then immaterial whether the distribution of x is normal or not. Such an estimate accounts for the energy spectrum $E_0^{2.7}$ of shower-producing particles, and for the energy spectrum of secondary shower particles (through the factor B). The factor B depends also on the angular distribution of shower particles. (cf. references 2 and 3).

More detailed data on actual energies of primary particles for individual showers and fluctuation curves will be given in a work devoted to the study of showers detected in emulsions at high altitudes.

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*The necessity of this has been demonstrated by N. L. Grigorov. A number of important observations has been made by G. P. Zhdanov.

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Translated by H. Kasha
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CONTRIBUTION TO THE THEORY OF THE POMERANCHUK EFFECT IN He^3

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POMERANCHUK[1] predicted that the melting curve of He^3 would have a minimum on the p-T diagram, and that below this minimum the heat of melting would be negative. Since this effect has been observed experimentally,[2] it is interesting to examine this problem by using the thermodynamic functions calculated on the basis of the Fermi-liquid model, as proposed by Landau.[3] Our purpose is to reconstruct the left branch of the melting curve from the experimentally-known portion of the curve above the minimum.

The equation relating the two melting temperatures, for equal pressure, is of the form

$$\Phi^{\mathrm{I}}(p, T_1) - \Phi^{\mathrm{I}}(p, T_2(p)) = \Phi^{\mathrm{II}}(p, T_1) - \Phi^{\mathrm{II}}(p, T_2(p)), \tag{1}$$

where $\Phi^{\mathrm{I}}(p, T_1)$ and $\Phi^{\mathrm{II}}(p, T_1)$ are the thermodynamic potentials below the minimum point for the liquid and solid phases respectively, and $\Phi^{\mathrm{I}}(p, T_2(p))$ and $\Phi^{\mathrm{II}}(p, T_2(p))$ are the corresponding quantities above the minimum point.

It is known that above 0.5°K the entropy of liquid He^3 is essentially of spin origin. On the other hand, the spin entropy should increase with increasing pressure, owing to the increase in the exchange interaction that contributes to the parallel orientation of the spins[3,4] and competes with the Fermi tendency towards the anti-parallel spin arrangement. From the equality $(\partial S/\partial p)_T = -(\partial V/\partial T)_p$ we see that the coefficient of expansion is negative in that region of temperatures, in which $(\partial S/\partial p)_T > 0$. Consequently, the density of liquid He^3 should have a maximum, as indeed was observed experimentally[5] (the temperature of the maximum is $T_0 \approx 0.4°K$). In view of the fact that the density of liquid He^3 has a maximum near the minimum point of the pT diagram, it is easy to show that the effect of the change in volume can be neglected. Assuming that the coefficient of expansion of solid He^3 is of the same order of magnitude as that of He^4, the change in volume can also be neglected in the solid phase. Equation (1) can then be replaced by

$$F^{\mathrm{I}}(T_1, V) - F^{\mathrm{I}}(T_2, (p), V)$$
$$= F^{\mathrm{II}}(T_1, V) - F^{\mathrm{II}}(T_2(p), V), \tag{2}$$
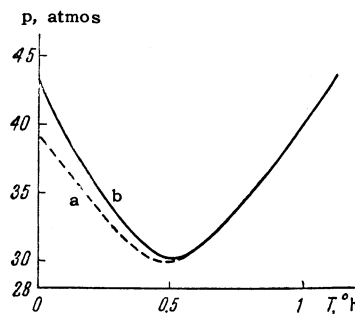
where $F(T, V)$ is the free energy.

FIG. 1

Using the results of Khalatnikov and Abrikosov,[4] it is possible to calculate the free energy of liquid He^3 for two possible forms of the spectrum

$$\varepsilon(p) = p^2/2m, \tag{3a}$$
$$\varepsilon(p) = (p - p_0)^2/2m. \tag{3b}$$

The calculations yield, respectively

$$F^{\mathrm{I}} = RT\{-2I_{3/2}/3I_{1/2} + \ln A\}, \tag{4a}$$
$$F^{\mathrm{I}} = RT\{-2I_{1/2}/I_{-1/2} + \ln A\}, \tag{4b}$$

where

Q, cal/mole

FIG. 2

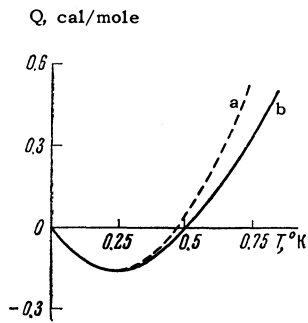$$I_\alpha = \int_0^\infty \frac{x^\alpha}{e^x/A + 1} dx, \quad A = e^{\mu/kT}.$$

In the solid phase, according to references 1 and 2, the spin orientation begins at temperatures considerably below those of the liquid phase. Consequently, we can write for the free energy $F^{II} = - RT \ln 2$. The thermal portion of the free energy, proportional to $RT(T/\Theta)^3$, we neglect since $T \ll \Theta$.

Solving (2) graphically, we find the connection between T_1 and $T_2(p)$. Knowing $T_2(p)$ from experiment,[6] it is possible to plot the p-T diagram (Fig. 1). In view of the fact that the entropy and specific heat of liquid He^3 are in better agreement with experiment for the spectrum (3b), the corresponding curve should fit better the transition from the liquid phase into the solid phase. As can be seen from Fig. 1, where the letters a and b correspond to spectra (3a) and (3b) respectively, the p-T diagram should have a minimum at $T \approx 0.5°K$ and $p \approx 30$ atmos.

The heat of melting is computed as $Q = T(S_l - S_s)$. Below 0.5°K the heat of melting is negative and reaches a maximum value at $T \approx 0.25°K$ (Fig. 2).*

In conclusion the author considers it his pleasant duty to thank Professor I. M. Lifshitz for suggesting the problem and for valuable advice.

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*In the calculation of Q, no account was taken of the dependence of the entropy on the pressure.

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Translated by J. G. Adashko
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DISCRETE ENERGY LOSSES OF ELECTRONS IN SOLIDS AND YIELD OF SECONDARY ELECTRONS

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THE yield of secondary electrons in metals is small. This is explained by the interaction between the secondary electrons that move in the substance and the conduction electrons. As a result of this interaction, many secondary electrons reach the surface with an energy less than the work function in vacuum. The loss of secondary electrons in dielectrics and semiconductors should obviously be due to a different mechanism. As early as in 1939, Bruining and deBoer proposed that substances with high and low values of the secondary-emission coefficient δ have different arrangements of the energy bands.[1]

The electrons reflected after interaction in media, like the incident electrons, participate apparently in the formation of secondary electrons. If it is assumed that secondary electrons are produced by the incident and reflected electrons via the same mechanism, then investigations on the energy losses of the reflected electrons can be generalized to include the incident electrons.

Many investigations[2-6] have led to the conclusion that the discrete energy losses of the low-energy electrons incident on matter are due to the electron excitation by the crystal lattice and to their transition from the filled band to one of the allowed free bands located above the potential of vacuum. Such a loss mechanism is accompanied by the appearance of electrons with increased energies in media. Under favorable conditions, if the energy of an electron reaching the surface of the substance is greater than the work function, it can escape into the vacuum as a secondary electron.