These observations relate to three different fillings. The mutual deviations in our determinations with a small transportable apparatus constructed especially with a view to the measurement of very low temperatures appear not to be larger than those in CHAPPUIS' results. Also the deviation of our mean value from that of CHAPPUIS is within the limits of deviation of his determinations with the large thermometer. We give here in addition the observations with CHAPPUIS' smaller apparatus:

1890 reservoir of „verre dur"	0,0036616—0,0036645
1st filling, 7 determination, mean	0,0036629
1890 2nd filling,	0,0036630—0,0036642
in 4 determination, mean	0,0036638

and the observations with the slightly varied initial pressure of 788 m. m.

1894 reservoir of „verre dur"	0,0036624—0,0036638
in 6 determination, mean	0,0036628
1894 reservoir of „verre dur",	0,0036621—0,0036626
mean	0,0036624

As could be expected larger deviations were found with this than in the determinations with the larger apparatus, in which the utmost accuracy was the chief object.

Physics. — Dr. E. VAN EVERDINGEN JR., "*On the* HALL-*effect and the resistance of crystals of bismuth within and without the magnetic field*". (Communication N°. 61 from the Physical Laboratory at Leiden, by Prof. H. KAMERLINGH ONNES).

1. In crystals of bismuth it is not possible to give one definite value to the HALL-coefficient or to the increase of the resistance in the magnetic field; on the contrary these quantities depend to a considerable extent on the position of the principal crystallographic axis with respect to the lines of magnetic force and the direction of the current. This follows from my measurements, published in the Proceedings of April 21, 1897, p. 494 and June 26, 1897,

p. 68 [1]). One of the hypotheses, introduced in order to explain the observed phenomena, amounted to this. that *no* increase of resistance would occur in the direction of the magnetisation. It would however have been sufficient to suppose, that the increase of resistance is *smaller* in the direction of the magnetisation than in the transverse directions. In order to allow of a decision between these suppositions, the increase of the resistance of the bars of bismuth N°. 1, 2 and 3 from the crystalline piece of bismuth from MERCK [2]) formerly mentioned, were measured once more while they were placed in the magnetic field with their longest dimension in the direction of the lines of force.

The results obtained with these bars made it appear most desirable to repeat the experiments with other and if possible better crystalline material. The remarkable results obtained by Mr. F. LOUIS PERROT at Genève for the thermo-electric constants of crystalline bismuth [3]) induced me to communicate with him. With extraordinary kindness he has put at my disposal one of the prisms of bismuth [4]) cut by himself with great care from a block of slowly cooled bismuth, for which assistance I take this opportunity of expressing my best thanks.

The complete results of the investigation on resistance, increase of resistance and HALL-effect in the bars cut from this prism I hope soon to publish; at present I wish to communicate separately a new particularity with respect to the HALL-effect which occurred during this work.

2. The observations lead to the following conclusion:

A bar of bismuth cut at right angles to the principal crystallographic axis, shows, in a magnetic field of about 5000 C. G. S. units *when placed with the principal axis* $\perp$ *the lines of force, a* HALL-*coefficient of normal magnitude and negative sign* (normal); *when placed with the principal axis* $\parallel$ *the lines of force, a smaller*, **positive** HALL-*coefficient.*

Hence the same bar of bismuth which in one position shows a HALL-effect similar to nickel for instance, after having been turned through 90° about the direction of its longest dimension, shows a HALL-effect similar to tellurium and antimonium.

The positions of the various bars before they were cut from the crystal is shown in fig. 1 (2 × nat. size).

[1]) Comm. Phys. Lab. Leiden, N°. 37, p. 7, N°. 40, p. 3.
[2]) Versl. d. Verg. 21 April 1897, p. 500. Comm. N°. 37, p. 16.
[3]) Arch. d. Sc. phys. et nat. (4) 6 p. 105 and 229, 1898, 7 p. 149, 1899.
[4]) Arch. d. Sc. phys. et nat. (4) 6 p. 121, 1898, Prism A.

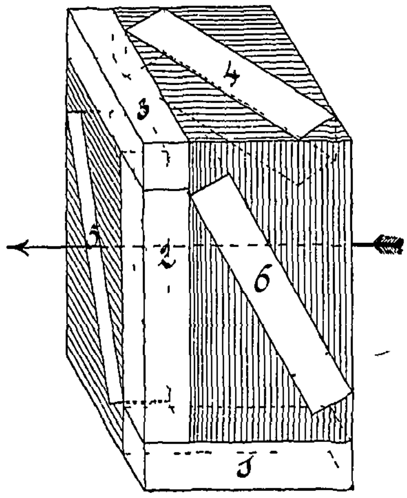

Fig. 1.

The principal axis, derived by PERROT from the position of the cleavage planes and characterised by the thermo-electric properties is indicated by an arrow. The bars 1, 2 and 3 have been cut along the three edges; 4, 5 and 6 with their longest dimension still parallel to one of the sides, but at angles of 30° or 60° to the edges of that side. If the crystal were completely homogeneous, No. 2, 3 and 5 fulfill the condition of being cut perpendicularly to the principal axis and ought to obey the rule given above.

The table below gives the results for the HALL-coefficient in two magnetic fields for each of the bars in 4 positions, always with the longest dimension perpendicular to the lines of force, but differing by consecutive rotation through 90° about that longest dimension. The numbers united by brackets refer to positions differing by 180°; in accordance with PERROT we indicate the positions in which the principal axis is perpendicular to the lines of force bij ⊥, the other positions by ||.

HALL-coefficient R.

	⊥		‖	
	MAGNETIC FIELD.			
N°.	5000	2900	5000	2900
2	— 9.2	— 11 0	— 0.15	— 0.70
	— 9.9	— 11.9	— 0.23	— 0 51
3	— 8 0	— 10 1	+ 0.16	— 0 10
	— 7.9	— 10.2	— 0.18	— 0.66
5	— 7 5	— 9.7	+ 0.58	+ 0 36
	— 7.4	— 9.6	+ 0 56	+ 0.19

A single view of the vertical columns and the corresponding positions ⊥ and || in a horizontal row is sufficient to carry the conviction, that the above mentioned relation of the HALL-coefficient to the position of the principal axis with respect to the lines of magnetic force not only is confirmed, but is even more marked than was found before. The new rule however, so far as the positive sign is concerned, is not satisfied in one position of 3 and in both positions of 2. The following remarks indicate why I nevertheless regard the results with 5 as normal.

1°. No certainty exists as to whether the original crystal was perfectly homogeneous, though it is certainly the most regular piece of bismuth ever tested for HALL-effect. PERROT himself admits the possibility that small irregularities, „macles" are present. If this be the case they are very probably most important at the edges, and hence particularly in the bars 2 and 3. The rather large discrepancy in bar 2 between the bracketed values indicates that this especially cannot have been quite homogeneous. Taking for granted that the rule given at the head of this § holds, irregularities can only alter the HALL-coefficient by a negative quantity in the position ||, and it would not require many to make that coefficient change sign altogether.

2°. Considering that a rotation of 90° at all events considerably alters the HALL-coefficient, the position of the bars would of course require to be regulated very accurately in order to exclude errors. With bars of about 3 mm. thickness it will not be astonishing that this accuracy was not attained. Here as well as with the first source of errors only diminution of a positive coefficient or even change into a negative one is to be expected. I suspect that this cause occurred with 3, the more so because in an experiment made some months ago in the first position || we also found a positive value but smaller than 0.16. On the contrary the value + 0.58 for 5 is a mean of values + 0.57 and + 0.59 obtained in rapid succession.

The observations further agree in this that a decrease in the magnetic field always causes a variation of the HALL-coefficient in the position || with a comparatively very large negative value. This gave rise to the supposition that the reversal of sign observed with 3 between 5000 and 2900 might occur with the other bars between other limits. With 2 this remains to be tested, but requires stronger fields. With 5 however in the first position || in a magnetic field of about 1300 C.G.S. —0.06, in the other position about 0 was really found, so that the supposition was here confirmed.

I am unaware of any disturbances which might cause an *apparent* positive HALL-coefficient in the method used by me. Only if the galvano-magnetic difference of temperature should rise here to an appreciable value much faster than usually, for instance in one second, it might have an influence to that effect. During the experiments there was no sign of this, and I consider such a disturbance to be quite improbable.

3. Certainly it will not be easy to give an explanation of these variations based upon the electron-theory. It seems however to me as if the reversal of sign need not represent a special difficulty, particularly because the theory had to reckon already with reversal by other influences. We take as an example the simplest theory which assumes the HALL-effect to be proportional to the difference of the migration-velocities (u—v). Usually in order to explain the phenomena in bismuth it is assumed that v is especially important, which constitutes an analogy with cathodic rays and the ZEEMAN effect. Hence in order to get a considerable variation of the HALL-coefficient it is certainly necessary to decrease v considerably. If this is carried far enough a reversal of sign of u—v may be expected. Should the objection be made that u here appears to be a non-negligible quantity, I can only remark that the positive value obtained for D (rotation of equipotential lines) for bismuth is even smaller than that for antimony and tellurium: and hence this does not constitute a *new* difficulty.

Reversal of sign was observed in consequence of:

a. Variation of temperature, with nickel, by CLOUGH and HALL [1]).

b. Variation of magnetic field, with alloys of bismuth with 1—6 pCt. of tin, by v. ETTINGSHAUSEN and NERNST [2]); with impure bismuth, by BEATTIE [3]).

c. Addition of an other metal in a constant field with bismuth mixed with increasing quantities of tin, by v. ETTINGSHAUSEN and NERNST [2]).

To this we can add now as fourth cause:

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1) Proc. Amer. Acad. 20 p. 189, 1893.

2) Wied. Ann. 33 p. 474, 1888.

3) TRANS. R. Soc. Edinb. 38(1) p. 225, 241, 1896.

d. Variation of position with respect to lines of magnetic force, in crystals of bismuth.

As mentioned before, in our experiments *b* also occurred.

In conclusion we note the fact, that increase of magnetic field *always* alters the HALL-coefficient by a *positive* amount, which seems to indicate that the influence of this increase is felt especially in v [1]).

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[1]) See § 6 Communication N⁰. 58, Versl. Kon Akad v. Wetensch. 30 Juni 1900, p. 195, Comm. N⁰. 58, p. 23.

(October 24, 1900.)