the form given here the ν ordinates are only $\frac{b_g}{b_{lim}}$ times smaller. But the advantage of the form given here is obvious, when there are different kinds of substances from the point of view of the law of correspondence. First of all it points out the cause for the existence of these different kinds, about which cause the form given originally does not reveal anything. Secondly it appears that attempts to find perfect correspondence between these different kinds must fail, and have certainly no chance of success by variations in the π and m ordinates. And thirdly it shows that the deviation between the different kinds of substances is a gradual one, and the coincidence in the rarefed gas-state is restored.

Physics. — *"On the* HALL*-effect, and on the change in resistance in a magnetic field at low temperatures.* VI. *The* HALL*effect for nickel, and the magnetic change in the resistance of nickel, mercury and iron at low temperatures down to the melting point of hydrogen".* By H. KAMERLINGH ONNES and BENGT BECKMAN. Communication N°. 132*a* from the Physical Laboratory at Leiden. (Communicated by Prof. H. KAMERLINGH ONNES).

(Communicated in the meeting of November 30, 1912).

§ 17.[1]) *Magnetic change in the resistance of solid mercury.* The resistance was measured of mercury contained in a glass capillary 9 cms. long, and of 0.12 mm. diameter. The capillary was U-shaped, and to either end were fused two glass leading tubes which were filled with mercury. The resistances were measured by the KOHLRAUSCH method of overlapping shunts, in which the main current was $I = 0.006$ amp. The mercury was frozen by blowing cooled hydrogen vapour into the cryostat through a glass tube whose lower extremity reached below the resistance. The resistance was found to be

7,97 Ω	at	$T = 287°,3$ K.
0,1014		$T = 20°,3$
0,0618		$T = 14°,5$

1) The sections of this paper are numbered in continuation of those of Comm. N°. 130*c* (Oct. 26, 1912).

TABLE XIX.
Magnetic change in the resistance of mercury.

$T = 20°.3$ K.		$T = 14°.5$ K.	
H in gauss.	$\frac{\Delta w}{w} \times 10^3$	H	$\frac{\Delta w}{w} \times 10^3$
9760	+ 1.3	10270	+ 5.5
10270	+ 1.5	10270	+ 6.5
10270	+ 1.6		

The measurements therefore show an increase of the resistance in the magnetic field. At

$$H = 10000 \text{ and } T = 20°,3 \text{ K} \quad \frac{\Delta w}{w} = +1,5 \times 10^{-3}$$

$$T = 14°,5 \quad \frac{\Delta w}{w} = +6 \times 10^{-3}$$

were obtained as mean values.

At these temperatures the temperature coefficient of the resistance is very great, and this lessens the accuracy of the above measurements, especially at $T = 14°.5$ K. The large increase occasioned by lowering the temperature from 20° to 14° K. is very striking.

§ 18. *The* HALL*effect for, and the magnetic change in the resistance of, nickel.* The material in the form of a plate of 0.053 mm. thick-

TABLE XX.
HALLeffect for nickel Ni_{pl}.

$T = 290°.5$ K			$T = 90°$ K.			$T = 20°.3$ K.			$T = 14°.5$ K.		
H	RH	$-R \times 10^4$	H	RH	$-R \times 10^4$	H	RH	$-R \times 10^4$	H	RH	$-R \times 10^4$
3010	18.8	62.4	2980	2.93	9.83	2970	1.48	4.98	4940	2.50	5.06
5170	31.2	60.3	4950	4.58	9.25	5640	2.86	5.08	8250	4.25	5.15
7260	39.3	54.1	7290	6.31	8.65	7260	3.53	4.86	10270	5.19	5.05
9065	43.1	47.6	9110	7.62	8.36	8250	4.08	4.95			
10270	44.9	43.7	10400	8.29	7.98	10270	4.81	4.68			

ness was pure SCHWERTE nickel. H and RH are given in C. G. S. units. I was 0.7 to 0 9 amp.

The results given in Table XX are shown graphically in Figs. 1 and 2.

The HALLeffect for nickel decreases as the temperature falls from ordinary room temperature; this has already been found by A. W. SMITH [1]) to be the case down to liquid air temperatures. According to A. KUNDT [2]) the HALLeffect for ferro-magnetic substances is proportional to the magnetisation and not to the field. Hence, when the magnetisation attains its maximum value, the HALLeffect must also exhibit a state of saturation, that is to say, the curves giving the HALLeffect as a function of the field must show a bend. SMITH'S

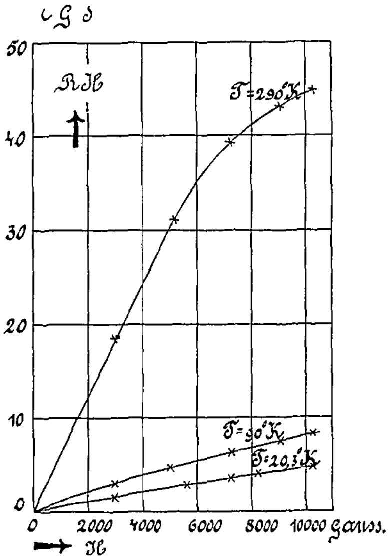

Fig. 1.

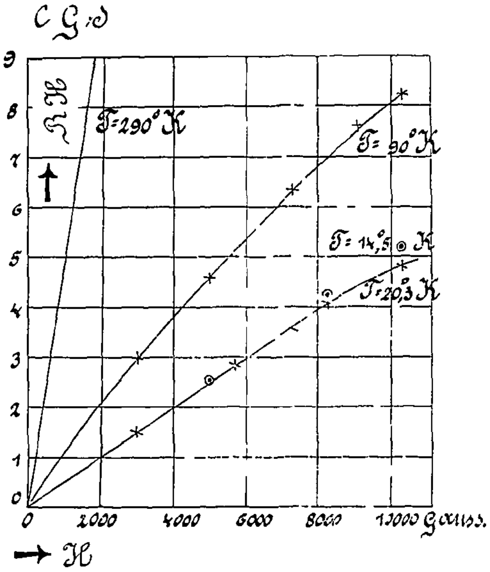

Fig. 2.

curves, covering a region of temperature from — 193° C. to + 546° C., show such a bend, which, as the temperature increases right up to the critical temperature for nickel, is displaced towards the weaker fields, thus corresponding to a diminution of the saturation magnetisation as the temperature rises. At 290° K. our present measurements show this bend clearly at about 5000 to 6000 gauss. At the lower temperatures there is no decided bend visible within the region of fields covered by our observations ($H < 10400$), thus if there are any bends at these temperatures, they must occur at still stronger fields.

1) A. W. SMITH. Phys. Rev. **30**, 1, 1910.

2) A KUNDT. Wied. Ann. **49**, 257, 1893

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At 14°.5 K. the HALLeffect is strictly proportional to the field, as is also the case at 20°.3 K. as far as $H = 9060$. At 90° K. the HALLcoefficient is a linear function of the field, diminishing as the field increases.

For the HALLcoefficient in very weak fields the relation

$$R_0 = ce^{bT}$$

holds.

The LEDUC quantity $D_L = \frac{R}{w}$, the tangent of the angle of rotation of the equipotential lines in unit field, is here a linear function of the temperature.

The following Table shows the extent to which those relations hold.

TABLE XXI.

R_0 and D_L as functions of the temperature.

T	$R_{0obs.}$	$R_{0calc.}$	$D_{Lcalc.}$	$D_{Lobs.}$
290° K.	66.0×10⁻⁴	67.5×10⁻⁴	5.37	5.37
90	11.2	10.5	3.07	3.10
20.3	5.0	5.3	2.22	2.30
(14.5	5.1	5.0	2.28	2.22)

For the nickel plate the magnetic change of resistance was also measured. I was 0.2 to 0.3 amp.

As the resistance of the plate is very small, and the changes were, at the most, 1.5 %, it was not possible to evaluate them with any greater accuracy.

As has also been observed by F. C. BLAKE [1]), G. BARLOW [2]) and C. W. HEAP [3]), there is an increase in the resistance of nickel in the weaker fields ($H < 3000$); in stronger fields the resistance diminishes, and, in the region $5600 < H < 10270$, it does so approximately linearly with the field. This behaviour is, to a large extent, the same throughout the region 290° K. $> T >$ 14°.5 K.

In strong fields the diminution in the resistance is somewhat greater at low temperatures than at ordinary temperature.

1) F. C. BLAKE. Ann. d. Phys. **28**, 449, 1909.
2) G. BARLOW. Proc. Roy. Soc. **71**, 30, 1903.
3) C. W. HEAP. Phil. Mag. (6) **22**, 900, 1911.

$T = 290^\circ.5$ K		$T = 90^\circ$ K		$T = 20^\circ.3$ K		$T = 14^\circ.5$ K	
H	$\frac{\Delta w}{w} \times 10^3$	H	$\frac{\Delta w}{w} \times 10^3$	H	$\frac{\Delta w}{w} \times 10^3$	H	$\frac{\Delta w}{w} \times 10^3$
1750	+ 0.5	2270	+ 2	1750	+ 1	2970	0
2500	+ 0.5	2520	+ 3	2520	+ 2	5640	— 7
2970	0	3770	0	3750	0	8250	— 11
3750	— 2	4950	— 5.5	5640	— 8	10270	— 13
5170	— 4	6140	— 6.5	8250	— 12		
7260	— 7	8290	— 9.5	9065	— 13		
9065	— 9	9110	— 12.5	10270	— 15		
10270	— 11	10400	— 14.0				
0	$w = 12.2 \times 10^{-4}\ \Omega$	0	$w = 3.63 \times 10^{-4}\ \Omega$	0	$w = 2.25 \times 10^{-4}\ \Omega$	0	$w = 2.23 \times 10^{-4}\ \Omega$

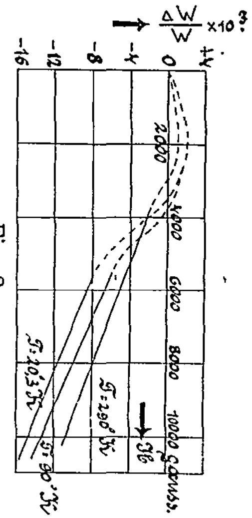

Fig. 3.

§ 19. *Change in the resistance of pure iron in a magnetic field.* As experimental material an iron wire from KOHLSWA, Sweden, was used for which we are indebted to the kindness of Prof. C. BENEDICKS. Stockholm. On analysis the following impurities were found present

C	0,10 %
S	0,007
P	0,028
Si	0,014
Mn	0,03

thus giving a total impurity of about 0,18 %. After analysis the wire was drawn by HERAEUS to a diameter of 0 1 mm.

Before it was drawn the temperature coefficient was $\frac{w_{80^0}}{w_{289^0}} = 0.14$;

afterwards it was $\frac{w_{80^0}}{w_{289^0}} = 0.17$.

The iron wire was wound non-inductively upon an ebonite cylinder, and was so placed in the magnetic field as to be perpendicular to the lines of force throughout. The method of overlapping shunts was used for determining the resistance. Resistances without field are given in Table XXIII.

TABLE XXIII.

Resistance of pure iron as a function of the temperature.

T	*w*
288°.0 K.	11.18 Ω
90	2.225
77.5	1.859
20.3	1.129
14.5	1.124

The temperature coefficient of the resistance is very small in the liquid hydrogen region; in liquid oxygen and nitrogen it is large. Resistances were measured at 288° K., 77° K., 20°,3 K. and 14°,5 K. The measurements at 77° K. are not quite trustworthy, and we communicate them only because they are sufficiently accurate to determine the orientation of the temperature curve.

Fig. 4 shows the resistance as a function of the field. The observations at 77° K. are indicated by a broken line.

TABLE XXIV
Magnetic change in the resistance of iron.

$T = 288°$ K.		$T = 20°.3$ K.		$T = 14°.5$ K.	
H	$\frac{\Delta w}{w} \times 10^4$	H	$\frac{\Delta w}{w} \times 10^4$	H	$\frac{\Delta w}{w} \times 10^4$
990	+ 2.8	1500	— 2.0	990	— 1.7
1500	+ 3.8	2520	— 2.9	2500	— 2.6
2520	+ 5.7	3750	— 2.7	3750	— 3.1
3750	+ 6.0	4940	— 2.2	4940	— 2.4
4940	+ 5.4	6110	— 0.9	6110	— 1.4
6110	+ 3.2	7260	+ 0.7	7260	+ 0.3
7260	+ 0.3	8250	+ 2.6	8250	+ 2.6
8260	— 2.1	9065	+ 3.6	9065	+ 3.6
9065	— 4.7	9750	+ 4.6	9750	+ 4.7
10270	— 9.1	10270	+ 5.2	10270	+ 5.4

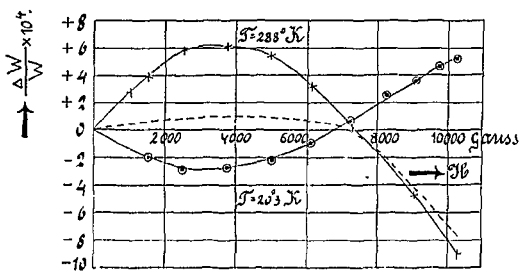

Fig. 4.

At 288° K the resistance increases in weak fields, and decreases in fields greater than 7000. This is in agreement with results obtained by L. Grunmach and F. Weidert [1]), C. W. Heap [2]) and others. At liquid hydrogen temperatures this behaviour is reversed, for the resistance diminishes in weaker fields and increases when $H > 7000$. There is a neutral zone at about $H = 7000$.

[1]) L. Grunmach and F. Weidert: Verh. d. Deutsch. Physik. Ges. 1906, 359.
[2]) C. W. Heap: l. c.