February 21, 1878.

Sir JOSEPH HOOKER, K.C.S.I., President, in the Chair.

The Presents received were laid on the table, and thanks ordered for them.

The following papers were read :—

I. "On the Alteration of the Thermal Conductivity of Iron and Steel caused by Magnetism." By HERBERT TOMLINSON, B.A., Demonstrator of Natural Philosophy, King's College, London. Communicated by Professor STOKES, Sec. Roy. Soc. Received December 17, 1877.

The writer has, for several months, been engaged in experimenting on the alteration of the electrical and thermal conductivity of iron and steel, produced by magnetism, with the intention of determining such alteration in absolute measure. But as, before the complete determination of the data sufficient for the purpose, a considerable time must elapse, he would venture to offer to the Society, in a preliminary note, some results which have already been obtained by him.

In these experiments, the apparatus chiefly employed to impart magnetism consisted of an electro-magnet, with soft iron cores, 1 inch in diameter and 5 inches in length, surrounded by cotton-covered copper wire, $\frac{1}{16}$th of an inch in diameter, having a resistance of nearly 1 ohm, and a coil constructed as follows:—a thin tube of polished tin, $1\frac{1}{4}$ inch internal diameter and $4\frac{1}{2}$ inches long, was covered with vulcanised caoutchouc to a depth of $\frac{1}{16}$th of an inch, and on this was wound 3 lbs. of cotton-covered copper wire, $\frac{1}{20}$th of an inch diameter, followed by 3 lbs. of wire, $\frac{1}{10}$th of an inch in diameter. Inside the first tube was placed a second, 1 inch internal diameter, connected by ebonite with the first at the two ends, the second tube being concentric with the first, and of the same length, so that, between the inner tube and the outer, should be interposed a layer of air nearly $\frac{1}{8}$th of an inch in thickness. This arrangement was employed to prevent the heat from the magnetising coil reaching the bars placed inside; also, to prevent ingress or egress of heat; the bars used with the coil were covered with vulcanised caoutchouc, so that they lay with their axes coinciding with the axis of the coil.

To measure the heat conducted along the bars two sets of thermo-elements were constructed. The first was made up of two small strips of copper, $\frac{1}{2}$ inch long and $\frac{1}{4}$ inch broad, of small thickness. To these was soldered about 1 foot of silk-covered german-silver wire $\frac{1}{20}$th of an inch in diameter, the copper strips being also connected

with a galvanometer by copper wires, well covered with caoutchouc, one end of each being soldered to the copper strips, so that either one or both the copper strips with the soldered German-silver wires could be employed as a thermo-element. In case it was found convenient to use only one of these, the other was kept well covered with sawdust. These elements will be called the G. S. elements. The second consisted of two small thermo-piles, each of 12 elements, of antimony and bismuth, and were each fitted into india-rubber tubes, so that they could be inserted into small wooden boxes, containing water, so as to fit water-tight. Sometimes these, like the G. S. elements, were used separately; at others, were made to neutralise each others effect on the galvanometer.

With these elements, a delicate Thomson's reflecting galvanometer, having a resistance of 2 ohms, was employed, the scale being placed about 6 feet from the mirror of the needle.

In the circuit of the magnetising current, a tangent galvanometer was placed, the needle of which was suspended by a very fine platinum wire, attached to a graduated torsion circle. The two thick copper wires which conveyed the current were each 27 centimetres in diameter and 14 inches apart.

A magnetometer was also employed to test the magnetism imparted, but, as the readings will not be given in this paper, no description of the instrument is necessary.

To heat one end of the bars two large Leslie's cubes were employed, having each two apertures projecting about 2 inches into the interior of the cubes. The apertures in one cube were $\frac{1}{2}$ inch square and placed in one side of the cube, about 3 inches apart from each other, and half way up the side. In the other cube the apertures were circular, and $\frac{1}{2}$ inch in diameter, and placed in the centres of opposite sides of the cube. Into these cubes bars of square and circular section were respectively inserted, and water filling the cubes was raised to 100° C.

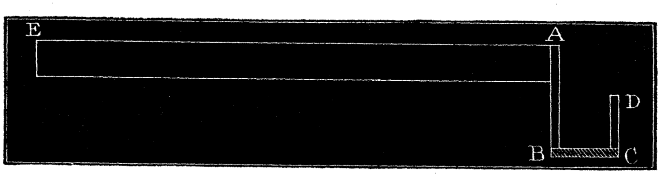
The first experiment was made on a soft iron bar, $\frac{1}{2}$ inch square in section. The bar was inserted into the Leslie's cube with square aperture, filled with boiling water, and into the other aperture was inserted a brass bar of the same section. The length of the iron bar was about 10 inches, and of the brass one, 18 inches. One of the G. S. elements was fastened on to the iron bar, and the other to the brass, by caoutchouc bands, the elements being insulated from the bars by thin paper. The G. S. elements were made to very nearly counteract each others effect by sliding one or other of them up and down the bars until the heat conducted by the bars to the elements was in both the same as nearly as possible. Underneath the bar was placed the electro-magnet, with a piece of white cardboard lying on the upper extremities of the soft iron cores, so that the cores were about 3 milli-

metres from the iron bar; the bar was also propped by a wooden support at the other end. A preliminary experiment had been made for the purpose of ascertaining whether the heat radiated from the electro-magnet would affect the thermo elements to any appreciable extent, and this was not found to be the case.

The water in the cube was now kept boiling for about nine hours, and after that time had elapsed it was ascertained that the flow of heat from one part of the bars to another compensated the loss from radiation, and the light on the scale remained stationary. (It should be observed that, as it was impossible to cause one thermo-element exactly to neutralise the other, a slight use of the adjusting magnet of the galvanometer was made to bring the light near the zero of the scale.) The current from a single bichromate cell was now sent through the coil of the electro-magnet. In a few moments the spot of light began to move very slowly across the scale in a direction indicating that the flow of heat through the iron bar was being checked, and in about fifteen minutes a deflection of about 25 divisions of the scale was obtained; the current of the cell was then stopped, when the light began slowly to return, and finally settled in apparently the exact position which it held before sending the current through the coil. This experiment was repeated several times on the same day, and on several other days, but always with the same result as regards direction, namely, showing a diminution of the flow of heat from longitudinal magnetisation.

As it was thought, however, that the electro-magnet might when in action perhaps produce an apparent diminution of flow of heat by slightly disturbing the bar in its position in the aperture, though every precaution had been used to prevent the chance of this, the bar in the next set of experiments was securely soldered into the cube, and again tested as before. Here, again, some five or six trials gave the same result, and seemed to show, most conclusively, that the thermal conductivity of soft iron is diminished by longitudinal magnetisation.

As the method of observation, however, was tedious and would give no idea of the amount of alteration of conductivity, other expedients were now adopted.



A piece of soft iron, BC, $\frac{1}{2}$ inch long, $\frac{1}{2}$ inch broad, and 2 millimetres in thickness, was soldered, as in the figure, to two pieces of brass, AB, CD, of the same breadth and thickness.

AB was 2 inches long and CD 1 inch.

The piece AB was also soldered to another piece of brass AE, having a section $\frac{1}{2}$ inch square, and length about 12 inches.

The whole was placed inside a wooden box, 2 feet long, 1 foot wide, and 2 feet high, lined on the outside with tinfoil.

AE passed through a circular hole, 2 inches in diameter, in the middle of one end of the box, and through two corresponding circular holes in a double screen of sheet tin, and thence into one of the square apertures of one of the Leslie's cubes. The electro-magnet was placed underneath BC, and two pieces of soft iron, about $3\frac{1}{2}$ inches in length, $\frac{1}{2}$ inch in breadth, and about 2 millimetres in thickness, were placed on the ends of the soft iron cores, so as to be on the same level with BC, and distant from B and C about 2 millimetres, the pieces of iron being separated from the cores by a piece of white paper. In some experiments the pieces of iron thus used were carefully secured to the electro-magnet by elastic straps, and, in others, by weights placed on them. A preliminary experiment, made with the strongest current that was ultimately used with the electro-magnet, showed that neither were the iron pieces on the cores appreciably shifted on magnetising the coil, nor was the heat radiated from the coil sufficient to produce any effect on one of the G. S. elements fastened by elastic bands to the back of CD. The other G. S. element was in this case buried in sawdust, with which the box was now filled, so as to cover completely the bars and electro magnet. The sawdust also filled the space between AB and CD, and the small portion of the brass bar AE, which was between the box and the Leslie cube, was covered with caoutchouc and cotton wool.

The lid of the box was now put on, and some time allowed to elapse until the light remained steady on the scale.

Boiling water was then put into the cube, and a burner placed underneath. Very shortly the light began to move across the scale, showing that the heat had been conducted along the compound bar to the thermo element, and then the number of divisions on the scale passed over by the light was taken for each minute. The adjusting magnet of the galvanometer had in these and similar experiments to be placed very low down in order that the number of divisions of the scale passed over might not exceed 60 per minute. When the light reached one end of the scale the adjusting magnet was used to bring it back again to the other. In these and similar experiments it was found that, after some time, either the number of divisions passed over per minute increased or diminished very slowly or else remained constant for some minutes. The following observations were made with the specimen in question, the light being near one end of the scale. The number of divisions passed over in consecutive minutes was as follows (the magnetising current will be called M. C.) :—

A M.C. not flowing. 1st minute 40	B M.C. flowing. 1st minute 34	C M.C. not flowing. 1st minute 31	D M.C. flowing. 1st minute 28
2nd minute 39 3rd " 38 4th " 34 5th " 36	2nd minute 34 3rd " 33 4th " 31 5th " 32	2nd minute 33 3rd " 31 4th " 31 5th " 30	2nd minute 29 3rd " 27 4th " 29 5th " 28
No. of divisions in last 4 minutes =147.	No. of divisions in last 4 minutes =130.	No. of divisions in last 4 minutes =125.	No. of divisions in last 4 minutes =113.

The light was then near the other end of the scale, so the adjusting magnet was employed to bring the light back again. The set of experiments here given, the first of many, is rather an unfavourable one, most of them giving results much closer together than those here given, and, in several instances, the flow of heat would seem perfectly steady for upwards of fifteen minutes.

The observations of the first minute in each case were not taken, in order to avoid error from very slight deviations of the galvanometer needles caused by the action of the electro-magnet, which however was placed at such a distance from the galvanometer, and in such a position as not, in most cases, to produce any such deflection, and to give time for the magnetism to produce its effect on the bar. It has been determined, that in experiments made in this manner, 1 minute seems quite sufficient for the above-mentioned purpose.

Taking A and C together, we obtain as a mean the number of divisions passed over in 4 minutes with the M. C. not flowing 136 as against 130 from B, with the current flowing; again, from B and D, with the current flowing, we obtained 121·5 as against 125, with the current not flowing, so that, in both cases, there is a less mean flow with the M. C. flowing than when it is not flowing. The mean of this particular set of experiments would give a decrease of flow, when the bar is magnetised longitudinally, of about 3·6 per cent. of the whole for a magnetising current, causing a deflection of the needle of the galvanometer of 18·6°. The mean of all the observations for the specimen, and for this current, gave a decrease of flow amounting to 3·3 per cent. of the whole.

The electro-magnet was now turned through 90°, so as to magnetise the iron transversely, and a similar set of experiments were made.

Here, again, the result was most conclusive, and the mean of several observations showed an *increase* of flow when the bar was magnetised transversely, amounting to about 3·2 per cent. of the whole for the same current strength.

Thus, the decrease of conductivity in one case seems roughly to be

equal to the increase in the other, but it is the intention of the author to make further researches into this part of the inquiry.

The batteries employed in these and subsequent experiments were slight modifications of Daniell's batteries, which, though having a very small resistance, maintained a constant current for some hours. These batteries the writer hopes to have the honour of describing to the Society on a future occasion.

Similar experiments were next made on a piece of hard steel, of similar dimensions to those of the iron, but the length of the brass bar, AE, was considerably shortened.

The result of the experiments proved that there was a decrease of flow, amounting to about 4 per cent., of the whole, when the bar was magnetised longitudinally with a current producing a deflection of 18° on the tangent galvanometer, and an increase of flow when magnetised by a current of 10° C transversely, amounting to about 3 per cent. of the whole (unfortunately, through accident at the time, the same magnetising current as used for longitudinal magnetisation could not be employed).

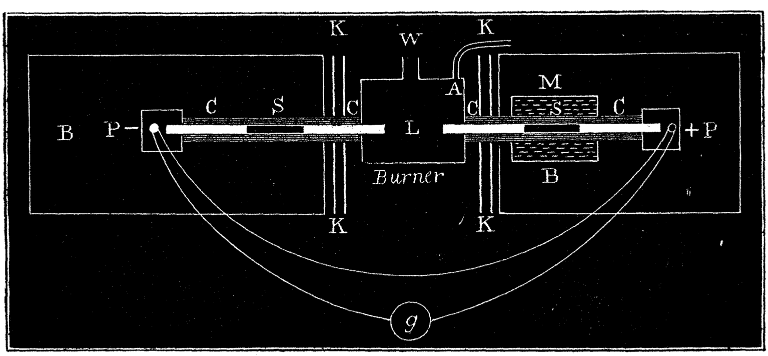
This last result was rather unexpected, as, though Sir William Thomson has shown (Phil. Trans., Feb. 28, 1856) that the electric conductivity of hard steel is diminished when the steel is magnetised longitudinally, some experiments of the writer in the same direction (Proc. of Royal Society, June 17, 1875) seemed to show that, in the case of hard steel, the contrary effect is produced, while Joule has proved (Phil. Mag., 1847) that, while a bar of iron, or even steel which is so hard that a file will just touch it, is lengthened by longitudinal magnetisation, iron under great strain, or steel so hard that a file will not touch it, is shortened.

Of course, the mere act of soldering the steel to the brass would, to a certain extent, soften the steel. A bar of steel, therefore, of circular section, $\frac{1}{2}$ inch in diameter and about 12 inches in length, was made so hard that it could not be touched with a file, and placed, with the usual precautions, on the poles of the electro-magnet, at a height of about 3 millimetres above the cores of the electro-magnet, one of the G. S. elements being secured to one end and the other end inserted in a Leslie's cube. But here, again, there was undoubtedly a decrease of conductivity, when the bar was magnetised longitudinally. Of course, however, the mere fact of heating the bar at one end to the temperature of boiling water would tend to soften the bar, and the writer is not quite satisfied but that it may be ascertained that, for low temperatures, the conductivity of hard steel is increased. It is intended, therefore, to make experiments on iron and steel, at different temperatures, both high and low, with a view of definitely settling this point.

Some experiments were next made with the magnetising coil de-

scribed in the beginning of the paper, but the effects produced were found to be so much less for the hard steel than when the electro-magnet was employed that it was found necessary to use the thermo piles, also mentioned above, and instead of employing the compensating magnet to bring the light on to the scale to cause the two piles, as much as possible, to neutralise each others effects. Accordingly the following arrangements were made:—

Two bars of hard steel, S, each $3\frac{1}{2}$ inches long and $\frac{1}{2}$ inch in diameter, were soldered at each end to two copper rods, each about $4\frac{1}{2}$ inches in length and $\frac{1}{2}$ inch in diameter. One copper terminal of each rod was inserted, as in the figure, into a Leslie's cube, L, to a distance of 2 inches, and the other terminal into a small wooden box, varnished inside with shell-lac, and capable of containing about 120 cubic centimetres of water. The bars were well covered with caoutchouc; KK are double screens, PP the two thermo elements, so arranged as to send their currents through the galvanometer in opposite directions, the wires connecting them with each other and the galvanometer being well covered with gutta-percha, and passing through small holes in the sides of the boxes. The two compound bars were thus made as exactly similar as possible, and also similarly placed, the only difference being that produced by the magnetising coil, M, whose axis coincided with that of the steel bar placed inside it.



The large boxes, B, were well filled with sawdust, and the lids being put on, the whole affair was left for some time, until the light remained steady on the scale. Boiling water was then poured into the hole, W, and a burner lighted underneath the cube, whilst the aperture at W, having been closed with a cork, the steam generated was allowed to pass through a smaller aperture at A, connected by tubing with a large vessel filled with water, for the purpose of condensing the steam.

Both the small boxes had originally the same quantity of water placed in them, and a previous experiment had shown that so exactly similar was the heat conducted along the bars to the water in the

boxes, that when some two hours or so had elapsed, the rise of temperature of the water in each box seemed as measured by an ordinary thermometer, marked off in degrees centigrade, to be exactly the same, namely, 10° C.

But as the same experiment had shown that the pile in the box on the left of the figure was very slightly more powerful than the other, the water in the box on the right was diminished very carefully by means of a small siphon, formed of india-rubber tubing, of very small bore, which was kept closed by a pinch-cock at one end, the tube passing through holes cut in the large box, through the sawdust, and through a small hole cut in the lid of the small box, so as to dip into the water. The little siphon was always kept charged, and, by means of the pinch-cock, any desired small quantity of water could be extracted from the box.

By this means it was found easy to make one pile so neutralise the other that a very slight use (if any is necessary) of the adjusting magnet was required, even when the magnet was near its most sensitive position with respect to the galvanometer needle.

On sending a current through the coil M, it was in a minute or so seen that the conductivity of the hard steel was diminished by the longitudinal magnetisation, and the amount of diminution was roughly determined by finding the amount of water necessary to be extracted from the box to again bring the light to the same slow rate of motion (about 2 divisions per minute) which it had before passing the magnetising current, and comparing this with the original amount of water in the box. The decrease of flow did not amount to 1 per cent. of the whole, even with the strongest battery used (current shown by the tangent galvanometer, 26°).

This plan was found to be highly successful for determining whether there was a diminution or not, but not equally so for determining the amount of decrease, owing to the great difficulty in this method of quickly making the light move at the same rate after magnetisation as before. Another method was therefore tried, which promises to give better results.

The figure will perhaps best explain the plan now adopted for making one pile completely neutralise the effect of the other.

P_1, P_2 are the two piles.

g the galvanometer.

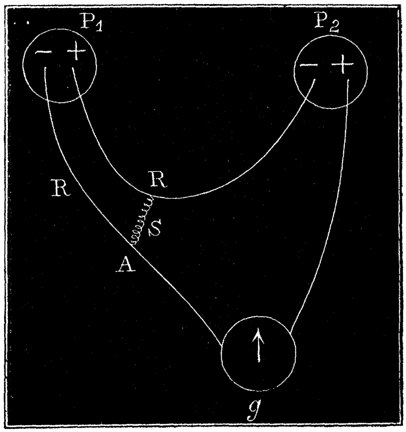
S the resistance of a shunt placed between the points AB, which could be varied at pleasure.

R the resistance of circuit AP_1B, including the resistance of the pile.

The same quantity of water was now put into each box, and the pile P_1 being slightly more powerful than P_2, the shunt S was adjusted until there was little or no motion of the light on the scale.

The magnetising current was then passed through the coil, and the shunt again adjusted, until the piles neutralised each other.

It can be readily shown that if x_1, x_2 be the units of heat imparted to the water in the two boxes in the same time, $\frac{x_2}{x_1} = \frac{S}{R + S}$ when the piles neutralise each other.



If, then, dx_2 be the diminution of flow caused by magnetisation, and dS the diminution of shunt resistance necessary to again make one pile neutralise the other,

$$\frac{x_2 - dx_2}{x_1} = \frac{S - dS}{R + S - dS}$$

$$\therefore \frac{dx_2}{x_2} = \frac{R \times dS}{S(R + S - dS)}$$

and thus the percentage of diminution of flow may be determined.

A few resistance coils were very roughly constructed for use in the shunt, S, and an attempt made to ascertain the actual amount of diminution of conductivity of the hard steel. This, again, appeared to be comparatively small, but as the coils used were not suitable for the purpose, the result is not given. But the writer has little reason to doubt that, with resistance coils suitable for such thermo-electric experiments, he will be able to measure, with fair accuracy, small variations of thermal conductivity in this way.

It should be added that similar experiments to these were made with soft iron bars, both with and without copper terminals, but the results of the experiments, of which altogether upwards of a hundred have now been made, show that in every case the thermal conductivity of soft iron is diminished by temporary longitudinal magnetisation and increased by transverse magnetisation, whilst in the case of steel, of

different degrees of hardness, at any rate, for the temperatures employed, magnetisation evidently produces the same kind of effect as with the soft iron. The amount of the alteration in the case of soft iron must have reached at least as high as 10 per cent., and may be greater. The experiments which the writer has made on electrical conductivity have shown that this is also very appreciably altered by magnetism, at least 6 per cent., even when the magnetisation was evidently not complete (Proc. of R. S., June 17, 1875), and has some reasons for believing that the amount of alteration for thermal and electrical conductivity will be found to be not very different. He hopes, however, to thoroughly investigate the whole subject.

It should be mentioned here that Sir William Thomson (Phil. Trans., Feb. 28, 1856,) expresses a strong opinion that the experiments of Dr. Maggi on this subject, on which he says doubts have been thrown by others, would be found correct, basing his opinion on the results of his own experiments on the alteration of electrical conductivity by magnetism. And, though the writer had some years ago made some attempts in the present direction (unfortunately before perusing Sir William Thomson's exceedingly valuable paper), he cannot conclude without expressing how greatly the suggestions there thrown out have assisted him in these and other experiments.

II. "Chemical Notes." By Dr. MAXWELL SIMPSON, F.R.S., Professor of Chemistry in Queen's College, Cork. Received January 2, 1878.

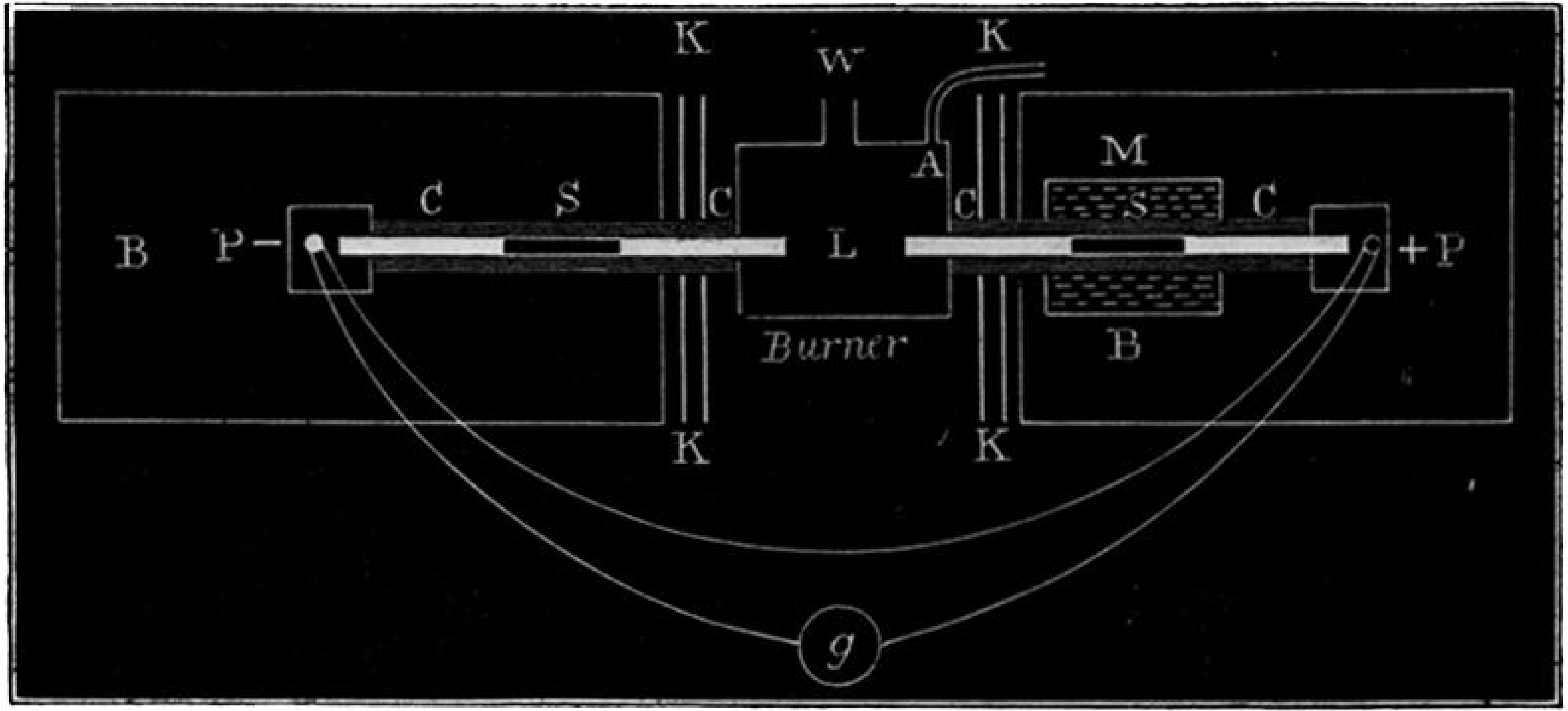
On the Direct Formation of the Chloro-Bromides of the Olefines and other non-saturated Compounds.

Chloro-bromide of Ethylene (C_2H_4ClBr).

The first step towards the direct formation of this and other chloro-bromides is, of course, the preparation of the solution of chloride of bromine. This I endeavoured to prepare by a process analogous to that by which I had formed the chloride of iodine.* I found, however, that in passing the chlorine into the bromine and water, a larger quantity of the former is carried off in the form of vapour. I continued the passage of the gas, nevertheless, till all the bromine was dissolved and the solution assumed a faint yellow tint. On conducting olefiant gas into this, I obtained a very small quantity of an oily liquid, part of which boiled between 106° and 110° Cent. Altogether, it is by

* "Annalen der Chemie," cxxxvi, 141.


E
A
D
B
C


K
W
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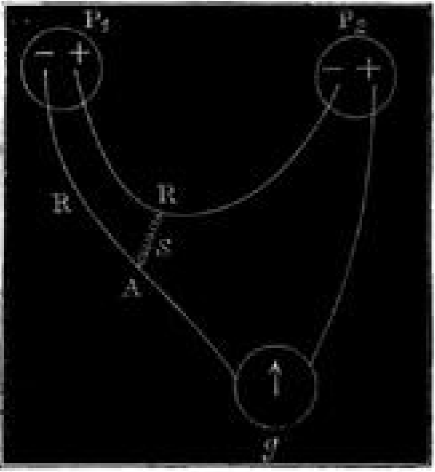

P_1
P_2
R
R
S
A
g