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RELATION BETWEEN THE VOLUME JUMP DURING MELTING AND THE VOLUME OF A SOLID AT THE MELTING POINT

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Kraut and Kennedy [1] have recently proposed an empirical formula relating the change in the melting point of a substance with the relative contraction of its solid phase. This formula is

$$\frac{T}{T_0} = 1 + m \frac{\Delta V}{V_0} \quad (1)$$

where $\Delta V/V_0 = (V_0 - V)/V_0$ is the relative contraction, T_0 the melting temperature when the volume of the solid phase is V_0 , T the melting temperature when the volume of the solid phase is V , and m a constant of the particular substance. To illustrate the correctness of formula (1), the authors use most frequently for the parameter $\Delta V/V_0$ the value of the compression along the 25-degree isotherm. This can hardly have any physical meaning, but since the compressibility does not depend strongly on the temperature and the derivative dT/dp is not large for the melting curves, it is possible to assume with equal justification that the term $\Delta V/V_0$ in Eq. (1) represents compression along the melting curve.

The results of [1] are presently under extensive discussion [3-7], and most authors attempt to find a connection between formula (1) and the hitherto known empirical and semi-empirical laws for the melting process. The results of these papers show that expression (1) does not contradict the hitherto known data, but nevertheless it cannot be derived, say, from the Lindeman equation [8] in rigorous fashion without introducing some assumptions.

We are thus forced to conclude that Eq. (1), discovered by Kraut and Kennedy, is of independent significance. Let us rewrite (1) in differential form

$$\frac{dV_s^m}{dT_m} = \text{const}, \quad (2)$$

where V_s^m is the volume of the solid phase at the melting point and T_m is the melting temperature.

We recall further the very interesting experimental fact, observed by M. K. Zhokhovskii [9], which can be written in the form

$$\frac{d \ln \Delta V^m}{dT_m} = \text{const}, \quad (3)$$

where ΔV^m is the jump of the volume during melting.

From (2) and (3) we get

$$\frac{d \ln \Delta V^m}{dV_s^m} = \text{const}, \quad (4)$$

or

$$\Delta V^m = a \exp(V_s^m/c), \quad (5)$$

where a and c are constants with dimension of volume.

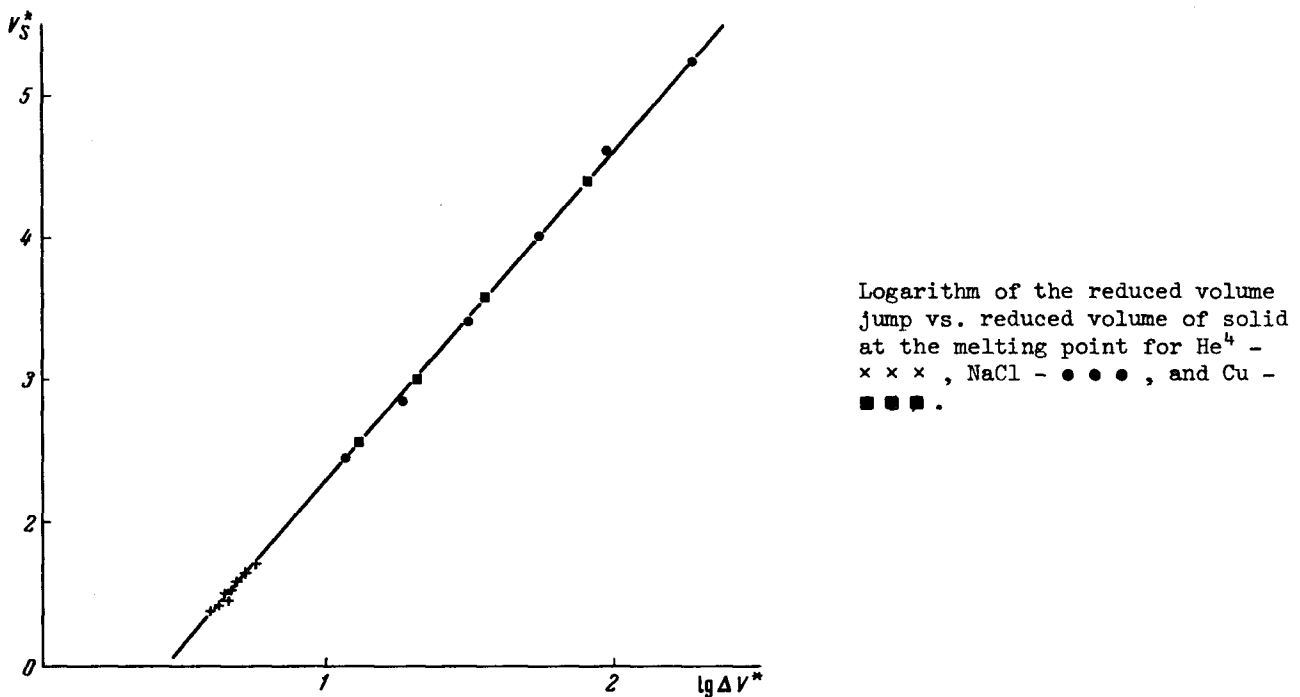
To check the conclusion contained in Eq. (5), we have used the experimental data on the melting of nitrogen [10], helium-3 and helium-4 [4], alkali-halide compounds [12], and a number of metals [13] obtained in experiments with shock waves. This check has shown that Eq. (5) describes well the experimental data up to very high pressures, corresponding to a reduction of the volume to less than one-half. Equation (5) can be rewritten in the form

$$\Delta V_m^* = \exp(V_s^*) \quad (6)$$

where

$$\Delta V_m^* = \Delta V^m/a, \quad V_s^* = V_s^m/c.$$

Consequently, the experimental data (ΔV and V_s) for different substances, expressed in corresponding reduced coordinates, are described by a single function.



The figure shows the dependence of the volume jump during melting on the volume of the solid phase at the melting point for copper [12], sodium chloride [12], and helium-4 [11], plotted in coordinates $\log \Delta V_m^*$ and V_s^* . The characteristic parameters a and c for these substances are listed in the table. It is seen from the figure that Eq. (6) agrees very well with experiment. All the foregoing leads to the following conclusions:

1. A universal connection exists between the volumes of the liquid and solid phases

along the melting curve. It can also be assumed that this connection remains in force also far from the melting curve, i.e., in the region of metastable existence of one of the phases.

Table

2. The wide range of validity of Simon's equation [13], which describes the melting curves of different substances, and the conclusion presented above, show that a universal connection can also exist between the entropies of the liquid and solid phases.

Substance	cm^3/g	cm^3/g
Cu	$8.19 \cdot 10^{-5}$	$2.7 \cdot 10^{-2}$
NaCl	$29.4 \cdot 10^{-5}$	$9.2 \cdot 10^{-2}$
He ⁴	0.109	1.766

3. The first two conclusions can explain the existence of formulas relating the melting temperature of substances with the properties of one phase only (see Lindeman's equation [8]).

4. It follows from (5) that under infinite contraction the volume jump during melting tends to a finite value; this is one more argument against the possible existence of a critical point on the melting curve.

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THRESHOLD OF EXCITATION OF TRANSVERSE ELASTIC WAVES BY A LASER BEAM

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When a high-intensity light wave produced by a laser propagates in a solid, interaction takes place between the light and elastic waves and can lead, under certain condition to growth of both longitudinal and transverse waves. Such a simultaneous excitation of longitudinal and transverse waves was revealed in [1] by stimulated Mandel'shtam-Brillouin scattering.

Let us consider a case in which a light wave with frequency ω_0 , wave vector k_0 , and electric-field amplitude E_0 is scattered simultaneously by a longitudinal and by a transverse wave. Then the wave vectors of both elastic waves are equal to $q = 2k_0$ (the Bragg condition), but their frequencies are different. In the case of an isotropic body, two waves are possible,