XVI. *On the Influence of Temperature on the Electric Conducting-Power of Thallium and Iron.* By A. Matthiessen, *F.R.S., Lecturer on Chemistry in St. Mary's Hospital, and* C. Vogt, *Ph.D.*

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It has been shown * that the conducting-power of several of the pure metals decreased between 0° and 100° to the same extent, namely 29·307 per cent. On continuing the research with other metals and alloys, we have found that thallium and iron form an exception to the above; and in the following we will describe the experiments made with these metals.

The thallium was kindly lent to us by Mr. Crookes, the discoverer of this new metal, who with great readiness placed a small quantity of it at our disposal.

On account of its extreme softness (for it is much softer than pure lead), it was easily cut with a knife to fit one of the small presses described in the 'Philosophical Magazine' (February 1857), and pressed without the application of heat. The wire, as soon as it came out of the small hole of the press, passed into a tube filled with water; for although the metal readily oxidizes in air, yet it may be kept under water, free from air, for some time without oxidation. When, however, the wire is exposed to the air for a short time, it loses its lustre and is soon covered with a coating of oxide, which, as in the cases of lead and zinc, protects in a great measure the metal from further oxidation. The error caused by the slight oxidation during the short time we were obliged to manipulate with the wire in air may therefore be overlooked, more especially as wires of the same piece of metal showed the same conducting-power when pressed at different times. Now, if the slight oxidation had any marked effect, we ought to have found great differences in the conducting-power of different wires, for it can scarcely be supposed that in all cases the same amount of oxidation had taken place. Again, although thallium appears to be attacked by alcohol, yet we found we might varnish the wire with a solution of shell-lac in alcohol; for the small quantity of alcohol contained in the first coating of varnish volatilizes so quickly that it has very little time to act on the wire; in fact the resistance of the wire was found to be the same when determined before being varnished, and after three or four coatings of varnish had dried on it. The reason of varnishing the wire was to protect the metal from the action of the hot oil.

The apparatus and precautions taken whilst determining the conducting-powers at different temperatures have already been fully described†. The normal wires used were

* "On the Influence of Temperature on the Electric Conducting-Power of Metals. By A. Matthiessen and M. von Bose," Philosophical Transactions, 1862, p. 1.

† Philosophical Transactions, 1862, p. 1.

made of German silver; these were compared with the gold-silver alloy *, and the values so obtained for their resistances reduced, for the sake of comparison with former observations, to that of a hard-drawn silver wire whose conducting-power at 0° is equal to 100, that of a hard-drawn gold-silver wire being then 15·03 at that temperature. As in the case of wires of most other metals, those of thallium were found to alter in conducting-power after having been kept at 100° for some time. It was therefore necessary to heat them for several days until their conducting-power showed no longer any alteration after cooling to the original temperature.

The length of the wire experimented with was 158 millims., and its diameter 0·502 millim.

			Reduced to 0° †.
Conducting-power found before heating the wire	. . .	8·808 at 13°·2	9·290
" " after being kept at 100° for 1 day	.	8·939 " 10·8	9·338
" " " " 2 days	.	8·941 " 11·8	9·378
" " " " 3 days	.	8·949 " 11·6	9·378
" " " " 4 days	.	8·990 " 10·2	9·368

The means of the conducting-powers for each of the following temperatures were—

T.	Conducting-power.		Difference.
	Observed.	Calculated.	
10°·40	8·987	8·979	+0·008
25·07	8·460	8·466	−0·006
39·22	7·996	8·006	−0·010
54·43	7·551	7·550	+0·001
69·68	7·138	7·132	+0·006
85·95	6·742	6·729	+0·013
100·13	6·404	6·414	−0·010

The formula deduced from the observations, from which the conducting-powers were calculated, was

$$\lambda = 9{\cdot}364 - 0{\cdot}037936t + 0{\cdot}00008467t^2,$$

or

$$\lambda_1 = 100 - 0{\cdot}40513t + 0{\cdot}0009042t^2,$$

corresponding to a percentage decrement of 31·471 per cent.

To check the above value another wire was made, and its conducting-power determined. The length of the wire was 187 millims., its diameter 0·421 millim., and the conducting-power found was

8·610 at 15°·6, or, reduced to 0° by the above formula, 9·169.

Now the first observation made with the first wire was 9·29 at 0°; or, as mean, we find the conducting-power of pure thallium at 0° equal to 9·23.

* Philosophical Magazine, February 1861.

† The manner in which these values were reduced is fully described in the paper already alluded to (Philosophical Transactions, 1862, p. 10).

Although we had already found, as will be shown in the following, that the conducting-power of iron decreases between 0° and 100° more than 29·307 per cent., the mean value deduced from the percentage decrements of eleven metals, yet we thought it would be interesting to check the above results, and we therefore applied to Professor LAMY, of Lille, for a specimen of the metal, who with great kindness lent us two small bars prepared at different times. The results obtained with these specimens fully confirm those obtained with Mr. CROOKES'S metal, both in respect to the conducting-power and to the percentage decrement.

The results obtained with these specimens were as follows:—

1st Bar.

Length . . . . 205 millims.
Diameter . . . 0·553 millim.

			Reduced to 0°.
Conducting-power found before heating the wire . . .	8·881 at 11°·8		9·330
" " after being kept at 100° for 1 day .	8·986 " 10·0		9·370
" " " " 2 days .	8·953 " 11·9		9·410
" " " " 3 days .	8·901 " 13·4		9·413

The means of the conducting-powers for each of the following temperatures were—

T.	Conducting-power.		Difference.
	Observed.	Calculated.	
13°·75	8·903	8·894	+0·009
25·23	8·477	8·483	−0·006
38·80	8·021	8·031	−0·010
54·68	7·544	7·547	−0·003
70·56	7·122	7·111	+0·011
82·71	6·819	6·811	+0·008
99·57	6·433	6·441	−0·008

The formula deduced from the observations, from which the conducting-powers were calculated, was

$$\lambda = 9{\cdot}419 - 0{\cdot}039520t + 0{\cdot}00009656t^2,$$

or

$$\lambda_1 = 100 - 0{\cdot}41958t + 0{\cdot}001025t^2,$$

corresponding to a percentage decrement of 31·706 per cent.

Another wire from the same piece of metal, the length of which was 136 millims. and the diameter 0·532, conducted

8·433 at 17°·8, or, reduced to 0°, 9·082.

A third wire, the length of which was 141 millims., the diameter 0·449 millim., conducted

8·758 at 12°·4, or, reduced to 0°, 9·223.

The first observation made with the first wire reduced to 0° was 9·33; and if we now

take the mean of these three values, we find the conducting-power of the first bar to be at 0° equal to

$$9{\cdot}212.$$

2nd Bar.

Length . . . . 155 millims.
Diameter . . . 0·502 millim.

		Reduced to 0°.
Conducting-power found before heating the wire . . .	8·377 at 14°·8	8·866
,, ,, after being kept at 100° for 1 day .	8·692 ,, 10·0	9·032
,, ,, ,, ,, 2 days .	8·764 ,, 8·6	9·058

The means of the conducting-powers observed at the following temperatures were—

T.	Conducting-power.
9°·0	8·747
54·5	7·258
100·0	6·240

from which numbers the following formula was deduced,

$$\lambda = 9{\cdot}054 - 0{\cdot}034697t + 0{\cdot}00006554t^2,$$

or

$$\lambda_1 = 100 - 0{\cdot}38322t + 0{\cdot}0007239t^2,$$

corresponding to a percentage decrement of, 31·083 per cent.

A second wire, 135·5 millims. long and having a diameter of 0·542 millim., was found to conduct

8·507 at 21°·2, or, reduced to 0°, 9·226.

Now, as before, taking the mean of this value and that found for the first determination, we find the conducting-power of the second bar equal to, at 0°,

$$9{\cdot}046.$$

From the foregoing it will be seen that the values obtained for the conducting-powers of the different specimens agree very closely with each other; for that found

	Conducting-power at 0°.	Percentage decrement for the conducting-power between 0° and 100°.
For Mr. Crookes's metal . .	9·230	31·471
For M. Lamy's 1st bar. . .	9·212	31·706
2nd bar . .	9·046	31·083
Mean . . .	9·163	31·420

and calculating, from the mean of the above, the formula for the correction of the conducting-power for temperature of thallium, we find it to be

$$\lambda = 9{\cdot}163 - 0{\cdot}036894t + 0{\cdot}00008104t^2,$$

where λ represents the conducting-power at $t°$.

The mean of the three formulæ reduced to the same unit at 0° was used for calculating the above, viz.

$$\lambda_1 = 100 - 0{\cdot}40264t + 0{\cdot}0008844t^2.$$

As thallium in many respects resembles lead, it seemed to us of peculiar interest to see whether in its electric behaviour it would resemble that metal, namely, if when alloyed with tin, cadmium, or zinc, the conducting-power of the alloy would be equal to the mean conducting-power of the volumes of the component metals. We are indebted to Mr. CROOKES for an alloy of thallium and tin containing only traces of the latter metal, and on testing its conducting-power we found it lower than that of pure thallium, showing that the addition of a better conductor (the conducting-power of tin being at 0° 12·366) causes a decrement in the conducting-power of the metal. Again, we alloyed a portion of M. LAMY's thallium with traces of cadmium; and here we also found the above observation confirmed (the conducting-power of cadmium being at 0° 23·725). Thallium, therefore, appears to belong to that class of metals* which, when alloyed with lead, tin, cadmium, or zinc, or with one another, do not conduct electricity in the ratio of their relative volumes, but always in a lower degree than the mean of their volumes, and not to that class of metals to which lead belongs, namely, those which when alloyed with one another conduct electricity in the ratio of their relative volumes.

Respecting the conducting-power of the alloys of thallium, we shall discuss them in our paper "On the Influence of Temperature on the Electric Conducting-Power of Alloys," which will shortly be ready for publication.

We are greatly indebted to the kindness of Professor PERCY, who placed at our disposal the specimens of iron used for the following experiments; in fact, with the exception of the two last, they are all from his collection. As several of them have been analysed by Mr. TOOKEY in his laboratory, the results we have obtained will be the more interesting, as they show how traces of foreign matter influence the conducting-power of iron.

We will first give the numerical results, and then make some remarks on them.

1. *Electrotype Iron*, deposited from a solution of pure sulphate of iron. The strips were very thin and porous; we could not, therefore, obtain concordant values for the conducting-power, but were able to determine the percentage decrement in the conducting-power between 0° and 100°. We have therefore taken the first observed conducting-power equal 100.

		Reduced to 0°.
Conducting-power found before heating the strip . .	100·000 at 18°·1	109·698
„ „ after being kept at 100° for 1 day.	100·520 at 16·8	109·539
„ „ „ „ 2 days	100·894 at 15·9	109·443

The means of the conducting-powers observed at the following temperatures were—

T.	Conducting-power.
10°·0	103·926
55·0	82·866
100·0	67·528

from which numbers the following formula was deduced,

$$\lambda = 109·38 - 0·55983t + 0·001413t^2,$$

or

$$\lambda_1 = 100 - 0·51182t + 0·0012915t^2,$$

corresponding to a percentage decrement of 38·262 per cent.

* Philosophical Transactions, 1860, p. 162.

2. No. 1, annealed and cooled in hydrogen.

			Reduced to 0°.
Conducting-power found before heating the strip		100·000 at 20°·8	111·375
,, ,, after being kept at 100° for	1 day	100·518 at 19·5	111·202
,, ,, ,, ,,	2 days	100·400 at 19·8	111·234
,, ,, ,, ,,	3 days	101·243 at 18·8	111·560

The means of the conducting-powers observed at the following temperatures were—

T.	Conducting-power.
12°·0	104·564
56·0	83·622
100·0	68·460

from which numbers the following formula was deduced,

$$\lambda=111{\cdot}275-0{\cdot}57745t+0{\cdot}0014928t^2,$$

or

$$\lambda_1=100-0{\cdot}51894t+0{\cdot}0013415t^2,$$

corresponding to a percentage decrement of 38·479 per cent.

3. Electrotype iron, a strip cut from the same foil as No. 1.

		Reduced to 0°.
Conducting-power found before heating the strip	100·000 at 16°·8	108·997
,, ,, after being kept at 100° for 1 day	99·867 at 17·6	109·299

The means of the conducting-powers observed at the following temperatures were—

T.	Conducting-power.
11°·0	102·958
55·5	82·324
100·0	67·396

from which numbers the following formula was deduced,

$$\lambda=108{\cdot}943-0{\cdot}55947t+0{\cdot}0014404t^2,$$

or

$$\lambda_1=100-0{\cdot}51355t+0{\cdot}0013221t^2,$$

corresponding to a percentage decrement of 38·134 per cent.

4. No. 3, annealed in air.

			Reduced to 0°.
Conducting-power found before heating the strip		100·000 at 21°·3	111·436
,, ,, after being kept at 100° for	1 day	102·944 at 17·2	112·356
,, ,, ,, ,,	2 days	102·705 at 17·6	112·323

The means of the conducting-powers observed at the following temperatures were—

T.	Conducting-power.
10°·0	107·025
55·0	85·427
100·0	69·636

from which numbers the following formula was deduced,

$$\lambda=112{\cdot}615-0{\cdot}57315t+0{\cdot}0014341t^2,$$

or

$$\lambda_1=100-0{\cdot}50895t+0{\cdot}0012735t^2,$$

corresponding to a percentage decrement of 38·16 per cent.

5. This, and likewise Nos. 6, 7, and 8, were cut and drawn into wire from pieces of metal which had been analysed. The analyses were as follows:—

	5. In 100 parts.	6. In 100 parts.	7. In 100 parts.	8. In 100 parts.
Sulphur	0·190	0·121	0·104	0·118
Phosphorus	0·020	0·173	0·106	0·228
Silicon	0·014	0·160	0·122	0·174
Carbon	0·230	0·040	0·020	0·020
Manganese, Cobalt, Nickel	0·110	0·029	0·280	0·250

The length of the wire used from No. 5 was 752 millims. and its diameter 0·658 millim.

		Reduced to 0°.
Conducting-power found before heating the wire	17·887 at 11°·4	15·712
,, ,, after being kept at 100° for 1 day	15·004 at 9·8	15·716

The means of the conducting-powers observed at the following temperatures were—

T.	Conducting-power.
10°·0	14·993
55·0	12·162
100·0	10·045

from which numbers the following formula was deduced,

$$\lambda = 15{\cdot}719 - 0{\cdot}07437t + 0{\cdot}0001763t^2,$$

or

$$\lambda_1 = 100 - 0{\cdot}47312t + 0{\cdot}0011242t^2,$$

corresponding to a percentage decrement of 36·07 per cent.

6. Length . . . . 1047 millims.
Diameter . . . 0·778 millim.

		Reduced to 0°.
Conducting-power found before heating the wire	14·543 at 15°·4	15·640
,, ,, after being kept at 100° for 1 day	15·002 at 9·4	15·682

The means of the conducting-powers observed at the following temperatures were—

T.	Conducting-power.
12°·0	14·809
56·0	12·078
100·0	10·029

from which numbers the following formula was deduced,

$$\lambda = 15{\cdot}672 - 0{\cdot}074045t + 0{\cdot}0001761t^2,$$

or

$$\lambda_1 = 100 - 0{\cdot}47247t + 0{\cdot}0011237t^2,$$

corresponding to a percentage decrement of 36·01 per cent.

7. Length . . . . 589 millims.
Diameter . . . 0·622 millim.

		Reduced to 0°.
Conducting-power found before heating the wire . .	13·351 at 13°·8	14·204
„ „ after being kept at 100° for 1 day .	13·469 at 12·8	14·266
„ „ „ „ 2 days .	13·435 at 13·4	14·268

The means of the conducting-powers observed at the following temperatures were—

T.	Conducting-power.
15°·0	13·340
57·5	11·063
100·0	9·312

from which numbers the following formula was deduced,

$$\lambda = 14{\cdot}269 - 0{\cdot}064133t + 0{\cdot}0001456t^2,$$

or

$$\lambda_1 = 100 - 0{\cdot}44946t + 0{\cdot}0010204t^2,$$

corresponding to a percentage decrement of 34·742 per cent.

8. This piece of metal was drawn into wire with great difficulty, owing to its being very brittle. The wire used was somewhat faulty, and this may account for the low conducting-power found.

Length . . . . 160 millims.
Diameter . . . 0·479 millim.

		Reduced to 0°.
Conducting-power found before heating the wire . .	11·242 at 16°·9	12·132
„ „ after being kept at 100° for 1 day .	11·275 at 17·9	12·222
„ „ „ „ 2 days .	11·287 at 18·0	12·241

The means of the conducting-powers observed at the following temperatures were—

T.	Conducting-power.
9°·67	11·814
54·77	9·694
99·80	8·137

from which numbers the following formula was deduced,

$$\lambda = 12{\cdot}342 - 0{\cdot}055894t + 0{\cdot}0001379t^2,$$

or

$$\lambda_1 = 100 - 0{\cdot}45291t + 0{\cdot}0011174t^2,$$

corresponding to a percentage decrement of 34·117 per cent.

9. This specimen formed the basis for some experiments made by Dr. PERCY on the absorption of carbon by iron, and was cut from the same piece of foil as Nos. 10, 11, 12. The strips of foil were first annealed in a current of dry hydrogen at a red heat for about two hours. No. 9 was therefore annealed in hydrogen, Nos. 10, 11, 12 treated first with No. 9, and then separately under a layer of sugar charcoal in a current of hydrogen for different lengths of time. They were all hardened. Dr. PERCY's experiments have not yet been published, but he informs us they will be given in his work on Metallurgy.

Length . . . . 171 millims.
Diameter . . . 0·402 millim.

		Reduced to 0°.
Conducting-power found before heating the strip . .	14·096 at 9°·4	14·723
„ „ after being kept at 100° for 1 day .	14·123 at 9·0	14·724

The means of the conducting-powers observed at the following temperatures were—

T.	Conducting-power.
10°·0	14·009
55·0	11·416
100·0	9·471

from which numbers the following formula was deduced,

$$\lambda = 14{\cdot}673 - 0{\cdot}067999t + 0{\cdot}0001597t^2,$$

or

$$\lambda_1 = 100 - 0{\cdot}46343t + 0{\cdot}0010884t^2,$$

corresponding to a percentage decrement of 35·459 per cent.

10. Heated for three hours under sugar charcoal in a current of hydrogen; the carbon taken up was 0·99 per cent.

Length . . . . 105 millims.
Diameter . . . 0·281 millim.

		Reduced to 0°.
Conducting-power found before heating the strip . .	10·376 at 6°·6	10·666
„ „ after being kept at 100° for 1 day .	10·282 at 9·0	10·676

The means of the conducting-powers observed at the following temperatures were—

T.	Conducting-power.
10°·0	10·218
55·0	8·499
100·0	7·177

from which numbers the following formula was deduced,

$$\lambda = 10{\cdot}654 - 0{\cdot}044560t + 0{\cdot}00009789t^2,$$

or

$$\lambda_1 = 100 - 0{\cdot}41825t + 0{\cdot}0009188t^2,$$

corresponding to a percentage decrement of 32·637 per cent.

11. Heated for four hours under sugar charcoal in a current of hydrogen; the carbon taken up was 0·933 per cent.

Length . . . . 177 millims.
Diameter. . . . 0·435 millim.

		Reduced to 0°.
Conducting-power found before heating the strip . .	9·568 at 9°·0	9·921
„ „ after being kept at 100° for 1 day .	9·668 at 6·4	9·921

The means of the conducting-powers observed at the following temperatures were—

T.	Conducting-power.
8°·0	9·610
54·0	8·027
100·0	6·832

from which numbers the following formula was deduced,

$$\lambda = 9{\cdot}925 - 0{\cdot}040097t + 0{\cdot}00009168t^2,$$

or

$$\lambda_1 = 100 - 0{\cdot}404t + 0{\cdot}0009237t^2,$$

corresponding to a percentage decrement of 31·163 per cent.

12. Heated for three hours under sugar charcoal in a current of hydrogen; the carbon taken up was 1·06 per cent.

Length . . . . 191 millims.
Diameter . . . 0·436 millim.

		Reduced to 0°.
Conducting-power found before heating the strip . .	9·032 at 11°·4	9·449
,, ,, after being kept at 100° for 1 day .	9·157 at 8·8	9·482
,, ,, ,, ,, 2 days .	9·162 at 8·6	9·480

The means of the conducting-powers observed at the following temperatures were—

T.	Conducting-power.
10°·0	9·090
55·0	7·652
100·0	6·564

from which numbers the following formula was deduced,

$$\lambda = 9{\cdot}457 - 0{\cdot}037573t + 0{\cdot}00008642t^2,$$

or

$$\lambda_1 = 100 - 0{\cdot}3973t + 0{\cdot}0009138t^2,$$

corresponding to a percentage decrement of 30·592 per cent.

13. Thin music wire melted with a quarter of its weight of peroxide of iron under a flux of plate glass.

Length . . . . 145·2 millims.
Diameter . . . 0·455 millim.

		Reduced to 0°.
Conducting-power found before heating the wire . .	12·537 at 13°·8	13·293
,, ,, after being kept at 100° for 1 day .	12·727 at 11·2	13·346
,, ,, ,, ,, 2 days .	12·731 at 11·6	13·374
,, ,, ,, ,, 3 days .	12·639 at 13·6	13·389

The means of the conducting-powers observed at the following temperatures were—

T.	Conducting-power.
14°·0	12·610
57·0	10·542
100·0	8·929

from which numbers the following formula was deduced,

$$\lambda = 13{\cdot}381 - 0{\cdot}056829t + 0{\cdot}000123t^2,$$

or

$$\lambda_1 = 100 - 0{\cdot}4247t + 0{\cdot}0009192t^2,$$

corresponding to a percentage decrement of 33·278 per cent.

14. A piece of narrow watch-spring.

Length . . . . 276 millims.
Diameter . . . 0·615 millim.

		Reduced to 0°.
Conducting-power found before heating the wire . .	8·254 at 11°·0	8·568
" " after being kept at 100° for 1 day . .	8·297 at 9·4	8·566

The means of the conducting-powers observed at the following temperatures were—

T.	Conducting-power.
10°·0	8·279
55·0	7·127
100·0	6·193

from which numbers the following formula was deduced,

$$\lambda = 8{\cdot}565 - 0{\cdot}029099t + 0{\cdot}00005383t^2,$$

or

$$\lambda_1 = 100 - 0{\cdot}33974t + 0{\cdot}0006285t^2,$$

corresponding to a percentage decrement of 27·689 per cent.

15. Commercial iron wire.

Length . . . . 1150 millims.
Diameter . . . 0·971 millim.

		Reduced to 0°.
Conducting-power found before heating the wire . .	13·163 at 10°·6	13·774
" " after being kept at 100° for 1 day .	13·157 at 10·8	13·779

The means of the conducting-powers observed at the following temperatures were—

T.	Conducting-power.
12°·0	13·082
56·0	10·859
100·0	9·117

from which numbers the following formula was deduced,

$$\lambda = 13{\cdot}772 - 0{\cdot}05897t + 0{\cdot}0001242t^2,$$

or

$$\lambda_1 = 100 - 0{\cdot}43514t + 0{\cdot}0009018t^2,$$

corresponding to a percentage decrement of 33·801 per cent.

We may here mention the reason of our having taken only observations at three intervals between 0° and 100°. It was found that almost the same formula may be deduced from three observations as from seven or more, if the temperature of the second observation is exactly the mean of the other two. Now as at each interval we always made three observations, it was easy with a little practice to regulate the temperature so as to obtain the wished-for temperature as mean. Of course sometimes we had to make four, five, or more observations in order to bring out the desired temperature. By only taking observations at three intervals, the labour of the research, especially of the calculations, was materially diminished.

In the following Table we have placed together the results obtained with the different sorts of iron:—

	Conducting-power at 0°.	Percentage decrement in the conducting-power between 0° and 100°.
Electrotype iron	—	38·262
Electrotype iron (annealed in hydrogen)	—	38·479
Electrotype iron	—	38·134
Electrotype iron (annealed in air)	—	38·160
No. 5	15·712	36·070
No. 6	15·640	36·010
No. 7	14·204	34·742
No. 8	12·132	34·117
No. 9	14·723	35·459
No. 10	10·666	32·637
No. 11	9·921	31·163
No. 12	9·449	30·592
No. 13	13·293	33·278
No. 14	8·568	27·689
No. 15	13·774	33·801

If we look at the above Table, the following important fact will be obvious, namely, the higher the conducting-power the higher the percentage decrement in the conducting-power between 0° and 100°; in fact we have always found this to be the case; and from experiments made with about 100 alloys in this direction we have not found a single case where the percentage decrement in the conducting-power between 0° and 100° is greater than that of the pure metals; further, we have found that we may deduce the conducting-power of the pure metal from that of the impure one when the impurity in it does not reduce it more than, say, 10 to 20 per cent.; for we have proved experimentally that within those limits the percentage decrement between 0° and 100° in the conducting-power of an impure metal varies in the same ratio as the conducting-power of the impure metal at 100°, compared with that of the pure metal at 100°. Thus the percentage decrement in the conducting-power of pure iron between 0° and 100° is 38·261 per cent., that of No. 5, 36·07 per cent. Now, if the above statement be correct, by multiplying the conducting-power of No. 5 at 100° by $\frac{38{\cdot}261}{36{\cdot}070}$, we shall obtain the conducting-power of the pure metal at 100°, and the conducting-power at 0° by dividing that number by 0·61734.

In the following Table we give the results of such a calculation with those specimens of iron the conducting-powers of which do not vary more than 20 per cent. from that deduced for the pure metal.

	Observed conducting-power at 0°.	Calculated conducting-power of pure iron at 0°.
No. 5 . . .	15·712	17·257
No. 6 . . .	15·640	17·223
No. 7 . . .	14·204	16·533
No. 9 . . .	14·723	16·606
No. 13 . . .	13·293	16·516
No. 15 . . .	13·774	16·717
	Mean	16·809

The reason for making the above deduction will be fully explained in our paper "On the Influence of Temperature on the Electric Conducting-power of Alloys." One glance, however, will show that the deduced values agree as well together as can be expected, considering that the results may be modified by the presence of carbon, sulphur, &c. In cases where we may assume that we have only solutions of one metal in another, the concordance in the deduced values is very great; in fact, when we experiment with metals whose conducting-power in a pure state is known, and when the impurity is only dissolved in it, then the deduced conducting-power agrees almost exactly with that found experimentally.

For resistance-thermometers, as described by SIEMENS*, the use of an iron wire would give much greater differences for the same increment of temperature than copper; for the resistance of pure copper wire increases for each degree about 0·4 per cent., whereas that of pure iron increases about 0·6 per cent. for each degree.

When we found that iron decreased in conducting-power between 0° and 100° more than the pure metals (and here again we will call attention to the fact that we have as yet found no alloy to decrease in conducting-power between 0° and 100° to a greater extent than that which the pure metals composing it would do), we thought that its being a magnetic body might possibly be the reason of it; but after having tested thallium, and found that the conducting-power of that metal also decreases more than that of the pure metals, we knew that this could not well be the case, for thallium is strongly diamagnetic†. Hearing, however, that Professor WÖHLER possessed specimens of pure cobalt and nickel wire prepared by M. DEVILLE, we wrote and asked him to lend them to us; this he immediately did, and on testing them we obtained the following results:—

Cobalt wire.

Length . . . . 270 millims.
Diameter . . . 0·468 millim.

		Reduced to 0°.
Conducting-power found before heating the wire . .	12·495 at 11°·6	12·899
,, ,, after being kept at 100° for 1 day .	12·466 at 12·6	12·905
,, ,, ,, ,, 2 days .	12·428 at 13·4	12·894

* Report of Government Submarine Cable Committee, p. 454.

† LAMY, Compt. Rend. 1862, vol. lv. p. 836. Mr. CROOKES informs us he has also found thallium strongly diamagnetic.

The means of the conducting-powers observed at the following temperatures were—

T.	Conducting-power.		Difference.
	Observed.	Calculated.	
8·65°	12·623	12·626	−0·003
24·97	12·080	12·073	+0·007
39·95	11·586	11·589	−0·003
54·88	11·127	11·128	−0·001
70·44	10·671	10·670	+0·001
84·00	10·289	10·291	−0·002
99·78	9·873	9·872	+0·001

The formula deduced from the observations, from which the conducting-powers were calculated, was

$$\lambda = 12{\cdot}930 - 0{\cdot}035521t + 0{\cdot}00004887t^2,$$

or

$$\lambda_1 = 100 - 0{\cdot}27472t + 0{\cdot}000378t^2,$$

corresponding to a percentage decrement of 23·692 per cent.

Nickel wire.

Length . . . . 240 millims.
Diameter . . . 0·408 millim.

		Reduced to 0°.
Conducting-power found before heating the wire . .	11·594 at 11·2°	12·035
„ „ after being kept at 100° for 1 day .	11·630 at 14·0	12·185
„ „ „ „ 2 days .	11·739 at 12·4	12·235
„ „ „ „ 3 days .	11·735 at 12·5	12·235

The means of the conducting-powers observed at the following temperatures were—

T.	Conducting-power.		Difference.
	Observed.	Calculated.	
12·38°	11·735	11·728	+0·007
24·20	11·260	11·276	−0·016
40·06	10·708	10·701	+0·007
53·86	10·239	10·230	+0·009
70·14	9·700	9·710	−0·010
83·93	9·302	9·298	+0·004
100·03	8·850	8·851	−0·001

The formula deduced from the observations, from which the conducting-powers were calculated, was

$$\lambda = 12{\cdot}222 - 0{\cdot}040787t + 0{\cdot}00007088t^2,$$

or

$$\lambda_1 = 100 - 0{\cdot}33372t + 0{\cdot}0005799t^2,$$

corresponding to a percentage decrement of 27·573 per cent.

From our experiments with alloys we should deduce that the cobalt and nickel wires

were not pure, and we are justified in making this statement by the fact that we have not yet found any metal in a pure and solid state to decrease in conducting-power between 0° and 100° less than 29·307 per cent., and, further, when we consider that, although these metals may have been pure when in the state of powder, yet very little is known about their behaviour to the crucibles at the high temperatures at which they fuse. It is well known how difficult it is to procure chemically pure iron in a fused state, on account of its decomposing the crucibles in which it is melted and taking up some impurities.

Assuming, therefore, that cobalt and nickel behave like most other pure metals, namely, decrease in conducting-power between 0° and 100°, 29·307 per cent., we may deduce from the above data the conducting-power of the pure metals.

The conducting-power of pure cobalt would then be 17·223 at 0°, and that of pure nickel 13·106 at 0°.

We hope shortly to be able to prepare some pure cobalt and nickel by depositing galvanoplastically those metals in the form of foil from solutions of their pure salts, and so to check the above deduced values for the conducting-power of the pure metals.

In conclusion, we give, in the following Table, the conducting-power of some of the pure metals, in order to show the places which the metals treated of in this paper take.

	Conducting-power at 0°.
Silver (hard drawn)	100·00
Copper ,,	99·95
Gold ,,	77·96
Zinc	29·02
Cadmium	23·72
Cobalt*	17·22
Iron*	16·81
Nickel*	13·11
Tin	12·36
Thallium	9·16
Lead	8·32
Arsenic	4·76
Antimony	4·62
Bismuth	1·245

* Probable value for the pure metal deduced from the observations with the impure one.