermediate-state concept (see [5-6]) should not be valid. It is therefore advisable to consider an alternative mechanism for such reactions, based on the model of direct interactions between the incident particles A and bound particles B and C, without formation of an inter-