EQUATION OF STATE FOR SOLID ARGON

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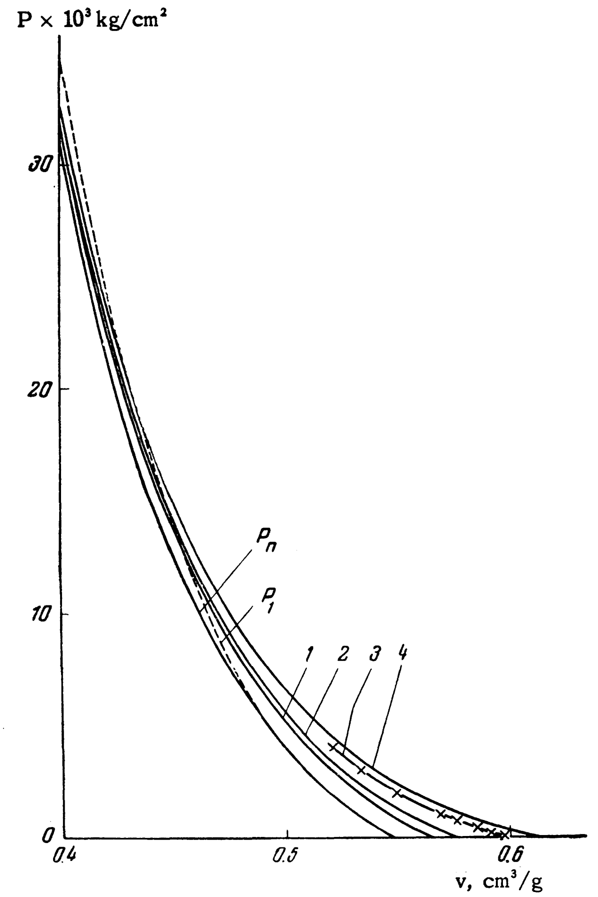
LET us take the volume dependence of the energy of a molecular crystal to be of the form[1]

$$E = A\exp(-Bx^{1/3}) - Cx^{-2}, \qquad (1)$$

where A, B, and C are experimentally determined constants, and $x = \rho_0/\rho$ is the reduced volume, ρ_0 being the density at absolute zero.

The power-law potential $E_1 = A_1x^{-3} - C_1x^{-2}$ used by Domb[2] is less accurate than Eq. (1), especially at high pressures.[1] This can be seen from the figure, where the dashed curve P_1 was obtained from Domb's potential E_1, and curve P_n was obtained from formula (1).



Pressure – volume relationship for crystalline argon. 1 – T = 65°K. 2 – T = 80°K. The crosses denote experimental points at 65°K taken from the work of Stewart.[3]

The free energy per unit mass, according to Debye's theory of the crystalline state, has the form

$$F = A\exp(-Bx^{1/3}) - Cx^{-2} + \frac{9}{8}Nk\Theta + NkT\,[3\ln(1 - e^{-\Theta/T}) - D(\Theta/T)] \qquad (2)$$

where N is the number of atoms per unit mass, k is Boltzmann's constant, Θ is Debye's characteristic temperature, which depends on the volume, T is the absolute temperature, and D(Θ/T) is the Debye function.

The third term in (2) is the zero-point vibrational energy of the lattice atoms, which for argon amounts to about 10% of the total energy of the crystal.

Using Eq. (2), we find the pressure P, the isothermal compressibility κ_T, and the coefficient of thermal expansion α from the formulas:

$$P = -\rho_0\left(\frac{\partial F}{\partial x}\right)_T; \quad \frac{1}{\varkappa_T} = -x\left(\frac{\partial p}{\partial x}\right)_T; \quad \alpha = \frac{1}{x}\left(\frac{\partial x}{\partial T}\right)_P = \varkappa_T\left(\frac{\partial P}{\partial T}\right)_x.$$

To determine the parameters A, B, and C we have used two points on the experimental curve P(x) at T = 65° K,[3] the value of the density ρ_0 from Dobbs et al,[4] and the expression $\Theta = ax^{2/3} \times (d^2F/dx^2)^{1/2}$, which follows immediately from the method of determining Θ when the constant a is found from the Debye temperature for T = 0.[5] Then with some reasonable approximations we obtain the following values for the constants:

$$A = 8.000; \quad B = 13.078; \quad C = 3.877 \text{ cal/mole}.$$

These values were used to calculate the parameters ρ(T) and α(T) shown in the table, and

T° K		20	40	60	80
ρ, g/cm³		1.763	1.735	1.690	1.634
	experiment[4]	1.764	1.737	1.691	1.636
α × 10⁴, deg⁻¹		5.6	10.7	14.8	19.4
	experiment[4]	4	12	15	18

P(v) for 65° K as shown in the figure, where $v = 1/\rho$. It can be seen that they agree well with the experimental results. The same good agreement is also found between the calculated and experimental values for the adiabatic compressibility.

From this it follows that the potential formula (1), when used with the above values of the parameters, is a good description of the current experimental data for solid argon, and may be used for extrapolating the equation of state to higher pressures.

In conclusion, I wish to thank V. N. Zharkov for proposing and discussing this subject.

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TWO CASES OF HYPERFRAGMENT DECAY

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UP to now only several decays of hyperfragments with $Z \geq 6$ has been described in the literature.[1-5] In three cases the binding energy of the Λ^0 particle has been estimated:

$$^{C}B_{\Lambda} = (13 \pm 6), \quad ^{N}B_{\Lambda} = (20 \pm 11),$$

$$^{O}B_{\Lambda} = (19.0 \pm 14.0)\ \text{Mev}.$$

In a stack of Ilford G5 emulsions, exposed in the stratosphere, we have observed a heavy hyperfragment which decayed by emission of a fast proton. This hyperfragment was interpreted as being F_{Λ} or Ne_{Λ}. A mesonic decay of a hyperfragment was also observed in this stack.

Case 1. A multiply charged hyperfragment is emitted from a star of the type 15 + 2n with a range $R = 127\,\mu$. The absence of δ rays near the end of the track and the narrowing of the track indicate that the hyperfragment came to rest. The charge of the hyperfragment is estimated from the length of the narrowing to be $Z = 8 \pm 2$. At the end of its track the hyperfragment decays into three charged particles (a, b, c in Fig. 1).

Particles a and b stop in the same emulsion after travelling 204 and $20\,\mu$ respectively. From the number of gaps and of δ rays, the charges of these particles were determined to be 1 and 1 — 2 respectively.

Particle c leaves the stack after penetrating 8 emulsions. The grain density and the multiple scattering yield a mass of $(2170 \pm 300)\ m_e$. Particle c thus can be identified to be a proton. Its energy is (117.3 ± 12.4) Mev.

The residual momentum of the three charged particles was computed for all possible types of particles allowed for a and b. Assuming that no neutral particles participate in the decay, the momentum unbalance has to be taken up by recoil of the residual nucleus leading to a range $R \leq 0.8\mu$.

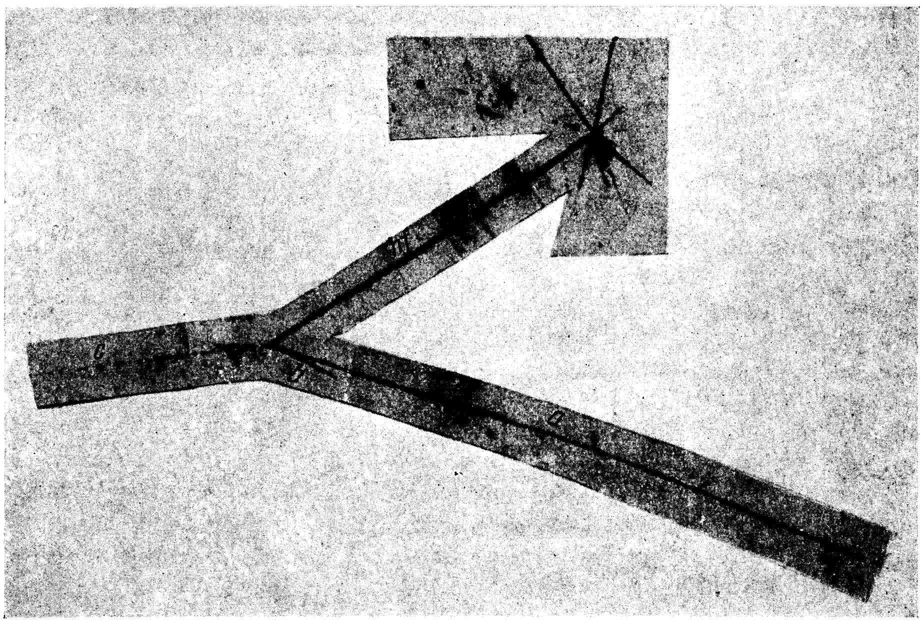

FIG. 1. Decay of a heavy hyperfragment.