The Electrical Resistance of Liquid Gallium in the Neighbourhood of its Melting Point

1950 Proc. Phys. Soc. B 63 662

(http://iopscience.iop.org/0370-1301/63/9/303)

The Electrical Resistance of Liquid Gallium in the Neighbourhood of its Melting Point

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Communicated by E. N. da C. Andrade; MS. received 17th May 1950

ABSTRACT. In order to determine whether any discontinuous change in electrical properties takes place when a liquid is supercooled, measurements have been made on the resistance of liquid gallium. No such discontinuity has been found, the resistance varying linearly with temperature over the range investigated.

The results yield values for the resistivity and temperature coefficient of resistance of liquid gallium.

§ 1. INTRODUCTION

RECENT experiments on supercooled liquids by Dodd and Hu Pak Mi (1949) have shown for several liquids a discontinuity in the viscosity–temperature curve occurring at the melting point as the liquid passes into the supercooled region. Since liquid gallium, a liquid metal (M.Pt. 29·9° c.), readily supercools, it is of interest to see whether any discontinuity occurs in any of its properties at the melting point. Viscosity and density measurements are at present being carried out in this laboratory, and the present paper describes the results of measurements of the electrical resistance of liquid gallium in the normal and in the supercooled state.

§ 2 PROCESSING OF GALLIUM

Gallium when melted, immediately acquires a surface coating of oxide which makes the metal wet glass, a condition unsuitable for accurate resistance measurements. About 40 gm. of gallium were melted in a quartz vessel and the oxide converted into the chlorides by addition of a little dilute hydrochloric acid. The vessel was exhausted through drying tubes and the excess acid absorbed in caustic soda tubes, leaving only gallium and a surface film of its chlorides. When the quartz vessel is maintained at red heat for two hours under a reduced pressure of 10^{-5} mm. Hg, the chlorides (boiling points 210° c. and 535° c.) boil off, leaving pure gallium with a shiny surface resembling clean mercury. This gallium does not now wet glass provided the vacuum is maintained. By tilting, the gallium was poured from the quartz vessel into the bulb of the resistometer joined to it by a cone and socket. The evacuated resistometer was then sealed off near this joint using a blow-pipe.

§ 3. APPARATUS

The resistometer (Figure 1) consists of a long (45 cm.) length of precision bore (1 mm.) capillary tubing in Pyrex with 1 cm. spheres blown at each end and connected to the reservoir bulb into which the gallium is initially introduced. Side tubes are fused to the spheres, and platinum strips sealed through the glass provide electrical contact between the gallium in the spheres and the mercury in the side tubes. The whole apparatus is mounted on a frame and immersed in a well-stirred water bath with the open ends of the side tubes just above the water level. The temperature of the bath was maintained constant to better than

0·01° c. and was measured with a mercury-in-glass thermometer calibrated to an accuracy within 0·02° c.

The electrical measurements were made on a Smith Difference Bridge in which the resistance of connecting leads is eliminated, so that resistances could be measured to an accuracy of about 0·00001 ohm.

§ 4. METHOD

The resistometer was first filled with liquid gallium and its resistance determined at a series of temperatures up to 20° c. above the melting point and also in the supercooled region. Readings taken at the same temperature for different fillings did not differ by more than 0·00004 ohm.

Since the measured resistance includes not only the resistance of the gallium in the capillary but also that of the mercury in the side tubes and of the platinum contacts, an estimation of these latter two resistances was obtained by measuring

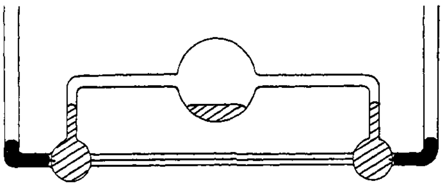

Figure 1.

the total resistance with the resistometer filled with pure mercury at 0° c. instead of gallium. The difference between this value and the value for the resistance of the mercury in the capillary tube, calculated from a knowledge of the resistivity of mercury and the dimensions of the capillary, gives the appropriate end correction at 0° c.

The uniformity and area of cross section of the tube were estimated by the usual mercury thread method and the length of the capillary was determined by a cathetometer.

§ 5 RESULTS

The measured resistance with the resistometer filled with Ga is plotted against temperature in Figure 2 over the range 0° to 50° c. It is seen that over this range the variation is linear, and moreover there is no indication whatever of any discontinuity occurring as the liquid passes through its melting point into the super-cooled region.

This confirms the work of Bridgman (1921) who made measurements on supercooled gallium at 0° c. and found the resistance to lie on a regular prolongation of the curve for the resistance above melting point. Guntz and Broniewski (1908) on the other hand found the resistance of the liquid to pass through a minimum and to increase again in the unstable region below the melting point.

§ 6. TEMPERATURE COEFFICIENT OF RESISTANCE

Neglecting the small resistance of the gallium in the end spheres, the measured resistance with the resistometer filled with gallium at temperature t °c. is given approximately by

$$R_0 + r_0 + (R_0\alpha + r_0\beta)t$$

where R_0 is the resistance at 0° c. of the gallium actually in the capillary, r_0 is the resistance of the mercury in the side tubes also at 0° c., and α and β are the temperature coefficients of gallium and mercury respectively. The slope of the line in Figure 2 is thus equal to $(R_0\alpha + r_0\beta)$, and the intercept on the resistance axis is $(R_0 + r_0)$.

At 0° c. Measured resistance when filled with mercury = 0·47752 ohm.
Calculated resistance of mercury in capillary = 0·47015 ohm.

Thus $r_0 = 0{\cdot}00737$ ohm ; $R_0 = 0{\cdot}13606$ ohm ; whence $\alpha = 1{\cdot}089 \times 10^{-3}$/deg. c.

It may be noted that, like mercury, liquid gallium has a much lower temperature coefficient of resistance than most other metals for which the coefficient approximates more nearly to the theoretical value ($3{\cdot}66 \times 10^{-3}$ per degree c.).

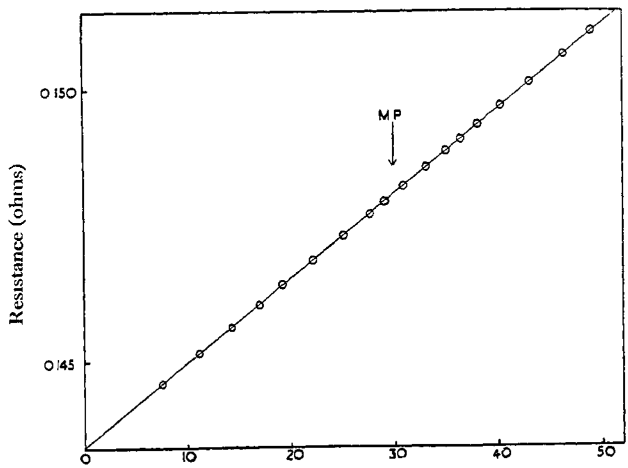

Figure 2

§7. RESISTIVITY OF LIQUID GALLIUM AT 0° c.

The results obtained with gallium enable an estimate to be made of the resistivity of gallium at 0° c., but in view of the uncertainty of the position of the ends of the capillary tube no great accuracy can be claimed. Since however the only published values for the resistivity differ widely, it is thought that even an approximate value might prove of use.

The area of cross section and the length of the capillary tube are $9{\cdot}0438 \times 10^{-3}$ cm² and 45·20 cm. respectively, whence $\sigma_0 = 2{\cdot}72_3 \times 10^{-5}$ ohm. cm. This value may be compared with the value $2{\cdot}592 \times 10^{-5}$ found by Bridgman (1921) and $2{\cdot}63 \times 10^{-5}$ given by Guntz and Broniewski (1908) both these values being at the melting point.

ACKNOWLEDGMENTS

The author wishes to acknowledge his indebtedness to Dr. G. R. Davies of the Chemical Research Laboratory, Teddington, for kindly lending the supply of gallium, and to Professor E. N. da C. Andrade for the interest he continues to show in this and related work.

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