Magnetoresistance of Liquid Sodium-Potassium Alloy

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The liquid alloy, Na-K, has been investigated for change of resistance in a magnetic field. The use of very fine containing tubes is believed to have minimized spurious effects due to motions in the liquid. The results of Fakidow and Kikoin are confirmed and in addition it is found that a longitudinal magnetic field produces a larger effect than a transverse field. For fields of over 2000 gauss there is a straight line relationship between magnetoresistance and field.

IT has recently been found by Fakidow and Kikoin[1] that the liquid alloy of sodium and potassium shows the phenomenon of magnetoresistance. This observation is of considerable importance because the effect in this alloy is so large that there can be little doubt as to its being genuine. It represents, therefore, the first distinct instance of magnetoresistance in liquids. The present paper describes further experiments on the alloy, in which the effect of a longitudinal field has been investigated.

The Na-K alloy was prepared and its composition determined by observation of the freezing point and reference to data given in the *International Critical Tables*. The sodium content was approximately 35 percent. The liquid alloy was then distilled in a vacuum through a series of bulbs and finally forced into a capillary tube by air pressure in a manner similar to that used by Fakidow and Kikoin. Platinum wires were sealed into bulbs at the ends of the capillary tube. These wires extended through each bulb and into each end of the capillary tube for a short distance. They fitted snugly into the capillary but allowed sufficient space for the alloy to flow through the bulb into the tube during the filling process. Two types of capillary tubes were used. In the first type, a straight tube about 20 cm long was bent back and forth so as to form a grid of parallel bars about 3 cm long connected at alternate ends by sharp bends. The second type was a straight tube, about 3 cm long, with no bends or turns.

The magnetic field was produced by a Weiss electromagnet, with pole pieces 10 cm in diameter and 3 cm apart.

The conventional type of Wheatstone bridge was used in measuring the resistance of the specimen. High sensitivity was secured by making the arms of the bridge as nearly equal as possible and by using a galvanometer of high sensitivity. This galvanometer was of the astatic needle type, equipped with a triple iron shield. A change of resistance of 5×10^{-7} ohms could be measured in a total resistance of 3 ohms.

The curves of Fig. 1 agree as well as could be expected with the results of Fakidow and Kikoin. The curve which they give, using a transverse field, is, in fact, almost coincident with curve III of Fig. 1.

In Fig. 1, the magnetoresistance is considerably smaller than in Fig. 2. This difference is probably due in part to the fact that different samples of the alloy were used in getting data for the two figures. Apparently the magnitude of the magnetoresistance is quite sensitive to the composition of the alloy. Another reason for the difference may be inaccurate determinations of R in dR/R. In correcting for the resistance of the fine platinum wires leading into the Na-K alloy it was difficult to get an accurate estimate of the correct length of these wires; they extended some distance into the alloy. The resistance of the wires being comparable with the resistance of the alloy an appreciable error could easily be introduced.

It will be noticed in Figs. 1 and 2 that there is an apparent dependence of the magnitude of dR/R on the diameter of the capillary tube. There are two reasons for this dependence. First, when different tubes are used, comparison of absolute values of dR/R cannot be made with a high degree of accuracy because of errors in allowing for lead resistances when R is determined. Second, a spurious, secondary effect due to motions of the liquid in the tube may arise.

[1] Fakidow and Kikoin, Physik. Zeits. d. Sowjetunion 3, 381 (1933).

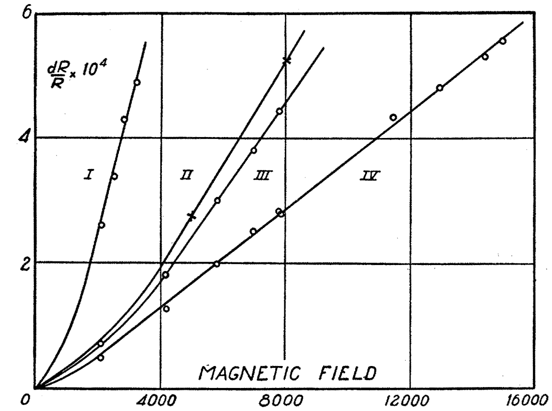

FIG. 1. Magnetoresistance of Na-K alloy contained in bent tubes. (I) Longitudinal field, tube diameter, 0.024 cm. (II) Transverse field, tube diameter, 0.024 cm. (III) Longitudinal field, tube diameter, 0.009 cm. (IV) Transverse field, tube diameter, 0.009 cm.

This secondary effect appears as an increase of resistance which is dependent on tube diameter, —the resistance increase having been found by Jones[2] to be proportional to the diameter for the case of mercury in large tubes.

It is believed that the spurious effect is very small in the present experiments and that differences in magnitude of dR/R for different tubes are due to errors in determining R. The reason for believing the spurious hydrodynamic effect to be small is because the capillary tubes in the present experiments were of such small diameter. Fakidow and Kikoin found only about 8 percent decrease in the effect when they changed the tube diameter from 1 mm to 0.5 mm. The tubes in the present experiment were considerably smaller than those used by Fakidow and Kikoin, hence there should be a considerably smaller dependence of the effect on tube diameter. Furthermore, a separate series of measurements was made on mercury in these fine tubes, and the resistance change was found to be negligibly small. If the spurious hydrodynamic effect is negligible in the case of mercury in these tubes we should expect it to be negligible for the alloy also.

In Fig. 2 curves III and IV show that when the current through the specimen is cut in half there is a slight increase in dR/R. Jones has found for mercury that the resistance increase due to hydrodynamic action is proportional to the current raised to the power -0.4, using a tube 5 mm in diameter and currents between 0.5 and 5.0 amperes. He suggests that for very small currents the resistance change would be independent of the current. In the present experiments it appears that the current is still large enough to produce a small effect, and therefore the spurious hydrodynamic effect has not been completely eliminated.

[2] T. J. Jones, Phil. Mag. **50**, 46 (1925).

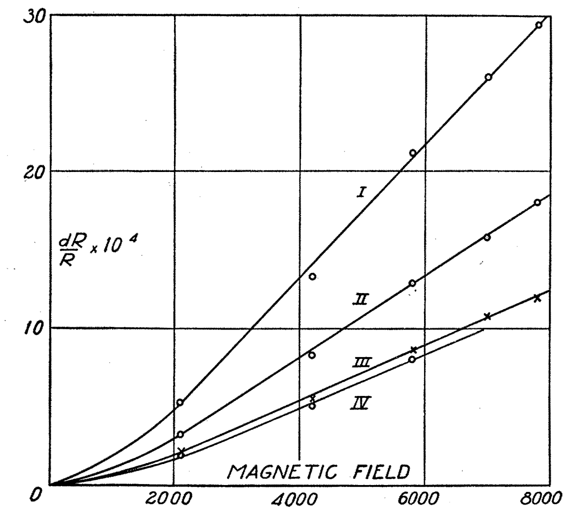

FIG. 2. Magnetoresistance of Na-K alloy contained in straight tubes. (I) Longitudinal field, tube diameter 0.008 cm, bridge current, 2.5 m.a. (II) Transverse field, tube diameter, 0.014 cm, bridge current, 2.5 m.a. (III) Transverse field, tube diameter, 0.008 cm, bridge current, 2.5 m.a. (IV) Transverse field, tube diameter, 0.008 cm, bridge current, 5.0 m.a.

There are certain general conclusions which may be drawn in spite of the possibility of errors of the kind discussed above. (1) An intrinsic magnetoresistance exists in the liquid alloy apart from any effect due to motions in the liquid. (2) A longitudinal magnetic field produces a larger effect than a transverse field. (3) Above 2000 gauss there is a straight line relation between dR/R and the field strength.

The second conclusion is a matter of some interest because in nonferromagnetic, polycrystalline solids the converse is true. The third conclusion states a relation which has been found to hold in solid metals for very large fields. The liquid state appears to make possible the straight line relation in much smaller fields.

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