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KNAW, Proceedings, 15 I, 1912, 1912, pp. 649-666

Physics. — *"On the* Hall *effect, and the change ~~in resistance~~ in a magnetic field at low temperatures. III. Measurements at temperatures between* + 17° C. *and* —200° C. *of the* Hall *effect, and of the change in the resistance of metals and alloys in a magnetic field".* By Bengt Beckman. (Communicated by Prof. H. Kamerlingh Onnes). Communication No. 130*a* from the Physical Laboratory of Leiden.

(Communicated in the meeting of September 28, 1912).

§ 1. *Introduction.* A communication was made by Kamerlingh Onnes and the present writer to the meeting of June 29th 1912, of the results of measurements of the Hall-effect and of the increase of resistance in a magnetic field made by us at liquid hydrogen temperatures. In the present paper those results are extended to the temperatures which are obtainable with liquid ethylene and liquid oxygen, with the same experimental material and following the same experimental methods. It is of great importance that observations made with any particular substance should be distributed as uniformly as possible over the region of temperature under investigation. The measurements now completed make it possible for the results obtained at liquid hydrogen temperatures to be compared with those of former experimenters, who, without exception, proceed only to liquid air temperatures.

For a description of methods and material we may refer to the above Communication N°. 129*a*. In order to complete the diagrams of the present paper the results for liquid hydrogen temperatures in the paper quoted are also indicated without making specific mention of the fact on each occasion. The present paper is confined to a discussion of the results obtained with bismuth.

I. Bismuth.

§ 2. *Change in the resistance of a wire of electrolytic bismuth.* The resistance of the bismuth wire Bi_{dI} was measured in eight different fields at five different temperatures: $T = 290°$ K, 170° K, 139°.5 K, 90° K, 72° K. These results are given in Table I. H is the field strength in gauss, w'_T the resistance in ohms in the magnetic field at the absolute temperature T, w_T the resistance without field at that temperature, and w_0 the resistance without field at 0° C.

Fig. 1 shows the increase of resistance as a function of the field at constant temperature (Isotherms), and fig. 2 the increase of resistance as a function of the temperature under constant field (Isopedals).

TABLE I.

Resistance of Bi_{dI} as a function of the temperature and of the field.

H in Gauss	$T = 290°$		$T = 170°$		$T = 139°.5$		$T = 90°$		$T = 72°$	
	w'	$\frac{w'}{w_0}$	w'	$\frac{w'}{w_0}$	w'	$\frac{w'}{w_0}$	w'	$\frac{w'}{w_0}$	w	$\frac{w'}{w_0}$
0	2.570	1.057	1.570	0.646	1.365	0.562	1.075	0.442	0.989	0.407
2760	2.770	1.140	2.366	0.973	2.571	1.058	3.92	1.613	4.68	1.926
5540	3.110	1.280	3.657	1.504	4.414	1.816	9.24	3.80	12.28	5.052
7370	3.473	1.388	4.612	1.897	5.894	2.425	14.20	5.84	19.10	7.86
9200	3.635	1.495	5.613	2.310	7.605	3.128	19.74	8.12	26.6	10.94
11850	4.002	1.646	7.299	3.003	10.56	4.346	29.82	12.27	41.2	16.95
13600	4.248	1.746	8.506	3.500	12.596	5.180	38.60	15.88	52.4	21.6
15670	4.540	1.868	10.204	4.199	15.51	6.380	48.05	19.77	67.2	27.65
17080	—	—	11.412	4.695	17.78	7.316	55.80	22.96	77.8	32.0

In Table II are collected some results obtained by different experimenters for the increase of resistance in a magnetic field. It contains values of $\frac{w_{83° \mathrm{K}}}{w_{273° \mathrm{K}}}$ and $\frac{w'_T}{w_0}$ in a field of 16 kilogauss at the temperature of liquid air.

TABLE II.

Increase of resistance in a field of 16 kilogauss.

$\frac{w_{83°}}{w_{273°}}$	T	$\frac{w'}{w_0}$	Observer
0.42—0.44	81°K.	13.3	**Blake** [1])
—	81°	18.3	**Blake**: 5*b*
—	83°	23.8	**Du Bois** and **Wills** [2])
0.43	90°	20.9	**Beckman**
	72°	28.7	
0.36	88°	32	**Dewar** and **Fleming** [3])

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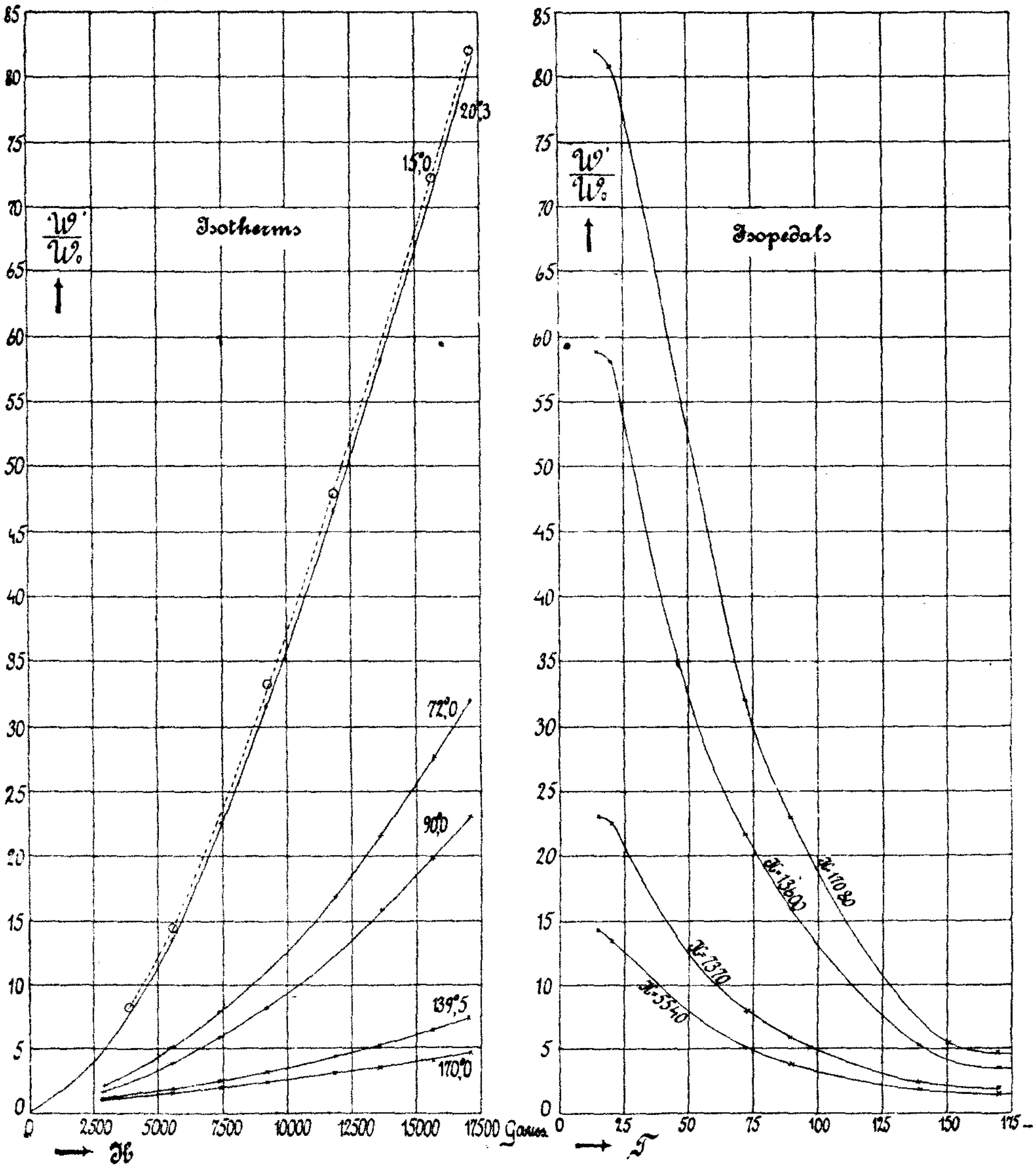
[1]) P. C. **Blake**: Ann. d. Physik. **28**, 449, 1909.
[2]) H. du **Bois** and A. P. **Wills**: Verh. d. Deutsch. Phys. Ges. **1**, 169, 1899.
[3]) J. **Dewar** and J. A. **Fleming**: Proc. Roy. Soc. **60**, **72**, 1896 and **425**, 1897.

Fig. 1 and 2.



The measurements by DEWAR and FLEMING give the largest results for $\frac{w'}{w_0}$ and at the same time the smallest results for $\frac{w_{83^\circ \mathrm{K}}}{w_{273^\circ \mathrm{K}}}$. They were probably obtained with extremely pure material. BLAKE worked with a large number of different bismuth wires. One of these, labelled 5*b*, gave a larger value for $\frac{w'}{w_0}$ than the others for which he gives a mean value. The wire with which I worked gives exactly this mean value for $\frac{w_{83^\circ \text{ K}}}{w_{273^\circ \text{ K}}}$, but a greater value for $\frac{w'}{w_0}$ at the temperature of liquid air. At higher temperatures there is also agreement between BLAKE's values for the latter ratio and mine.

The maximum in the isopedals found by BLAKE to lie at 36600 gauss at the temperature $T = 99^\circ$ K. and which, for lower temperatures, ought to be found at lower fields, was not observed in the present experiments.

In the weaker fields the isotherms are convex towards the axis of abscissae; from 12 Kilogauss upwards they become straight. For $H > 12000$ the relationship

$$\frac{w'}{w} = aH + b \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

holds, where a and b are constants, while, at lower temperatures

$$a = a_0 e^{-\beta T} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

to a first approximation. The following Table shows to what degree of approximation this relationship holds.

TABLE III.

a for Bi_{dI}.

T	$a_{obs.}$	$a_{calc.}$
170	1.94	1.95
139.5	4.2	4.5
90	18.3	17.1
72	29.7	27.9
20	117.5	114
15	121	131

Even at the boiling point of oxygen b is already clearly negative — 26.5). As the temperature falls the absolute value of $|b|$ increases rapidly, and at hydrogen temperatures it reaches the value — 110.

§ 3. *The* HALL *effect and the increase of resistance of plates of compressed electrolytic bismuth.* Tables IV and V contain the results of measurements made at ordinary temperature and at two liquid oxygen temperatures with the plates Bi_{pI} and Bi_{pII}. R is the HALL-

TABLE IV.

Hall effect, asymmetry and resistance change for Bi_{pI}.

H	$T = 289°$				$T = 90°$					$T = 74°.5$				
	RH	D	$-R$	$\left[\frac{w'}{w}\right]_T$	RH	D	R	Q	$\left[\frac{w'}{w}\right]_T$	RH	D	$-R$	Q	$\left[\frac{w'}{w}\right]_T$
2060	13.9×10^3	0.2×10^3	6.75	1.06	43.8×10^3	3.0×10^3	21.25	—	2.48	54.3×10^3	0.8×10^3	26.35	—	3.08
3450	20.9	0.1	6.06	1.12	63.5	5.7	18.4	—	3.84	72.7	8.9	21.05	—	5.17
5660	29.1	1.1	5.14	1.21	88.8	12.6	15.7	—	6.45	109.6	12.9	19.35	—	9.16
7160	33.2	0	4.64	1.29	105.7	17.2	14.75	2.3	8.50	136	25.7	19.0	2.3	12.3
9880	40.3	0.9	4.08	1.45	142.6	33	14.45	2.7	13.10	190.2	42.7	19.25	2.3	19.45
11090	42.6	1.1	3.84	1.50	—	—	—	—	—	215	52	19.4	2.4	23.0
0	$w_{289°} = 0.00209\ \Omega$				$w_{90} = 0.00097\ \Omega$					$w_{74.5} = 0.00088\ \Omega$.				

TABLE V.

Hall effect, asymmetry and resistance change for Bi_{pII}

H	$T = 289°$				$T = 90°$					$T = 73°$				
	RH	D	$-R$	$\left[\frac{w'}{w}\right]_T$	RH	D	$-R$	Q	$\left[\frac{w'}{w}\right]_T$	RH	D	$-R$	Q	$\left[\frac{w'}{w}\right]_T$
2060	18.7×10^3	0.1×10^3	9.08	1.023	74.3×10^3	0.9×10^3	36.1	—	1.295	94.4×10^3	1.3×10^3	45.8	—	1.386
3450	28.2	0.1	8.17	1.057	110.7	1.5	32.1	—	1.59	139.5	3.5	40.4	—	1.727
5660	39.8	0.2	7.05	1.108	155.2	6.2	27.4	—	—	205	8.5	36.2	—	2.355
7160	46.1	0.2	6.44	1.148	185.8	10	25.95	0.68	2.47	248	13.7	34.6	0.76	2.787
8520	52.1	0.4	6.12	1.186	214.2	14	25.15	0.74	2.89	289	16.5	33.9	0.73	3.255
9880	55.9	0.1	5.66	1.222	243.0	18	24.6	0.79	3.28	330.5	20.5	33.5	0.75	3.718
11090	59.9	0.4	5.41	1.260	267.3	22	24.1	0.82	3.67	367	24.2	33.1	0.78	4.12
12090	62.8	0.7	5.19	1.287	288.0	24	23.8	0.82	3.94	398	28.5	32.9	0.82	4.483
0	$w_{289°} = 0.00389\ \Omega$				$w_{90°} = 0.00444\ \Omega$					$w_{73°} = 0.00455\ \Omega$				

coefficient in $C. G. S.$ units, D is the asymmetry and Q is the quantity

$$\frac{D}{\frac{w'}{w} - 1}.$$

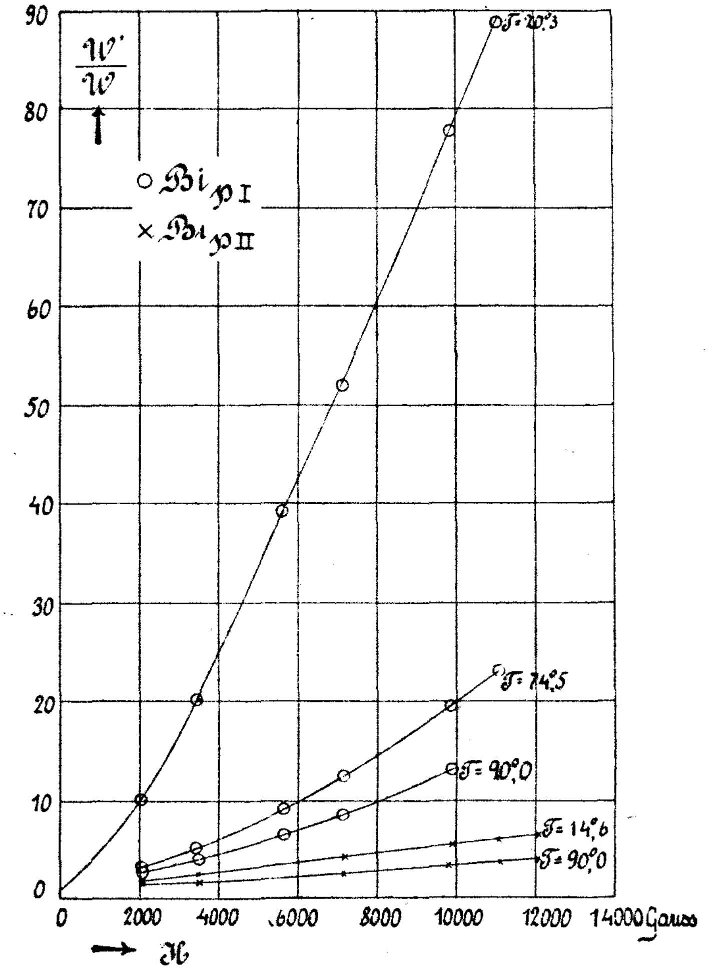


Fig. 3.

Figs. 3 and 4 show the resistance increase, and fig. 5 the Hall effect as functions of the field for various temperatures [1]).

The isotherms of the magnetic increase of resistance are of the same nature as those for Bi_{dI}, but the rectilinear portion of the curve now begins at 7 kilogauss. Equation (2) also holds in this case

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[1]) Remembering that $RH = \frac{Ed}{I}$ where E is the Hall potential difference, d the thickness of the plate, and I the main current, we see that RH is the Hall potential difference for $d = 1$ and I 1.

for the region $90^\circ K \leqq T > 15^\circ K$. This is evident from Table VI.

The diminution of the resistance at low temperatures without a magnetic field is practically the same for both Bi_{pI} and Bi_{dI}.

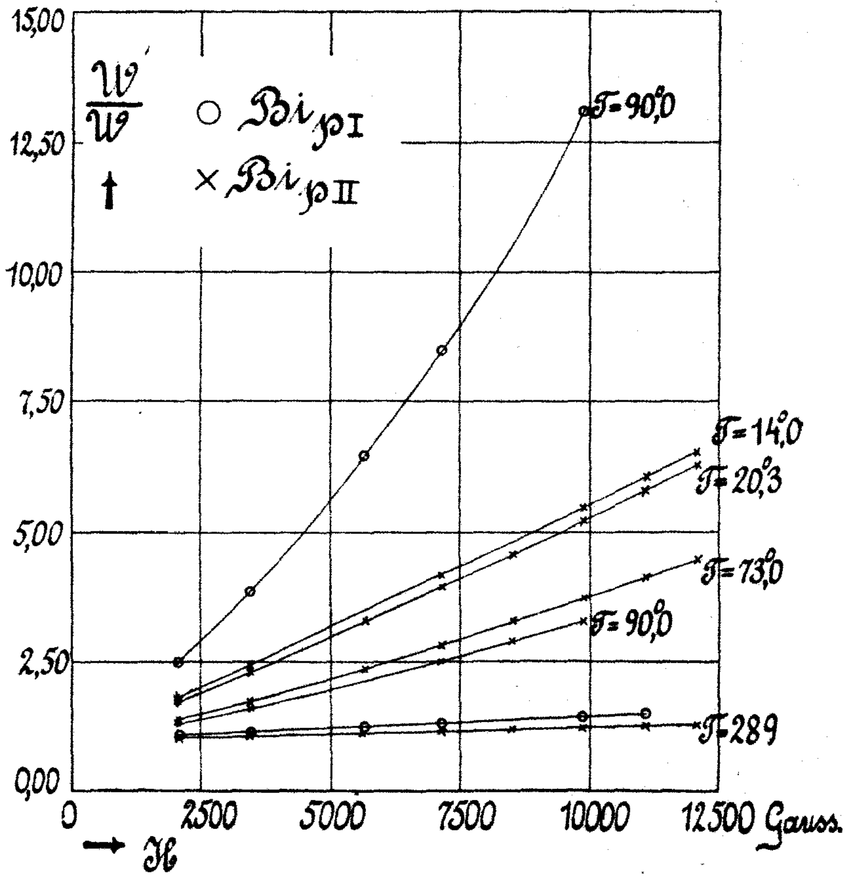

Fig. 4.

TABLE VI.

a for *Bi*.

Bi_{pI}			Bi_{pII}		
7	a_{obs}	$a_{calc.}$	T	$a_{obs.}$	$a_{calc.}$
90	1.69	1.77	90°	29.3	31
74.5	2.7	2.55	73°	35.8	34.4
20.3	9.2	9.1	20°.3	47.3	47.3
			14.6	48.3	49

In liquid air the magnetic increase of resistance, however, appears to be much greater for Bi_{dI}, just as was found to be the case in liquid hydrogen[1]).

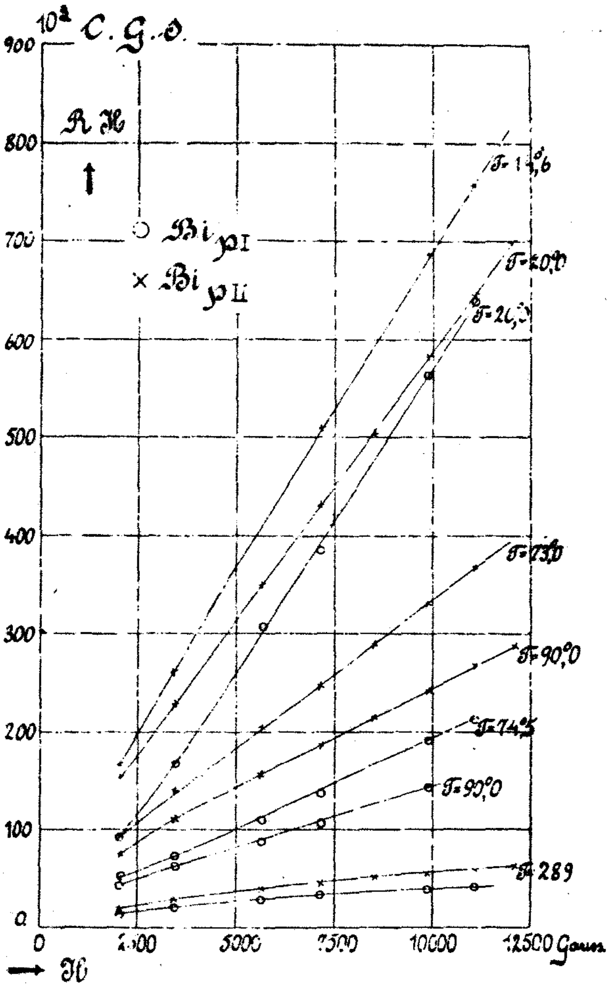

Fig. 5.

For $H = 11090$ we find at

		Bi_{dI}	Bi_{pI}	Bi_{pII}
$T = 90^\circ$	K	$\frac{w'}{w_0} = 11,6$	7,5	3,25
$T = 20,3^\circ$	K	$\frac{w'}{w_0} = 42$	19,7	4,7

For Bi_{pII} the resistance temperature coefficient with no magnetic field is negative, which undoubtedly points to the presence of impurity.

At $T = 289^\circ K$ the specific resistance of Bi_{pI} is about $1,5 \times 10^4$, and for Bi_{pII} $2,3 \times 10^4$ C.G.S.

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[1] H. **Kamerlingh Onnes** and **Bengt Beckman**, Comm. N⁰. 129*a*

The magnetic change of resistance is much smaller for Bi_{pII} particularly so at low temperatures.

Just as in the experiments in liquid hydrogen, for $H > 3000$, RH becomes a linear function of the field

$$RH = a' H + b' \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

Following J. BECQUEREL [1]) we may regard the HALL-effect for bismuth as resulting from two components. One of these is proportional to the field, and was always negative for the plates (Bi_{pI}, Bi_{pII}) I used. The other is constant or, as one may say, saturated, for these plates from $H = 3000$ upwards.

Within the temperature region

$$90° K \geq T > 15° K$$

a' can, to a first approximation, be satisfactorily represented by

$$a' = a_0' e^{-\beta T} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

The agreement for $T = 90° K$ between observation and calculation from (3) with $a' = 20.6$ and $b' = 39,3 \times 10^3$ for the plate Bi_{pII} is exhibited in Table VII, while Table VIII shows how far the relationship (4) holds.

TABLE VII.

Linear variation of the HALL effect in strong fields for Bi_{pII} at $T = 90° K$.

H	$RH_{obs.}$	$RH_{calc.}$
3450	110.7×10^3	110.4×10^3
5660	155.2	155.8
7160	185.8	186.8
8520	214.2	214.8
9880	243.0	242.8
11090	267.3	267.8
12090	288.0	288.3

The constant b' which gives the value of the second component of the effect in the state of saturation is commonly negative. Only for Bi_{pI} at hydrogen temperatures does it become positive. With

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[1]) J. BECQUEREL: C. R. 154, 1795, 1912.

Bi_{pII} b' is almost constant for $T \leqq 90°$; with Bi_{pI} b' is very small and for $T \geqq 72° K$ is practically constant.

In strong fields the constant R approaches a limiting value in accordance with equation (3). In weak fields RH for Bi_{pI}, is inversely proportional to the temperature at $T = 289° K$, $90° K$, $74°,5 K$.

TABLE VIII.

a' for Bi_{pI}			a' for Bi_{pII}		
T	$a'_{obs.}$	$a'_{calc.}$	T	$a'_{obs.}$	$a'_{calc.}$
90°	12.4	12.1	90°	20.6	22.0
74.5	17.7	17.4	73°	29.8	27.6
20.3	62.1	62.6	20.3	54.3	57.3
			14.6	64.5	62.4

Tables IV and V also contain the quantity $Q = \dfrac{D}{\dfrac{w'}{w} - 1}$. For $H > 7000$, Q is either a linear function of the field, or a constant[1]).

Physics. — "*On the* HALL *effect and the change in resistance in a magnetic field at low temperatures.* IV. *Measurements at temperatures between* + 17° C. *and* — 200° C. *of the* HALL *effect, and of the change in the resistance of metals and alloys in a magnetic field.*" By BENGT BECKMAN. Communication N°. 130*b* from the Physical Laboratory at Leiden. (Communicated by Prof. KAMERLINGH ONNES).

(This Communication is a continuation of Comm. N° 130*a* in which the behaviour of bismuth was discussed.)

II. *Gold, Silver, Copper, Palladium.*

§ 4. HALL *effect for Gold.* From the temperature decrease of the resistance without magnetic field[2]), $\dfrac{w_{T=20}}{w_{T=290}} = 0{,}035$, it is to be supposed that this plate is composed of purer gold than that of the wire

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[1]) Cf. E .v. EVERDINGEN, Leiden Communications Suppl. no. 2. p. 57.

[2]) H. KAMERLINGH ONNES and BENGT BECKMAN.; Comm. N°. 129*a*.

Au_{s} of Comm. N°. 99, which was known to contain 0,03 % impurity. The thickness of the plate was 0,101 mm.

TABLE IX.
HALL effect for Gold Au_{pl}.

$T = 290°$ K.			$T = 90°$ K.			$T = 77°$ K.		
H	RH	$-R \times 10^4$	H	RH	$-R \times 10^4$	H	RH	$-R \times 10^4$
7730	5.62	7.27	7730	5.82	7.53	4940	3.75	7.59
9500	6.75	7.11	9500	7.24	7.62	9065	6.95	7.67
11080	8.11	7.32	11080	8.53	7.70	10270	7.72	7.59
12200	8.85	7.25	12200	9.24	7.58			
$w_{290°} = 2,2 \times 15^{-6}\ \Omega$			$w_{90°} = 54,6 \times 10^{-6}\ \Omega$					

§ 5. HALL *effect for Silver.* The plate Ag_{pl} was found to be of practically the same purity as that of the wire Ag_{I} of Comm. N°. 92 which contained 0,18 % impurity. The thickness of the plate was 0,096 mm.

TABLE X.
HALL effect for Silver Ag_{pl}.

$T = 290°$ K.			$T = 90°$ K.	
H	RH	$-R \times 10^4$	RH	$-R \times 10^4$
4940	3.97	8.04	4.10	8.30
7260	5.81	8.01	5.92	8.15
9065	7.23	7.98	7.45	8.22
10270	8.16	7.95	8.38	8.16
$w_{290°} = 173 \times 10^{-6}\ \Omega$			$w_{90°} = 37 \times 10^{-6}\ \Omega$	

§ 6. HALL *effect for electrolytic Copper.* The thickness of the plate Cu_{pl} was 0.057 mm.

TABLE XI.

HALL effect for Copper Cu_{pl}.

H	$T = 290°$ K.		$T = 90°$ K.	
	RH	$-R \times 10^4$	RH	$-R \times 10^4$
7260	3.59	4.95	4.05	5.58
9065	4.42	4.87	5.04	5.56
10270	5.08	4.95	5.66	5.51
	$w_{290°} = 312 \times 10^{-6}\ \Omega$		$w_{90°} = 54 \times 10^{-6}\ \Omega$	

§ 7. HALL *effect for Palladium.* The thickness of the plate was 0,100 mm.

TABLE XII.

HALL effect for palladium Pd_{pl}.

$T = 290°$ K.			$T = 90°$ K.		
H	RH	$-R \times 10^4$	H	RH	$-R \times 10^4$
8250	5.61	6.80	8250	5.85	7.10
9065	6.04	6.66	9065	6.35	7.01
9760	6.64	6.80	9760	6.77	6.94
			10090	7.06	7.00
$w_{290°} = 126 \times 10^{-5}\ \Omega$			$w_{90°} = 70 \times 10^{-5}\ \Omega$		

§ 8. *Summary of the variation of the* HALL *coefficient for different metals.* The results obtained in § 4—7 are collected in Tables XIII and XIV. For R is taken at each temperature the mean of the values [1] for the different fields.

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[1] It has not been possible to determine the thickness of the plates with a greater accuracy than about 3 %, which of course influences the absolute values of the HALL coefficients. This inexactitude, however, makes no difference as to the temperature coefficient of the HALL effect, the measurement of which has been the principal object of this investigation.

TABLE XIII.
Hall coefficient R.

T	Au_{pl}	Ag_{pl}	Cu_{pl}	Pd_{pl}
290°K.	7.24×10^{-4}	8.00×10^{-4}	4.92×10^{-4}	6.75×10^{-4}
90°	7.61	8.21	5.56	6.99
77°	7.62	—	—	—

TABLE XIV.
Variation of the **Hall** coefficient $\frac{R_T}{R_{290°K}}$

T	Au_{pl}	Ag_{pl}	Cu_{pl}	Pd_{pl}
290°K.	1	1	1	1
90°	1.05	1.025	1.13	1.035
77°	1.05	—	—	—

From these observations, therefore, the **Hall** coefficient for *Au*, *Ag* and *Pd* is almost constant from ordinary temperature down to that of liquid air. A distinct increase is first observed on proceeding to hydrogen temperatures [1]), which amounts to 25—35 °/₀ for Gold, Silver and Copper, and 100 °/₀ in the case of Palladium.

A. W. **Smith** [2]) gives the following values for the ratio $\frac{R_{83°\,\mathrm{K}}}{R_{293°\,\mathrm{K}}}$ for

Au	*Ag*	*Cu*	*Pd*
1.03	1.095	1.205	1.27

This gives agreement in the case of *Au*, but with *Ag* and *Cu*, and particularly with *Pd*, **Smith**'s results deviate considerably from mine. In the case of *Cu* and *Ag* the lack of agreement may perhaps be ascribed to the presence of impurity.

The relationship

$$R_0 = \frac{3\pi}{8N\varepsilon}$$

deduced for the **Hall** effect by R. **Gans** [3]) has been utilised by

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[1]) H. **Kamerlingh Onnes** and **Bengt Beckman**, l. c.

[2]) A. W. **Smith**, Phys. Rev. **30**. 1. 1910.

[3]) R. **Gans**, Ann. d. Phys. **20**. 293. 1906.

J. **Koenigsberger** and J. **Weiss**[1]) to obtain the variation of the electron density (N) from the temperature coefficient of the **Hall** effect. From this relation it should follow that the density of the electrons in *Au*, *Ag*, *Cu*, *Pd* varies very slowly with the temperature, much more slowly than $\sqrt{T}$.

III. *Alloys.*

§ 9. *Gold-silver*. The alloys investigated contained 2 °/₀ of silver by volume.

TABLE XV.
Hall effect for a gold alloy.

H	$T = 290^\circ$ K.		$T = 90^\circ$ K.	
	RH	$-R \times 10^4$	RH	$-R \times 10^4$
8250	5.58	6.77	5.40	6.54
9065	6.18	6.82	6.01	6.63
9760	6.61	6.77	6.44	6.59
10270	6.94	6.76	6.86	6.67
0	$w_{290^\circ} = 3.81 \times 10^{-4}\ \Omega$		$w_{90^\circ} = 1.77 \times 10^{-4}\ \Omega$	

Hence the mean value of R is for

$$T = 290^\circ\ \mathrm{K}. \quad R = 6.78 \times 10^{-4}$$
$$90^\circ \quad R = 6.61$$

The hydrogen experiments gave [2]) for

$$T = 20.^\circ 3\ \mathrm{K} \quad R = 6.69 \times 10^{-4}$$
$$T = 14.^\circ 5 \quad R = 6.48$$

Hence the **Hall** coefficient for this alloy is almost constant; on proceeding to low temperatures it begins to exhibit a slight *decrease*.

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[1]) J. **Koenigsberger** and J. **Weiss**, Ann. d. Phys. **35**. 1. 1911.

[2]) H. **Kamerlingh Onnes** and **Bengt Beckman**, l. c.

Physics. — "*On the* Hall *effect and the change in resistance in a magnetic field at low temperatures.* V. *Measurements on the* Hall *effect for alloys at the boiling point of hydrogen and at lower temperatures.*" By H. Kamerlingh Onnes and Bengt Beckman. Communication N°. 130^c from the Physical Laboratory at Leiden.

VI. *Gold-silver alloys.*

§ 16 1). In § 12 of Comm. N°. 129^a observations on the Hall effect for an alloy of gold and silver $(Au\text{-}Ag)_I$ with 2 atom °/₀ of Ag are published. We now give the results of our measurements on two $Au\text{-}Ag$ alloys, containing greater percentages of silver.

The alloy $(Au\text{-}Ag)_{II}$ contained 10,6 atom °/₀ of silver 2). The thickness of the plate was 0.049 mm. The Hall effect was measured at the temperatures $T = 290°$, 20°,3 and 14.5° K.

We found:

TABLE XV.
The Hall effect for $(Au-Ag)_{II}$

H	$T = 290°$ K.		$T = 20°.3$ K.		$T = 14.5°$ K.	
	RH	$-R \times 10^4$	RH	$-R \times 10^4$	RH	$-R \times 10^4$
8250	4.59	5.57	3.07	3.72	3.04	3.69
9360	5.47	5.61	3.47	3.71	3.52	3.76
10270	5.70	5.55	3.82	3.72	3.83	3.73
0	$w = 8.06 \times 10^{-4}\,\Omega$ $\frac{w}{w_0} = 1.03$		$w = 4.58 \times 10^{-4}\,\Omega$ $\frac{w}{w_0} = 0.585$		$w = 4.54 \times 10^{-4}\,\Omega$ $\frac{w}{w_0} = 0.58$	

The alloy $(Au\text{-}Ag)_{III}$ contained 30 atom °/₀ of silver. The thickness of the plate was 0.078 mm.

We found:

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1) The sections of this paper are numbered in continuation of those of Comm. N°. 129c. (Sept. '12).

2) The exact analysis being made now the composition is given in atom °/₀.

TABLE XVI.

The HALL effect for $(Au—Ag)_{III}$.

H	$T = 290° K$		$T = 20°.3 K$		$T = 15° K$	
	RH	$-R \times 10^4$	RH	$-R \times 10^4$	RH	$-R \times 10^4$
8250	4.62	5.60	3.00	3.64	3.12	3.78
9360	5.23	5.59	3.30	3.53	3.42	3.66
10270	5.67	5.53	3.73	3.63	3.81	3.71
0	$w = 9.47 \times 10^{-4}\,\Omega$ $\frac{w}{w_0} = 1.015$		$w = 7.05 \times 10^{-4}\,\Omega$ $\frac{w}{w_0} = 0.755$		$w = 7.02 \times 10^{-4}\,\Omega$ $\frac{w}{w_0} = 0.75$	

The results of measurements on gold and on the three gold-silver alloys are brought together in the tables XVII and XVIII.

TABLE XVII.

The HALL coefficient for gold and gold-silver alloys.

T	Au_{pl}	$(Au—Ag)_I$	$(Au\ \ Ag)_{II}$	$(Au—Ag)_{III}$
290° K	7.2×10^{-4}	6.8×10^{-4}	5.6×10^{-4}	5.6×10^{-4}
20.3	9.8	6.7	3.7	3.6
15.0	9.8	6.50	3.7	3.7

TABLE XVIII.

Change of the HALL coefficient $\frac{R_T}{R_{290°K.}}$ on cooling to and in the region of liquid hydrogen temperatures.

T	Au_{pl}	$(Au—Ag)_I$	$(Au—Ag)_{II}$	$(Au—Ag)_{III}$
290° K.	1	1	1	1
20.3	1.355	0.985	0.665	0.646
15	1.355	0.955	0.665	0.667

Thus, $\frac{R_{T=20}}{R_{T=290}}$ diminishes by greater percentages of silver. For pure gold $R_{T=20.3} > R_{T=290}$, but for alloys with more than 2 °/o of silver by volume $R_{T=20.3} < R_{T=290}$.

The curve that represents the relation between the **Hall** coefficient $R_{T=20.3}$ and the percentages of silver is of a shape analogous to that representing the conductibility or the temperature coefficient of the resistance as a function of percentages of silver. The curve for $R_{T=20.3}$ at first descends very rapidly for small admixtures of Ag; at higher concentrations it becomes flatter.

The **Hall** coefficient $R_{T=20.3}$ is approximately a linear function of the quantity $\frac{w_{T=20.3}}{w_{T=273}}$ for alloys with less than about 8 °/o by volume of Ag.

The **Hall** coefficient $R_{T=290}$ diminishes too, though much more slowly than $R_{T=20,3}$, when the percentage of Ag increases.

Physics. — "*On the triple point of methane*". By C. A. **Crommelin**. Comm. N°. 131*b* from the physical Laboratory at Leiden. (Communicated by Prof. H. **Kamerlingh Onnes**).

The measurements made by Prof. **Mathias**, Prof. **Kamerlingh Onnes** and myself on the diameter for argon[1]) afforded an opportunity of determining the pressure and temperature of methane at its triple-point. For, when the cryostat was filled with liquid methane, and the pressure was reduced so as to give a temperature of about — 183° C. the methane was covered with a solid crust. A slight increase of the pressure caused the solid methane to spread itself in small pieces throughout the liquid. While these pieces were kept in constant motion through the liquid by means of the stirrer, the following triple point constants were observed:

$$t = -183.15 \text{ K.} \qquad p = 7.0 \text{ cm.}$$

On account of the manner in which these figures have been determined they must be considered to be very accurate.

As far as I am aware there has hitherto been only one other determination of these data — that of **Olszewski**[2]) — who found

$$t = -185.°8 \text{ and } p = 8.0 \text{ cm.}$$

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[1]) Comm. No. 131*a*.

[2]) K. **Olszewski**, C. R. 100, page 940, 1885.