of interaction of the atom pair, owing to the zero-point vibrations of the atoms. It was furthermore found that the atomic structure in the vicinity of ~ 2 — 5° K is little sensitive to changes in temperature and does not change upon transition through the λ point.

In view of the specific nature of liquid helium, it is interesting to study not only its average atomic structure, but also the fluctuations of this structure. We have obtained[2] an equation for the quadratic fluctuations of the coordination number in the liquid

$$(\delta z)^2 \equiv \overline{(\Delta z)^2} = \bar{z} + \frac{8\pi^2}{v^2} \int_0^{r_1} \int_0^{r_1} g(r)\, g(\rho) \left\{ \int_{|r-\rho|}^{r+\rho} (g(t) - 1)\, t\, dt \right\} r\, dr \rho\, d\rho, \qquad (1)$$

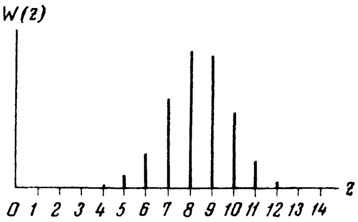
where g(r) is the radial distribution function, v the average volume per particle, r_1 the abscissa of the first minimum of g(r), and $\bar{z}$ the average coordination number

$$\bar{z} = \frac{4\pi}{v} \int_0^{r_1} g(r)\, r^2\, dr. \qquad (2)$$

In the derivation of (1) we used the superposition approximation from the theory of liquids, in which the triple distribution function is replaced by a product of binary distribution functions. At the present time it is well known that the superposition approximateion gives a higher order than actually exists in the liquid. One can therefore think that a calculation based on (1) should lead to values of δz that are too low.

We have calculated δz using Eq. (1) for liquid helium with the aid of an experimental function g(r) (from reference 1), which is the average of several series of measurements at temperatures below 2.25° K. The curves given in reference 1 for T = 4.24 and 5.04° K differ quite insignificantly from that selected by us and lead to the same results, within the accuracy limits possible in practical numerical integration. When $r_1 = 4.6$ A, Eq. (2) yields $\bar{z} = 8.4$, which is in good agreement with the value indicated in reference 1, where another method of calculation is used, while Eq. (1) yields $\delta z = 1.47$. Thus, the relative mean-squared fluctuation of the number of nearest neighbors of a certain atom is 18% and, as indicated above, this number is apparently too low. We obtain a relatively high fluctuation level for the microstructure of liquid helium.

If the distribution of the number of nearest neighbors of a selected atom, W(z), is assumed to be approximately Gaussian, a knowledge of $\bar{z}$ and δz makes it possible to plot this distribution. The estimates obtained above for $\bar{z}$ and δz then lead to the distribution W(z) shown in the diagram, where the ordinates are plotted in an arbitrary scale. The noticeable magnitude of fluctuations of z is seen here quite clearly.



One must indicate, however, that the foregoing results for liquid helium do not differ substantially from analogous results obtained for other liquids.[2]

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[1] D. G. Hurst and D. G. Henshaw, Phys. Rev. **100**, 994 (1955).

[2] V. K. Prokhorenko and I. Z. Fisher, Журнал физической химии (J. Phys. Chem.) **31**, 2145 (1957).

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DIRECT PROOF OF THE APPLICABILITY OF THE MASSEY ADIABATIC CRITERION TO PROCESSES OF DOUBLE CHARGE EXCHANGE

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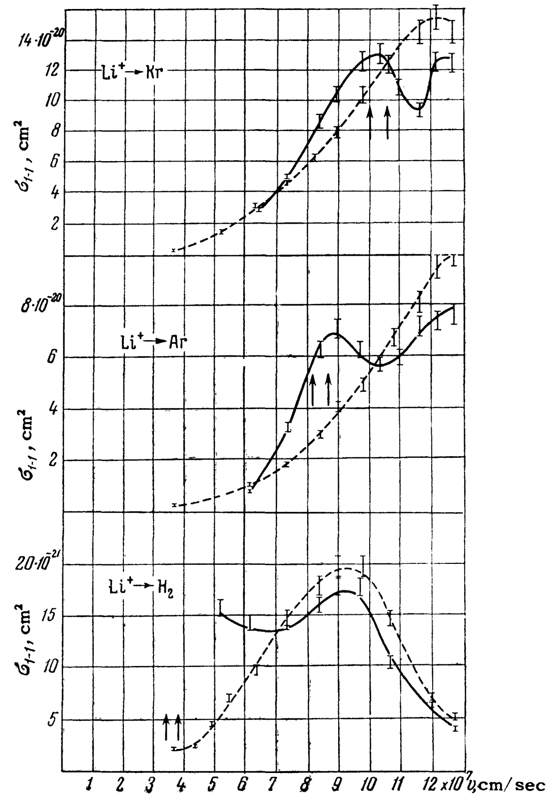
An investigation of the dependence of the effective cross sections for double charge exchange of H^+ and F^+ on their velocity has shown that two maxima are observed on the $\sigma_{1-1}(v)$ curves for these ions.[1] In reference 1 this fact was treated from the point of view of the Massey adiabatic criterion, according to which the maximum cross section of an inelastic process with a resonance defect ΔE is observed when a $|\Delta E|/hv_{\max} \approx 1$. The presence of two maxima on the $\sigma_{1-1}(v)$ curves for the processes $H^+ \rightarrow H^-$ and $F^+ \rightarrow F^-$ is explained either by the formation of slow excited doubly-charged ions (the $H^+ \rightarrow H^-$ process) or by the fact that the primary beam may contain admixtures of ions in excited metastable states (the $F^+ \rightarrow F^-$ process). The two maxima on the $\sigma_{1-1}(v)$ curves were explained by the fact that the process $F^+ \rightarrow F^-$ is also accompanied by the process $F^{+*} \rightarrow F^-$ with a resonance defect different from that of the former process, but having the same value of the constant a. The excitation energies of the F^+ ions, calculated on the basis of this assumption, agree within the limits of errors with the energy values known from spectroscopic investigations (cf. Table II, reference 1).

To check the correctness of these assumptions, we investigated the processes $B^+ \rightarrow B^-$ in Xe, Kr, and H_2 and $O^+ \rightarrow O^-$ in Xe. The $\sigma_{1-1}(v)$ curves displayed three maxima for $B^+ \rightarrow B^-$ and two maxima for $O^+ \rightarrow O^-$. The observed maxima, as can be seen from the accompanying table,

Process	Calculated excitation energy, ev	Ion term	Term energy, ev
$B^+ - Kr$	5.6±1.6	$2s2p\ ^3P^0$	4.6
$B^+ - Kr$	11.7±1.6	$2p^2\ ^3P$	12.1
$B^+ - Xe$	5.0±0.9	$2s2p\ ^3P^0$	4.6
$B^+ - Xe$	11.3±1.0	$2p^2\ ^3P$	12.1
$B^+ - H_2$	4.4±0.3	$2s2p^3P^0$	4.6
$B^+ - H_2$	11.0±2.0	$2p^2\ ^3P$	12.1
$O^+ - Xe$	24.2±0.5	$2s2p^4\ ^2S$	24.4

which compares the calculated excitation energies of B^+ and O^+ with the tabulated data,[2] are due to the presence of B^+ ions in the excited states $2s\,2p\,^3P^0$ and $2p^3\,^3P$ and of O^+ ions in the $2s\,2p^4\ ^2S$ state in the primary beam. The good agreement between the calculated and tabulated values of the excitation energy of the B^+ and O^+ ions gives further confirmation of the correctness of the premises used to explain the presence of several maxima on the $\sigma_{1-1}(v)$ curves. However, as indicated in reference 1, it is possible to prove directly the applicability of the Massy adiabatic criterion to an evaluation of the forms of the $\sigma_{1-1}(v)$ curves. For this purpose it is necessary to compare the forms of these curves in two cases: a) when it is known with certainty that the beam emerging from the source has no excited ions (thermionic source), and b) when the beam may contain excited ions (high-frequency ionic source).



To make such a comparison, we measured the effective cross section σ_{1-1} for $Li^+ \rightarrow Li^-$ in Kr, A, and H_2 using Li^+ beams from a thermionic and a high-frequency source.* The resultant $\sigma_{1-1}(v)$ curves are shown in the diagram. The curve (dotted) obtained with the aid of a thermionic source (described in reference 3) shows only one maximum connected with the $Li^+ \rightarrow Li^-$ process for the Li^+ ion in the ground state. The curve obtained with the high-frequency source (solid line) shows an additional maximum due to the Li^+ ions in excited states $2s\,^3S$ and $2s\,^1S$, with excitation energies 59 and 60.7 ev, contained in the beam. The arrows on the diagram indicate the positions of the maxima† for the processes $Li^+(^3S) \rightarrow Li^-$ and $Li^+(^1S) \rightarrow Li^-$, calculated on the basis of the Massey criterion under the assumption that the constant a for these processes has the same value, on the order of 1.5 A, as for the $Li^+ \rightarrow Li^-$ process, which determines the position of the main maximum. As seen from the diagram, the additional maxima for Kr and A, within the limits of experimental error, appear in the locations called for by the Massey criterion.‡ It follows from this fact that the assumption that the constant a has the same value for double charge-exchange processes for unexcited and excited ions is correct. The results of the investigation of the $Li^+ \rightarrow Li^-$ process prove directly the possibility of applying the adiabatic Massey criterion to double charge exchange of these ions, and also confirm the correctness of the explanation of the nature of additional maxima on the σ_{1-1} curves for the processes $F^+ \rightarrow F^-$, $B^+ \rightarrow B^-$, and $O^+ \rightarrow O^-$.

We express our gratitude to A. D. Timofeev, who participated in the initial stage of the investigation of double charge exchange of lithium ions from a thermionic source.

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*We have designed for this purpose a high-frequency source operating with LiCl vapor. This source will be described elsewhere.

†In view of the small energy difference between the terms $2s^3S$ and $2s^1S$, the additional maxima connected with these states are not separated.

‡We could not establish the position of the additional maximum on the $\sigma_{1-1}(\nu)$ curve for H_2 because of the low intensity of the Li^+ beam at low energies; it is clear from the course of the curve, however, that this maximum does not exist.

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ELECTRON-NEUTRINO ANGULAR CORRELATION IN THE BETA DECAY OF THE FREE NEUTRON

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WE have determined the electron-neutrino angular correlation in the β decay of the free neutron by studying the decay-electron spectrum for a fixed recoil proton momentum. Figure 1 shows a schematic diagram of the apparatus. A collimated neutron beam 35 mm in diameter from the heavy-water reactor of the U.S.S.R. Academy of Sciences passed into an aluminum vacuum chamber which contained detectors and magnetic lenses to focus the decay electrons and recoil protons.

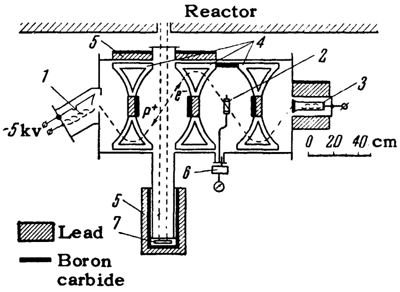

FIG. 1. Experimental setup: 1 – electron multiplier; 2 – Geiger-Mueller counter; 3 – photomultiplier; 4 – magnetic lenses; 5 – shield; 6 – device for filling the Geiger-Mueller counter; 7 – monitor.

The selection of electrons by momentum was done by the two consecutive toroidal magnetic lenses[1] pictured in the drawing to the right of the neutron beam. The resolving power of this system of spectrometers is ±3%. At the intermediate focus of the spectrometers there was a thin-walled (3 mg/cm^2 terelene) Geiger-Mueller counter filled with methylal at 110 mm Hg with forced gas circulation. At the second focus the electrons were detected by a counter consisting of a plastic scintillator 90 mm in diameter and 1 mm thick, a light pipe, and a BS photomultiplier.

With the help of this design only those electrons which passed through both detectors were chosen by means of a double coincidence with 0.2 μsec resolving time. The use of two consecutive lenses to detect electrons permitted us to reduce considerably the background of accidental coincidences and to limit the volume in which the detected decay occurred.

The separation of protons by momentum was done by a single toroidal spectrometer. An electron multiplier described in reference 2 was used to count the protons.

In the experiment we studied triple coincidences between the proton and electron detectors. To compensate for the flight time of the proton, pulses from the double coincidence circuit were delayed by 1.3 μsec relative to pulses from the proton detector. The resolving time of the triple coincidence circuit was 0.7 μsec.

In taking the data we regularly checked the efficiency of the electron multiplier with a calibrated α source and the operation of the Geiger-Mueller counter and the photomultiplier with the help of a Sr^{90} source.

The flow of neutrons was controlled with a monitor. The results of the measurements are shown in Fig. 2. The solid lines show the calculated forms of the electron spectra for different values of the electron-neutrino angular correlation coefficient.

The experimental points are shown with their standard errors. The results, worked out by the method of least squares, give the value $\lambda = -0.06 \pm 0.13$. Only statistical errors are given here. Possible systematic errors are being studied. The value we found is slightly different from the value of λ obtained by Robson[3] ($\lambda = +0.07 \pm 0.12$). If we assume that in β decay the main contribu-