

III. SOLID STATE PHYSICS

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A. PHASE TRANSITIONS

Since the completion of our work on critical-point fluctuations (see October 15, 1948 Progress Report) our attention has been called to several important works on this subject. It therefore seems worthwhile to give a brief critical review of their relationships to our own work.

It is clear that the usual difficulty of infinite critical-point fluctuations arises from the fact that the work necessary to produce these fluctuations vanishes at the critical point if calculated in the usual approximation. Consequently, it becomes necessary to take into account contributions to the work which are otherwise negligible. It is not surprising that, since every additional term in the work makes the fluctuations finite, there should be a variety of methods of treating this problem. It is, furthermore, not possible to say a priori which of these additional work terms is most important in any particular case.

From this point of view, it appears that the various theories which have been proposed are not so mutually incompatible as their proponents considered them to be. In fact it has been shown that the work of Ornstein and Zernike (1) and that of Rocard (2) are closely related to our theory. More precisely, the equations of Ornstein and Zernike and those of Rocard can be derived from our work if certain special assumptions are made; these assumptions are, of course, different in the two cases.

Two more points may be mentioned. Firstly, the suggestion of Yvon (3), that the effect of gravity is important in giving rise to finite fluctuations in the case of the critical point of a gas seems to be reasonable, but we have not considered this effect since we were concerned with developing a general theory which would apply to λ -points in solids as well as critical points. Secondly, no matter what effect one considers as giving rise to finite critical-point fluctuations, these fluctuations are orders of magnitude larger at the critical point than elsewhere, and consequently it is necessary to consider the correlations of fluctuations in different volume elements along the lines of the theory we have developed.

A paper, "On the General Theory of Phase Transitions", has been completed. It is to be published as part of a volume containing the minutes of the N.R.C. Symposium on Phase Transitions held at Cornell University, August 1948.

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B. VACUUM SPECTROGRAPH

The design and most of the construction of the vacuum spectrograph is completed. Work is in progress in the design of the x-ray tube and excitation chambers. It is currently planned to use an electrostatic electron multiplier as the detecting element in the spectroscope.

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C. THEORY OF LIQUID HELIUM

We are considering the thermodynamics of liquid helium in some detail, regarding the λ -point of helium as a critical point in the sense used in the general theory of phase transitions developed by Tisza (4). The purpose is twofold. The first is the insight which a detailed treatment of a specific example might give into the general theory of phase transitions. Thus, historically, Ehrenfest's equations, and his classification of phase transitions as being of various orders, stemmed from Keesom's working out of relations between the apparent jumps in specific heat and thermal expansion coefficients in helium at the λ -point in terms of the slope $(dP/dT)_\lambda$ of the λ -line. The second aim of our investigation is to see whether the introduction of quasi-thermodynamic parameters, in line with this theory, could be of assistance in developing a microscopic theory of phenomena in liquid helium.

We find that the experimental curve of specific heat versus temperature for liquid helium in the neighborhood of the λ -point can be fitted by an empirical formula in which it is assumed that the c_p becomes infinite at the λ -point as $(|T - T_\lambda|)^{-m}$, where m is about 1/6 or 1/4 depending on which side of the λ -point one considers. (The infinities would be wiped out in the experimental curve because of the finite temperature intervals used in measurement.)

Assuming this form for the singularity in c_p , we find that the singularities in the curves of thermal-expansion coefficient and of compressibility must have the same form, with numerical coefficients given in terms of the slope $(dP/dT)_\lambda$ of the λ -line. These relations are the natural extension of the Ehrenfest equations, (which assume a jump in the specific heat), to phase transitions of the type, treated by Tisza (4), which assume singularities in the specific heat.

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References

- (1) L. Ornstein and F. Zernike, Phys. Zeits. 19, 134 (1918); 27, 761 (1926).
- (2) Y. Rocard, Jour. de Phys. 4, 165 (1933).
- (3) J. Yvon, Actualites Scientifiques et Industrielles, #542, 543, Paris, (1937).
- (4) L. Tisza, "On The General Theory of Phase Transitions" (written for the N.R.C. Symposium at Cornell University).