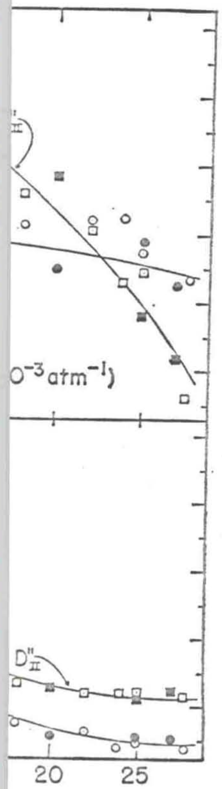
:fore we conclude that
e are no experimental
ılculated results must

ious isotherms yield
ınd these values are
parameters of a loga-
er which our calcula-
to 1 atm on each side
d that there is con-
ted points. This is
the calculation which
ars as a small change
fficulties arise in the
s obtained very good
vork near the melting
tions he presents for
otained are increasing
ngularity. Grilly[18] has
ution at a number of
s not present these
we have been able to
ters that fit his data.
. 11, and considering
d the fact that the



in atm⁻¹) for the loga-
squares are for $T<T_\lambda$.
ılculations from experi-
indrical approximation
lly (Ref. 18).

comparison had to be rather indirect, we find that the agreement is excellent.

It is also possible to calculate the isothermal compressibility from our expansion-coefficient data by using the thermodynamic relation

$$\left(\frac{\partial V}{\partial T}\right)_P=\left(\frac{\partial V}{\partial T}\right)_t-\left(\frac{\partial P}{\partial T}\right)_t Vk_T. \tag{8}$$

We have calculated k_T from this expression for the region $10^{-3}<|P-P_\lambda|<1$ atm by using the cylindrical approximation[26] and these points are also shown in Fig. 11. It is apparent that while the new intercept parameters are in good agreement with the other values, the slope parameters are not. In particular the cylindrical approximation indicates that the two logarithmic branches are close to being parallel. This is the consequence of the two branches of α_P being nearly parallel and the form of the approximation used. Since there is this disagreement we conclude that the conditions required for the cylindrical approximation to be valid have not been fulfilled. It should be noted that according to our first calculations, A_{II}'' is greater than zero at low pressures. This means only that the minimum in k_T along the isobars is closer to the transition than 10^{-3} atm. Thus the limiting form of the compressibility has not been reached and the cylindrical approximation can not be valid under these conditions.

Some of the anomalies of certain properties are shown in Fig. 12. The k_T minima along the isotherms and along the isobars and the minima of the isobaric molar volume are presented in a P-T diagram. The locus of $\alpha_P=0$ is also the locus of entropy maxima, in virtue of a Maxwell relation. It is interesting to note the gradual widening of the separation of the curves from the λ line as the pressure increases. The $\alpha_P=0$ curve becomes roughly parallel to the λ line above about 20 atm.

IV. CONCLUSION

We have presented and examined molar volume data for liquid He⁴ and have used them to calculate various

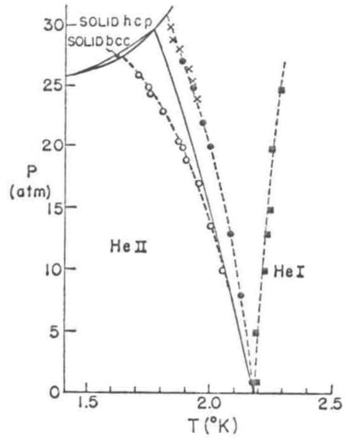


FIG. 12. The P-T phase diagram of He⁴ close to the λ line. Black circles: locus of $\alpha_P=0$ (present results); X: locus of $\alpha_P=0$ [Grilly and Mills (Ref. 5)]. Open circles: k_T minima along the isotherms [Grilly (Ref. 18)]. Black squares: k_T minima along the isobars (present results). Solid line: λ line

other thermodynamic properties of the fluid. In particular we have made a detailed study of the isobaric coefficient of thermal expansion to within about 2.10^{-5}°K of the λ line. This coefficient can be represented for all pressures in terms of a logarithmic singularity which becomes steeper as the pressure is increased. This conclusion is reached at least for the interval $10^{-2}\geqslant|T-T_\lambda|\geqslant 2\times10^{-5}$. The derivative $(\partial P/\partial T)_V$ can also be expressed in terms of a logarithmic singularity over this range of $|T-T_\lambda|$, although it is clear that this relationship cannot hold at the λ line. The derivatives $(\partial P/\partial T)_V$ as well as k_T are in agreement with all available direct measurements. On the other hand, we have attempted to use the cylindrical approximation for calculating k_T and have found that it does not give satisfactory results over the range of temperature displacement down to 10^{-5}°K.

ACKNOWLEDGMENTS

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[26] A. B. Pippard, *The Elements of Classical Thermodynamics* (Cambridge University Press, Cambridge, England, 1957), Chap. IX.