Letters to the Editor

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NOTES ON POINTS IN SOME OF THIS WEEK'S LETTERS APPEAR ON P. 214.

CORRESPONDENTS ARE INVITED TO ATTACH SIMILAR SUMMARIES TO THEIR COMMUNICATIONS.

Heat Transport in Liquid Helium below 1°

EXPERIMENTS by Pickard[1], which will shortly be published, have shown that the specific heat of liquid helium becomes roughly proportional to T^3 at about 0·9°–0·8°, that is, that the anomalous part of it has died out. This fact suggests that the other properties depending on the transition of atoms or groups of atoms into a state of higher energy—which is responsible for the λ-phenomenon—will also disappear in this region. The most conspicuous property of this type is the anomalous heat conduction which has lately been investigated by various authors[2]. The presumption that this anomalous conduction would vanish at very low temperatures was supported by a casual observation: we found that if a capsule[3] of the type used in magnetic cooling experiments contains insufficient helium to cover the salt completely, temperature differences within the capsule equalize only very slowly. One might have expected, remembering the well-known characteristics of liquid helium II found by Rollin[4], that a film of helium would cover the salt and bring about rapid equalization of temperature.

We have carried out some experiments on the heat conduction of the liquid in the following manner: two containers—each holding about 1 gm. of powdered iron alum—are connected by a capillary and this 'twin-capsule' is filled with liquid to a level above the salt in the upper part. The temperature of each part could be measured separately. As the heat capacities of the salt and helium are known, we could determine the amount of heat flowing from one part to the other, if a temperature difference between them was established either by a differential heat influx from outside or deliberately by radioactive heating. We used a capillary of 18 mm. length and 0·5 mm. diameter and worked with temperature differences not exceeding 0·1°. The experiments were restricted to the region between 0·2° and 0·5°, as experimental difficulties prevented us obtaining good results at higher temperatures. For reasons which we shall discuss in a detailed publication, the absolute value of the temperature may be wrong by about 10 per cent. If the results are expressed in terms of a heat conductivity (ϰ), one obtains the following values:

$T°$	ϰ
0·5	$2 \cdot 2 \times 10^{-3}$ cal. deg.$^{-1}$ cm.$^{-1}$ sec.$^{-1}$
0·4	1·4 ,, ,, ,, ,, ,,
0·3	0·7 ,, ,, ,, ,, ,,
0·2	0·2 ,, ,, ,, ,, ,,

These values are of the order of magnitude of normal conductivities. To give an idea of the times necessary for obtaining a decrease of a temperature difference to its e^{th} part in our experimental conditions, we mention that they amount to about 1, 2, 7, 50 minutes at 0·5°, 0·4°, 0·3° and 0·2° respectively. (This is in agreement with a preliminary experiment carried out with Rollin[4b] using a wider capillary and less salt; see also the remark of Shire and Allen[5].)

Our value at 0·5° is smaller by a factor 10^4 than the smallest value measured by Keesom[6], and it appears impossible to obtain Keesom's figure by extrapolating our curve. This, as well as the fact that our values are nearly proportional to Pickard's 'normal' specific heats seems to justify the assumption that we are concerned here solely with 'lattice' conduction. Heat conductivity can be represented quite generally[7] as the product of a specific heat, a velocity and a mean free path. Assuming that in our case heat is transported by elastic waves, we can calculate from the specific heat and the velocity of sound[8] that the mean free path of these waves is of the order of 10^{-3} cm. Owing to the approximate proportionality of ϰ and C_v, it is nearly constant in the temperature region in question, a fact suggesting that the mean free path is determined by the disturbances due to the zero point energy. We shall investigate this point more quantitatively after having improved the apparatus. We shall examine also at which dimensions ϰ begins to be dependent on the diameter of the capillary, as this would provide an independent means of determining the mean free path[9].

These results obviously imply that a rapid transport of heat by means of films will also cease at the temperatures in question. (*Added in proof:* experimental confirmation of this has now been obtained.) It may be mentioned that the investigation of the film phenomenon at very low temperatures has the advantage that—owing to the minute pressures of the gas—transport of heat by evaporation and recondensation is excluded. It should be noted also that our results indicate that it should be possible to employ liquid helium below 0·1°—using, of course, appropriate dimensions—in order to establish, or cancel at will, thermal contact, which is impossible in the region of anomalous conductivity. This is important when working with a magnetic two-stage apparatus, as is necessary, for example, in trying to utilize nuclear paramagnetism in order to obtain still lower temperatures than can be achieved in the ordinary way.

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[1] Pickard, G. L., Dissertation, Oxford (1937).
[2] See, for example, Keesom (ref. 6), Rollin (ref. 4), Allen, Peierls, Uddin, NATURE, **140**, 62 (1937); Cockcroft, *Nuovo Cimento*, **15**, 35 (1938).
[3] Kürti, N., Rollin, B. V., Simon, F., *Physica*, **3**, 266 (1936).
[4] Rollin, B. V., (*a*) Dissertation, Oxford (1935); (*b*) *Proc. VII. Int. Cong. Refrig.*, The Hague, **1**, 187 (1936); (*c*) Ref. 3. See also: Daunt, J. G., and Mendelssohn, K., NATURE, **141**, 911 (1938); and Kikoin, A. K., and Lasareff, B. G., NATURE, **141**, 912 (1938).
[5] Shire, E. S., and Allen, J. F., *Proc. Camb. Phil. Soc.*, **34**, 307 (1938).
[6] Keesom, W. H., Keesom, A. P., and Saris, B. F., *Physica*, **5**, 281 (1938).
[7] Debye, P., "Vorträge über die kinetische Theorie der Materie und Elektrizität" (Teubner, 1914), 50.
[8] Burton, E. F., NATURE, **141**, 970 (1938).
[9] Casimir, H. B. G., *Physica*, **5**, 495 (1938).