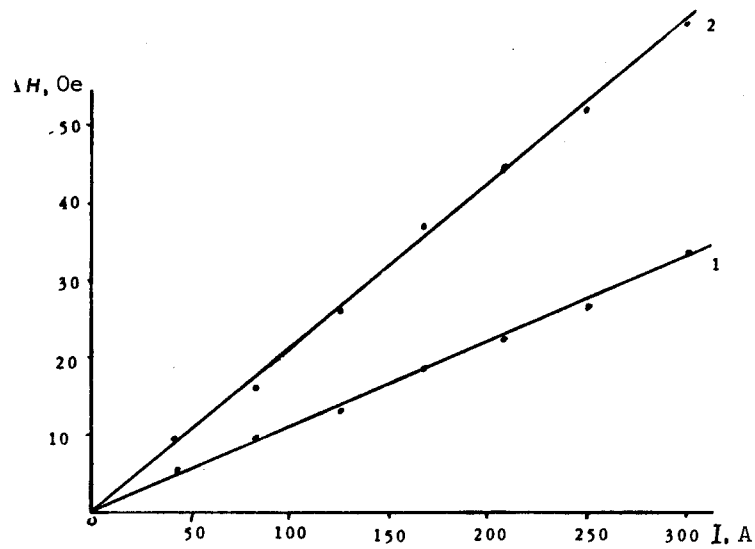

Fig. 2. Change of magnetic field vs. the current through the specimen. The curves correspond to the following initial magnetic field: 1 - 170 Oe, 2 - 340 Oe.

We see that in this case the change of the magnetic field depends linearly both on the initial field H_0 and on the current through the specimen. The corresponding experimental plots of the paramagnetic effect are shown in Figs. 1 and 2. The plots for the diamagnetic effect are analogous.

We note in conclusion that the carrier mobility of the employed material, estimated from the magnetoresistance effect, amounts to $\sim 2 \times 10^5$ cm^2/V-sec at the experimental temperature. The observed magnitudes of the kinetic diamagnetism and paramagnetism correspond to the same value of the mobility.

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MELTING OF SODIUM AT HIGH PRESSURES

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The melting of sodium at pressures up to 12,000 kg/cm^2 was investigated by Bridgman [1, 2]. Unfortunately, Bridgman's results are insufficiently complete in many cases (there are no determinations of the absolute values of the solid and liquid sodium), and are sometimes quite unconvincing. The latter pertains, principally, to the character of variation of the melting heat of the sodium with changing pressure.

These circumstances have induced us to study the melting of sodium at high pressures by a volume method. Measurement of the volume of sodium in the region of the melting curve at pressures up to 25,000 kg/cm^2 were performed with the aid of a piston piezometer of construction similar to that described in [3]. As a result of the experiments, we determined the values of the volumes of the solid and liquid sodium and their difference ΔV along the melting curve.

Further, using the Clausius-Clapeyron equation $dT/dP = \Delta V/\Delta S$ and using the relations $\Delta H = T\Delta S$ and $\Delta H = \Delta U + P\Delta V$ we can easily calculate the changes of the entropy ΔS, of the enthalpy ΔH, and of the internal energy ΔU of the melting of sodium.

However, unlike Bridgman's work [1], the temperature pickup (chromel-alumel thermocouple) was subjected in our measurements to the action of high pressures, causing an appearance of a systematic error in the determination of the temperature [4].

Therefore to calculate the necessary derivatives we preferred to use the Simon equation, the coefficients of which were determined in [5] on the basis of Bridgman's data [1].

We note that the differences between the melting temperatures of sodium calculated with the aid of the Simon equation and those determined experimentally, correspond in general to the expected effect of the influence of the pressure on the thermal emf of chromel-alumel thermocouples [4].

The results of the measurements and of the subsequent calculations are listed in the table and are illustrated in Figs. 1 and 2. The maximum error in the determination of the volume was of the order of 0.1%. The pressure was measured accurate to ±20 kg/cm^2 in the range up to 15,000 kg/cm^2, and not worse than ±100 kg/cm^2 at higher pressures.

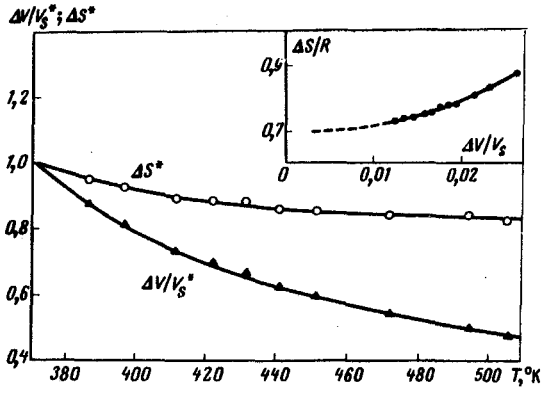

Fig. 1. Entropy jump and relative volume jump in melting of sodium, in relative units, vs. the temperature. The given quantities are referred to the values at atmospheric pressure. The insert shows the dependence of the entropy jump on the relative volume jump in the case of melting sodium.

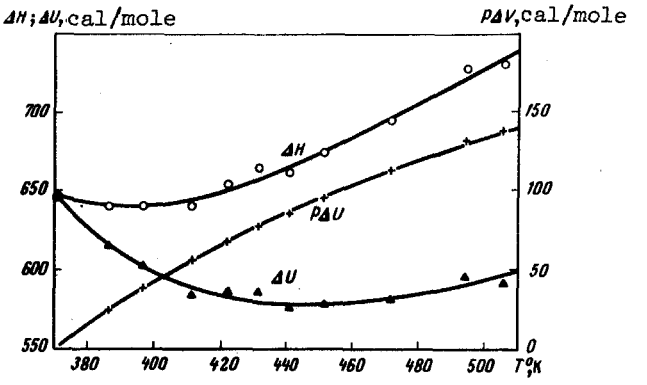

Fig. 2. Temperature dependence of enthalpy jump, of the internal energy, and of the work of expansion of melting sodium.

Figure 1 demonstrates clearly that it is impossible for the relative jump of the volume and the jump of the entropy to vanish simultaneously in the case of melting sodium, even under infinite compression. Furthermore, the presented material allows us to state that the entropy jump upon melting of sodium has an asymptotic limit. As to the volume jump ΔV, we see at present no reasons why ΔV cannot assume arbitrarily small values at a perfectly finite value of the volume V_S.

Thus, just as in the case of the melting of argon [6], we arrive at the conclusion that

$$\left.\begin{array}{l}\Delta S \to \text{const} \\ \Delta V/V_S \to 0\end{array}\right\} \quad \text{as} \quad T \to \infty$$

We now turn to Fig. 2, which shows the melting heat ΔH, the jump of internal energy ΔU and the work of expansion PΔV during melting of sodium as functions of the temperature.

In examining the minimum on the ΔU(T) curve, which is the cause of the corresponding minimum on the ΔH(T) curve, it should be recalled that the internal energy U is a sum of two parts, thermal and static.

P, kg/cm^2	T, °K	V_S, cm^3/mole	ΔV, cm^3/mole	$\frac{\Delta V}{V_S}$	$\frac{\Delta S}{R}$	ΔH, cal/mole	ΔU, cal/mole
1	370.8	24.168	0.640	0.0264	0.877	646	646
1940	386.6	23.549	0.547	0.0232	0.834	640	616
3310	396.8	23.154	0.499	0.0215	0.813	641	602
5460	411.6	22.597	0.439	0.0194	0.783	640	584
7070	422.0	22.215	0.410	0.0184	0.780	654	586
8640	431.4	21.852	0.385	0.0176	0.775	664	586
10300	440.9	21.507	0.355	0.0165	0.756	662	576
12270	451.4	21.126	0.333	0.0157	0.752	674	578
16445	472.1	20.390	0.293	0.0144	0.741	695	582
21600	494.6	19.605	0.260	0.0133	0.739	727	595
24370	505.8	19.235	0.241	0.0125	0.726	730	592

P - melting pressure, T - melting temperature calculated from the Simon equation, the coefficients of which are given in [5], V_S - volume of the solid sodium at the melting point, ΔV - jump of the volume upon melting, ΔS - jump of entropy upon melting, R - gas constant, ΔH and ΔU - jumps of enthalpy and internal energy upon melting.

In the present discussion we assume that the thermal part of the internal energy does not experience significant changes during melting. The reasons for this are, in the least, the very close values of the specific heats of the liquid and of the solid near the melting temperature [7]. Consequently the ΔU(T) plot on Fig. 2 characterizes, in the main, the behavior of the jump of the static part of the internal energy along the melting curve. In this connection, the minimum on the ΔU(T) curve can be interpreted as the result of competition between the corresponding contributions from changes of the energies of the interparticle repulsion and attraction, accompanying the melting and having different dependences on the difference of the volumes of the solid and liquid phases. There is no doubt that it is precisely the change of the energy of repulsion upon melting which causes the growth of the function ΔU(T) in the region of high temperatures. The reason for this can be readily explained by considering the limiting case with ΔV = 0 and ΔS = const. Obviously under these conditions the irregular packing of the atoms in the liquids ensures an increase of energy as a result of the nonlinear character of the interatomic forces.

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TEMPERATURE DEPENDENCE OF THE JUMP OF THE DEFORMATION STRESS IN A SUPERCONDUCTING TRANSITION

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A superconducting transition changes the deformation stress of a metal quite strongly. The stress jump $\Delta\sigma = \sigma_n - \sigma_s$ is appreciable (σ_n and σ_s are the deformation stresses of the metal in the normal and superconducting states, respectively) and has been observed in a number of metals (Pb, Nb, In, Sn) by indirect or direct methods [1 - 6]. This new result is attributed to differences in the deceleration of the dislocations by the conduction electrons in the normal and in the superconducting states. It is therefore very important to relate the observed change of the macroscopic characteristics of plastic deformation with the fundamental properties of the superconductor, for example, by measuring the temperature dependence of the jump in the stress. Such bulk measurements, which are needed for a reliable establishment of the type of temperature dependence, have never been performed. As shown in [6], in Pb at temperatures below $0.58T/T_c$, the value of $\Delta\sigma$ changes insignificantly with temperature. A sharp dependence of $\Delta\sigma$ was observed in Pb [4] near T_c, and it was asserted that this dependence is the same as for the critical field, i.e., $\Delta\sigma \sim 1 - (T/T_c)^2$. However, as shown in [5], such a statement is ambiguous.

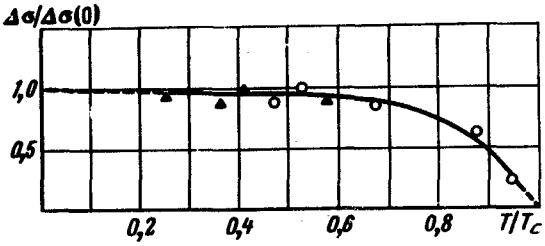

Fig. 1. Temperature dependence of the jump of the deformation stress $\Delta\sigma = \sigma_n - \sigma_s$, normalized to $\Delta\sigma(0)$: Δ - Pb, 0 - In.

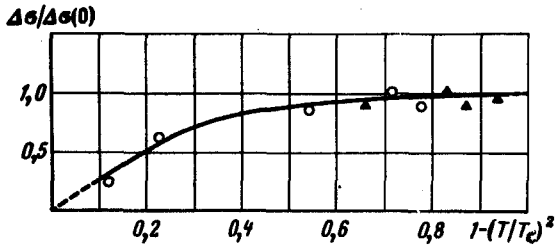

Fig. 2. Dependence of the normalized deformation-stress jump on $1 - (T/T_c)^2$: Δ - Pb, 0 - In.

We undertook the present investigation in order to establish the character of the temperature dependence of the deformation-stress jump as the metal goes over from the superconducting to the normal state. The transition at each measurement temperature was realized by turning on and off the magnetic field of a superconducting solenoid, inside of which the sample was continuously deformed. The objects of the investigation were 99.9995% pure Pb and 99.999% pure