

the system. Because of this condition, cross section (1) has a resonance character for low energies.

For energies comparable to the energy $\Delta\epsilon$ of the hyperfine structure the scattering cross section varies according to which of the hyperfine states in p_μ is occupied. As was shown earlier,⁶ the scattering cross section for a $F = 1 \rightarrow F = 0$ transition is very large (the transition probability for the more exact parametric values is $W \approx 5 \times 10^9 \text{ sec}^{-1}$). Therefore, p_μ mesic atoms pass to the state $F = 0$ in a time $t \approx 2 \times 10^{-10} \text{ sec}$ and acquire an energy $\frac{1}{2}\Delta\epsilon \approx 0.1 \text{ eV}$. The elastic scattering cross section of p_μ in the $F = 0$ state can be obtained in a way analogous to that reported earlier,⁶

$$\sigma_{el} = 2\pi \left| \frac{(\lambda_g + 3\lambda_u) + 4ik_2\lambda_u\lambda_g}{4 + ik_1(\lambda_g + 3\lambda_u) + ik_2(3\lambda_g + \lambda_u) - 4k_1k_2\lambda_u\lambda_g} \right|^2, \quad (2)$$

where $k_1 = \sqrt{M_p\epsilon}$, $k_2 = \sqrt{M_p(\epsilon - \Delta\epsilon)}$, and ϵ is the energy in the center-of-mass system. It is important to note that the value of $\lambda_g + 3\lambda_u$, which with the values of λ_g and λ_u given above determines the elastic cross section, is very small (while the value of $\lambda_g - \lambda_u$ entering into the inelastic cross section is large). Therefore, the elastic scattering cross section is very small:† for $\epsilon = 0$, $\sigma_{el} \approx 1.7 \times 10^{-22}$, and for $\epsilon = \frac{1}{4}\Delta\epsilon$, $\sigma_{el} \approx 2.2 \times 10^{-22} \text{ cm}^2$.

For $\epsilon = \frac{1}{4}\Delta\epsilon$, the inelastic cross section for the process by which pp_μ mesic molecules are formed is⁵ $\sigma_{inel} = W_{pp\mu}/Nv \approx 2.4 \times 10^{-22} \text{ cm}^2$. Thus, the mean free path of a mesic atom that has passed from $F = 1$ to $F = 0$ is $\lambda \approx 1/N\sigma_{tot} \approx 0.5 \text{ mm}$, i.e., a noticeable "fissure" can be observed even in pure hydrogen.

The $d_\mu + d$ cross section for energies greater than the hyperfine structure level is analogous to Eq. (1):

$$\sigma = 2\pi \left(\frac{2}{3} \frac{\lambda_g^2}{1 + k^2\lambda_g^2} + \frac{1}{3} \frac{\lambda_u^2}{1 + k^2\lambda_u^2} \right); \quad \lambda_g = 6.7; \quad \lambda_u = 5.7.$$

This cross section is two times smaller than the one obtained by Cohen et al.² We note that in the case of $d_\mu + d$ collisions a transition to a lower state of the d_μ ($F = \frac{1}{2}$) hyperfine structure is also possible (although the probability of this is considerably less than for the resonance transition in p_μ). This circumstance could, roughly speaking, triple the probability of $\mu^- + d \rightarrow n + n + \nu$ capture in comparison to the value computed by A. Rudik,⁸ if it is assumed that the capture of a μ^- meson from the $F = \frac{3}{2}$ state is very much suppressed. However, the formation of dd_μ molecules causes the blending of

the $F = \frac{1}{2}$ and $F = \frac{3}{2}$ states, and subsequent catalysis of the $d + d$ reaction would appear to make experiments for the study of the $\mu^- + d \rightarrow n + n + \nu$ reaction in deuterium impracticable.

*Assuming that $kR_0 \ll 1$ [R_0 is the interaction radius of the potentials $E_g(R)$ and $E_u(R)$].

†It should be noted that actually the cross section may be quite different from these values because of the sensitivity of the resonance value for λ_g on the exact form of the potential.

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FLUCTUATIONS OF ATOMIC STRUCTURE IN LIQUID HELIUM

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A detailed investigation of the atomic structure of liquid helium was carried out¹ by studying the scattering of slow neutrons. It was found that the packing of the atoms is quite dense, with an average coordination number of approximately eight units. However, the average distance between nearest atoms exceeded considerably the distance to the minimum on the curve of potential energy

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 $\sim 2 - 5^\circ\text{K}$ 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 obtained² an equation for the quadratic fluctuations of the coordination number in the liquid

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

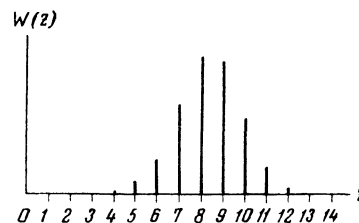
where $g(r)$ is the radial distribution function, v the average volume per particle, r_1 the abscissa of the first minimum of $g(r)$, and \overline{z} the average coordination number

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

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 approximation 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 $r_1 = 4.6 \text{ \AA}$, Eq. (2) yields $\overline{z} = 8.4$, 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 \overline{z} and δz makes it possible to plot this distribution. The estimates obtained above for \overline{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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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 $|\Delta E|/h\nu_{\text{max}} \approx 1$. The presence of two maxima on the $\sigma_{1-1}(v)$ curves for the processes $\text{H}^+ \rightarrow \text{H}^-$ and $\text{F}^+ \rightarrow \text{F}^-$ is explained either by the formation of slow excited doubly-charged ions (the $\text{H}^+ \rightarrow \text{H}^-$ process)