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Physics. — *"Further experiments with liquid helium. C. On the change of electric resistance of pure metals at very low temperatures etc. IV. The resistance of pure mercury at helium temperatures."* By Prof. H. KAMERLINGH ONNES. Communication N°. 120^b from the Physical Laboratory at Leiden.

§ 1. *Introduction.* Since the appearance of the last Communication dealing with liquid helium temperatures (December 1910 liquid helium has been successfully transferred from the apparatus in which it was liquefied to another vessel connected with it, in which the measuring apparatus for the experiments could be immersed — in fact, to a *helium cryostat.* The arrangements adopted for this purpose which have been found to be quite reliable will be described in full detail in a subsequent Communication. In the meantime there is every reason for the publication of a preliminary note dealing only with the results of the first measurements made with this apparatus, in which I have once more obtained invaluable assistance from Dr. DORSMAN and Mr. G. HOLST. These results confirm and extend the conclusions drawn from the previous experiments upon the change with temperature of the resistance of metals. Moreover, it was, in the first place shown that liquid helium is an excellent insulator, a fact which had not hitherto been specifically established. This was of importance since the resistance measurements were made with naked wires, a method that is permissible only if the electrical conductivity of the liquid helium is inappreciable.

§ 2. *The resistance of gold at helium temperatures.* In the second place a link in the chain of reasoning which I adopted in § 3 of Communication N°. 119^B to show that the resistance of pure gold is already inappreciable at the boiling point of liquid helium has been put to the test by determining the resistance in liquid helium of the gold wire Au_{III}, which was then estimated by extrapolation on the analogy of the platinum measurements. Within the limits of experimental error, which are indeed greater for the present experiment than was the case for the others, that value is now supported by direct measurement. The conclusion that the resistance of pure gold within the limits of accuracy experimentally obtainable vanishes at helium temperatures is hereby greatly strengthened.

§ 3. *The resistance of pure mercury.* The third most important determination was one of the resistance of mercury. In Communication N°. 119 a formula was deduced for the resistance of solid mercury; this formula was based upon the idea of resistance vibrators, and a suitable frequency ν was ascribed to the vibrators wich makes $\beta \nu = a = 30$ (β = PLANCK's number 4.864×10^{-11}). From this it was concluded:

1. That the resistance of pure mercury would be found to be much smaller at the boiling point of helium than at hydrogen temperatures, although its accurate quantitative determination would still be obtainable by experiment; 2. that the resistance at that stage would not yet be independent of the temperature, and 3. that at very low temperatures such as could be obtained by helium evaporating under reduced pressure the resistance would, within the limits of experimental accuracy, become zero.

Experiment has completely confirmed this forecast. While the resistance at 13°.9 K is still 0.034 times the resistance of solid mercury extrapolated to 0°C. at 4°.3 K, it is only 0.0013, while at 3° K it falls to less than 0.0001.

The fact, experimentally established, that a pure metal can be brought to such a condition that its electrical resistance becomes zero, or at least differs inappreciably from that value, is certainly of itself of the highest importance. The confirmation of my forecast[1]) of this behaviour affords strong support to the opinion to which I had been led that the resistance of pure metals (at least of platinum, gold, mercury, and such like) is a function of the PLANCK vibrators in a state of radiation equilibrium. (Such vibrators were applied by EINSTEIN to the theory of the specific heats of solid substances, and by NERNST to the specific heats of gases).

With regard to the value of the frequency of the resistance vibrators assumed before (one could try to obtain frequencies from resistances) it is certainly worth noting that the wave-length in vacuo which corresponds with the period of the mercury resistance vibrators is about 0.5 mm., while RUBENS has just found that a mercury lamp emits vibrations of very long wave-length of about 0.3 mm. In this way a connection is unexpectedly revealed between the change with the temperature of the electrical resistance of metals and their long wave emission.

The results just given for the resistance of mercury are, since they are founded upon a single experiment, communicated with all reserve.

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[1]) In connection with its deduction it is to be noted that the gold-silver thermo-element behaved in liquid helium quite so as the experiments in liquid hydrogen (KAMERLINGH ONNES and CLAY, Comm. N°. 107*b*) made expect.

While I hope to publish a more detailed description of the investigation which has led to these results in the near future, and while new experiments are being prepared, which will enable me to attain a greater degree of accuracy, it seemed to me desirable to indicate briefly the present position of the problem [1]).

[1]) That this is justified is apparent from important papers which I have just received as this goes to press; in one NERNST extends the investigation referred to in Comm. N°. 119 of the specific heats and is also independently led to assume a connection between the energy of vibrators and electrical resistance, and in the other this hypothesis is further developed by LINDEMANN.

E R R A T A.

In the Proceedings of the Meeting of March 25, 1911.

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(May 26, 1911)