electric field during the solidification of the sample. In no case has any evidence of an effect of the electric field been found, and it is concluded that the orientation present is due to the temperature gradient and the effect of interfaces during solidification, but not due to the orientating action of the electric field on the molecules.

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# THE HALL AND ALLIED EFFECTS IN CAST BISMUTH PLATES AS AFFECTED BY THE RATE OF COOLING

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While measuring the four transverse thermomagnetic and galvanomagnetic effects in a plate of bismuth cast from the molten metal certain abnormalities were noted in the results. As no published data could be found this research was undertaken to determine the effect of the rate of cooling of bismuth plates cast from the molten metal with respect to the four transverse effects and to help establish the relationship between heat and electricity.

The four transverse galvanomagnetic and thermomagnetic effects are shown schematically in figure 1, as they are most likely to be found

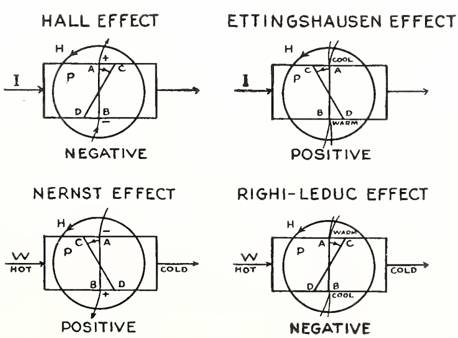


Fig. 1. Schematic diagram of the various effects.

in bismuth according to the convention of Campbell (1). The plate is represented by the rectangle P, I is the primary current, the circle H represents the magnetic field, the direction of the Amperian current in the electromagnet is given by the arrowhead. AB is an equipotential or equitemperature line, as the case may be, before the field H is on, CD is the position of this equipotential or equitemperature line, respectively, after the field is excited. If the direction of rotation of the line AB to the position of CD is opposed to the direction of the Amperian current H, as in the Hall and Righi-Leduc effects, the effect is negative. If the direction of rotation of the equipotential or equitemperature line AB to the position of CD is in the direction of the magnetic field H, as in Ettingshausen and Nernst effects, the effect is said to be positive.

A brass mold was used in casting the first two plates, but due to the difficulty in getting the bismuth loose from the brass sides was discarded for an aluminium mold. It was found that if the bismuth cooled slowly the plate appeared to be a single thin crystal with a definite cleavage plane almost parallel to the direction of expansion. Plates I and II were cooled in air and permitted to expand along the width of the plate. Plates III and IV cooled very slowly, expanding along the width and length respectively. Plate V was made by fast cooling brought about by pressing a piece of ice against each side of the heated mold and contents. This plate expanded along the width of the plate and had no definite cleavage plane. The crystals had random orientation and were reasonably large. Plate VI was made by placing the heated mold and contents in a solution of ice and ammonium chloride at — 10° C. When the molten metal and mold were placed in the freezing mixture the bismuth shot out of the mold with explosive violence. It was found necessary to close the top of the mold before a satisfactory plate was obtained.

It is known that some gases have a greater solubility in iron, copper, and a few other metals when liquid than when solid. It was suspected that this explosive nature of bismuth, cooled quickly, was due to the rapid evolution of gases absorbed while molten. To determine the amount of this absorption about 3 cc. of bismuth were melted under the following conditions: in a vacuum, one-half atmospheric pressure and atmospheric pressure. If there were any gases absorbed in the molten state the quantity was so small that it was not detectable. Since bismuth expands 3.3 per cent in solidifying it seems to the writer that this rapid change in volume is a more plausible explanation of the explosive nature of bismuth.

Plate VII, of electrolytic bismuth, was furnished by Dr. F. C. Mathers of the Department of Chemistry.

The potentiometer method was used to measure the various effects. A flip coil and ballistic galvanometer was used to measure the field intensities. The thermocouples were copper, constantin of No. 40 B. & S. wire.

Fig. 2 shows a plot of the data taken for the Hall effect corrected for the Ettingshausen effect, which is superimposed on the Hall effect in the seven plates used. Field intensities H are plotted as ordinates.

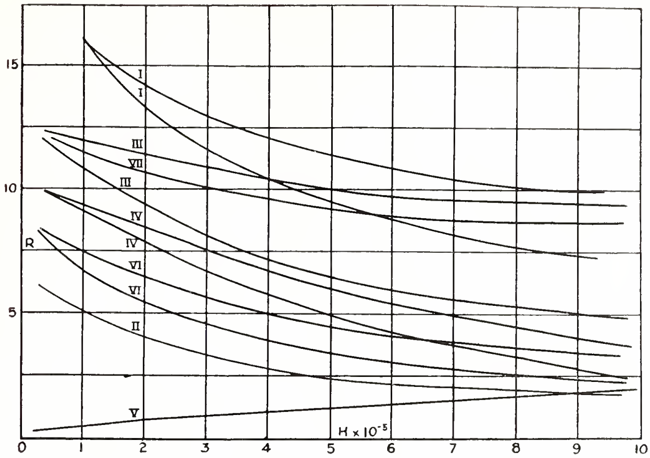


Fig. 2. Hall coefficient against Field Intensities.[1]

The Roman numerals above the curves indicate the plate for which the curve was drawn. Two curves having the same number indicate that the coefficient changed magnitude when the field was reversed. In taking data for these curves the plate was kept at room temperature and a current of 1.5 amperes was used. The Hall coefficient in Plate V was positive and increased as the field was increased. In all the other plates it was negative and decreased as the field was increased. No dissymmetry was found in Plate II, which was cooled in air, V, which was cooled quickly, and VII, which is electrolytic, i. e., the magnitude of the coefficient does not change when the field is reversed. Dissymmetry was

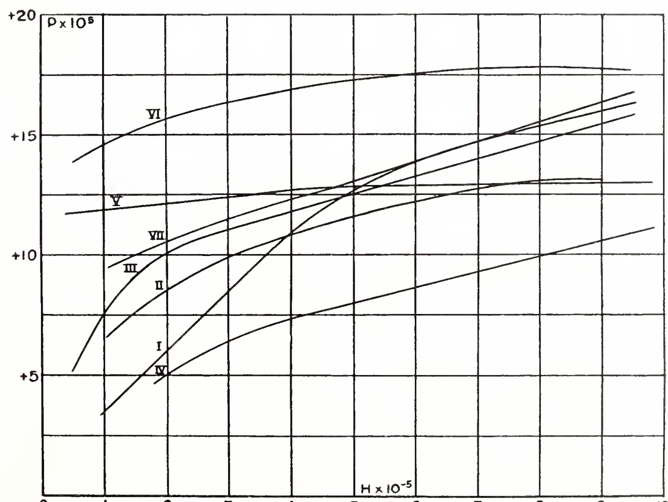


Fig. 3. Ettingshausen Coefficients against Field Intensities.[1]

[1] H x $10^{-5}$ should read, H x $10^{-3}$.

found in all the other plates when the field was reversed. Plate III, which was cooled slowly and had a very uniform crystalline structure, was found to exhibit the largest, while VI, formed by quenching, showed the smallest dissymmetry. Although Plates I and II were cooled under the same conditions the magnitude of the Hall coefficients of Plate II was approximately one-third the value for Plate I.

Fig. 3 shows the results of the data taken for the Ettingshausen effect. Field intensities are plotted as abscissae and Ettingshausen coefficient $P \times 10^5$ as ordinates. The plate was kept at room temperature and a current of 1.5 amperes was permitted to flow through the plate for at least two hours until a steady state was reached. The Ettingshausen temperature change took effect quickly at first and then more slowly, reaching a maximum after about a minute. From the graph it

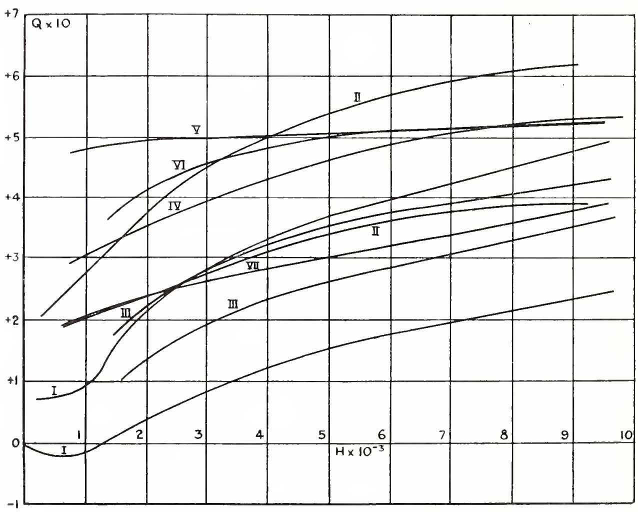


Fig. 4. Nernst Coefficients against Field Intensities.

is seen that the Ettingshausen coefficient increases with increase in field and tends to approach a limiting value. P for Plate VI shows a slight decline for high field intensities. Plates I, II, III, and IV were found to reach their limiting value more slowly than Plates V and VI, which were cooled quickly, and Plate VII, which is electrolytic.

Fig. 4 shows the results of the data for the Nernst effect corrected for the Righi-Leduc effect, which is superimposed on it. Field intensities H are plotted as abscissae and Nernst coefficients Q x 10 as ordinates.

In Plate I the Nernst coefficient was found to be negative with the field in one direction and positive with field reversed below 1300 gauss. Above 1300 gauss the coefficient was positive for either direction of the field. All the other plates were found to have a positive coefficient for all field intensities. A dissymmetry with reversal of the field was also found for the Plates IV, V, VI, and VII. The Nernst coefficient approaches a limit for high field intensities, but this limit is not the same magnitude except for Plates IV, V, and VI, which were cooled quickly. It is concluded from these curves that fast cooling causes the Nernst coefficient to approach the same value at high field intensities. The coefficient in Plate VII, electrolytic bismuth, was found to be positive for all field intensities.

The results for the Righi-Leduc effect are shown in fig. 5. Field intensities H are plotted as abscissae and Righi-Leduc coefficients $S \times 10^6$ as ordinates. A large dissymmetry with direction of field was found for Plate I. With the field in one direction the coefficient is negative and decreased as the field was increased. When the field was reversed the coefficient was negative below and positive above a field intensity of 5200 gauss. A dissymmetry with reversal of field was found for Plate III. The coefficients were positive for low field in-

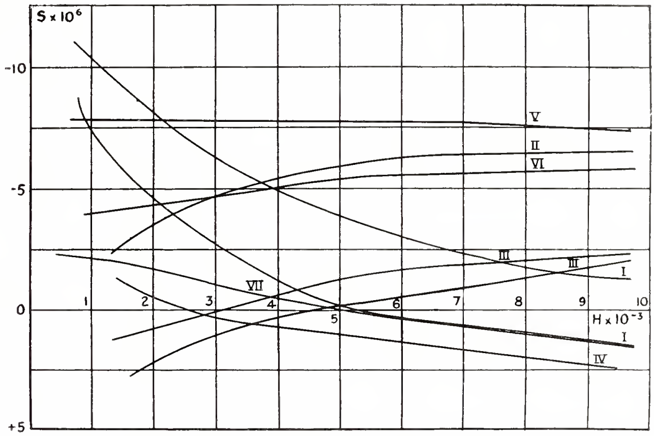


Fig. 5. Righi-Leduc Coefficients against Field Intensities.

tensities, but reversed at 3000 and 4700 gauss, respectively, and became negative as the field was increased. No dissymmetry with reversal of field was found for Plate IV, but the coefficient was negative below and positive above 2600 gauss. The coefficients of Plates V and VI are negative for all field intensities and no dissymmetry was found with reversal of field. No dissymmetry with reversal of the field was found for Plate VII, electrolytic bismuth, but the coefficient was negative below positive above field intensities of 5200 gauss.

In an effort to get some relation between the Hall, Ettingshausen, Nernst, and Righi-Leduc coefficients tables were made of the various values for each plate at 2000, 5000, and 9000 gauss from the curves shown in figures 2-5. According to Zahn (2), who extended Drude's (3) theory for the Hall and Allied effects, the ratios of the

$$\frac{\text{Hall coefficient}}{\text{Ettingshausen coefficient}} \quad \text{and} \quad \frac{\text{Nernst coefficient}}{\text{Righi-Leduc coefficient}}$$

should equal $2.5 \times 10^4$, and the sign of the ratio should be positive. When these ratios were calculated from the above mentioned tables of coefficients very little correlation was found between the magnitude and sign of the ratio.

The conclusion reached from this research are as follows:

1. The explosive nature of bismuth is not due to the absorption of gases when liquid, but is due to the sudden increase in volume on freezing.

2. The rate of cooling, size, and orientation of the crystals determined to a large extent the magnitude of the various coefficients.

3. There is very little correlation between the ratios of

$$\frac{\text{Hall coefficient}}{\text{Ettingshausen coefficient}} \quad \text{and} \quad \frac{\text{Nernst coefficient}}{\text{Righi-Leduc coefficient.}}$$

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# CHARACTER OF THE $^3$S TERMS IN THE MERCURY SPECTRUM

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On the basis of perturbation calculations in quantum mechanics and assuming the existence of more than one optical electron Langer[1] deduced an equation for the energy of the terms of spectra of complex atoms in the form of

$$\nu_n = \frac{R}{\left[n + \sum_{o}^{\alpha} \frac{p_{in}}{\nu_i \nu_n}\right]^2} = \frac{R}{(n^*)^2}$$

where $p_{in}$ is a function of the probability of transition between the terms $\nu_i$ and $\nu_n$, and the $\nu_i$ is an observable spectroscopic term. This cannot be any term, but must arise from an electron configuration with nearly equivalent energy as that of one of the terms $\nu_n$ of the series. When no perturbing term $\nu_i$ is near enough to $\nu_n$ the formula reduces to the usual Ritz form and the plot of the quantum defect $n^*$-n against $\nu_n$ is then a straight line. Where, however, the $\nu_i$ has a value falling amongst the terms of a series to which it does not belong then the plot of $n^*$-n for that series should be similar to a dispersion curve around an absorption line.

Langer pointed out that such cases arise in the arc spectrum of mercury as well as other metals. A plot of the terms of the $^3$S series determined from the $2^3P_2$-$m^3$S lines was made by Shenstone and Russell[2]