On the Influence of a Magnetic Field and of Mechanical Stirring on the Potential Difference of an Electrolytic Cell.

By

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In the present experiment the writer made an investigation on the effect of a magnetic field on the potential difference between the electrodes in an electrolytic cell, and also the influence of mechanical stirring on it when a steady current was sent through the cell.

When a steady current is sent through an electrolyte, polarisation occurs at the electrodes; and it seems that the magnetic effect on the electrodes has an intimate relation to it.

Polarisation always takes place in a living tissue when an electric current flows through it. A living body is built up of many cells, each of which consists of protoplasma and a semipermeable membrane; and, when an electric current flows from one cell to another, a difference of concentration of ions, and, consequently, polarisation takes place at the membrane. Further investigation of such polarisation is highly necessary in electrophysiological researches.

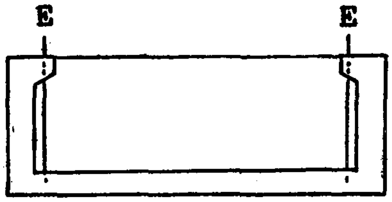
Besides the effect of a magnetic field on the electrodes, the writer examined whether a mechanical stirring of the solution near the electrodes has any influence on the electrical nature of the system, and found that the effect of such stirring of the solution in the neighbourhood of one electrode on the potential difference between the electrodes is similar in nature to that of the magnetic field when it is applied to the same electrode.

Method of Experiment.

The experiments were carried on by the following two methods.

In one method, a Wheatstone bridge was employed, and in the other, the potential difference between the electrodes was measured by a galvanometer connected to the electrodes in parallel with the battery circuit.

The electrolytic cell used was prepared in the following manner. An ebonite plate was cut out in the form indicated in the annexed figure, both sides being closed with glass plates. At both ends of the ebonite frame, platinum or iron wires E were supported, and served as the electrodes. Many cells of various sizes were used, the largest one being 20×3×2 cm in size. The platinum electrodes were platinized before each experiment, and were well washed with distilled water. The iron electrodes were ordinary iron wires, and they were polished before each experiment. The galvanometer employed was one of a d'Arsonval type. The electromotive force was applied between the electrodes of the cell by means of one or two storage batteries or dry batteries connected in series. The electrolyte used was half mol. iron trichloride solution etc., and the cell was subjected to the magnetic field due to an electromagnet, whose maximum intensity was 6900 Gauss.



In the Wheatstone bridge method, the zero point of the needle of the galvanometer was not always constant in consequence of variation in the internal condition of the cell; but a certain amount of deflection was clearly observed when a magnetic field was applied to the electrodes.

In the other method, the cell, a storage battery and a resistance box was connected in series; and, in parallel with the cell, there was a high resistance circuit, a small portion of which being shunted by the galvanometer. In this case also the zero point of the galvanometer needle was not constant.

The mechanical stirring of the solution in the cell, was performed with the same arrangement described above.

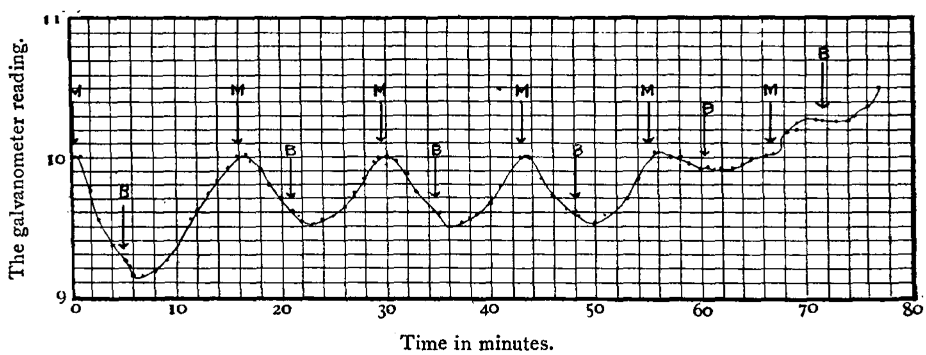
Experiment.

I. The magnetic field applied on both electrodes and its repeated application.

The current in the battery circuit was so adjusted that no gas bubbles appeared at the electrodes. The electrolyte used was a half mol. iron trichloride solution. The platinum electrodes were platinized, and they were both placed between the poles of the electromagnet.

When the magnetic field was applied, a variation of the deflection of the galvanometer needle occurred similar to that of the diminution of the potential difference due to the polarisation of the cell.

By making successive applications of the same given magnetic field, at the intervals shown in the following curve, the effect became less and less.



M denotes the time at which the magnetic field was applied.
B denotes the time at which the magnetic field was taken off.

II. The relation between the intensity of the magnetic field and its effect.

A magnetic field of various strengths, from 3000 Gauss up to 6900 Gauss, was applied. The arrangement was the same as that of experiment I. The effect increased with the magnetic field, but finally approached to a certain limit asymptotically.

III. Application of the magnetic field on each of the electrodes.

In this case, by using the cell of suitable size, the distance between the electrodes was made sufficiently great so that when one electrode was placed between the poles of the electromagnet the other was far away from them.

The effect was much greater when the cathode was placed in the magnetic field than when the anode was placed in it. When iron electrodes were employed instead of platinum ones, the result was complex as is to be described in V.

IV. Experiment with platinum electrodes in other salts.

When a ferrous sulphate solution or a potassium ferricyanide solution was used, the effect was similar in nature to that in the case of an iron trichloride solution, but of less intensity. When a cobalt nitrate solution was used, the effect was slight; and in the case of nickel chloride solution it was still much slighter.

V. Application of the magnetic field on each of the iron electrodes.

The arrangement was the same as that in experiment III, the iron electrodes being used.

(a). With a sufficiently strong magnetic field the effect was similar to that obtained in the case of the platinum electrodes, but with a weak magnetic field the galvanometer needle showed an increment of the potential difference of the cell when it was applied to the anode.

(b). When a certain relatively strong current was sent through the battery circuit, the application of the magnetic field on either of the electrodes caused a diminution of the potential difference between the electrodes. But when the current was weak, in the case of the anode there was a very slight increment of the potential difference between the electrodes, whilst in the case of the cathode there was the usual diminution.

VI. The electromotive force of the cell set up in consequence of the stirring of the electrolyte.

As electrodes the writer used platinum, iron, copper and nickel. The electrodes, which consisted of a pair of one of those metals, were each time immersed in a proper solution. When the solution in the neighbourhood of one of the electrodes was stirred, a galvanometer deflection was observed, which further increased with violent stirring, but finally reached a certain limitting value.

The result of the experiments is given in the following table.

The metal used as the electrode.	The solution.	Potential at the disturbed electrode.	Potential at the other undisturbed electrode.
iron	half mol. iron trichloride	+	–
nickel	1 mol. nickel chloride	+	–
platinum	dilute hydrochloric acid	–	+
copper	dilute hydrochloric acid	–	+

VII. Mechanical stirring of the solution.

The apparatus was just the same as that in experiment V.

The effect of mechanical stirring of the electrolyte round an electrode was examined. The electrolyte round one electrode was stirred mechanically with a fine glass rod. care being taken as much as possible not to affect the portion of the electrolyte round the other electrode.

The effect was more or less similar in nature to the case of a magnetic field, but more conspicuous. When the current in the battery circuit was weak, mechanical stirring of the electrolyte near the cathode caused a diminution of the potential difference between the electrodes, whilst the stirring near the anode caused a nearly equal amount of increment. When the current in the battery circuit was made stronger, the increment of the potential difference due to the stirring near the anode became smaller.

It was here to be remarked that in all the experiments mentioned above the results obtained were not quantitative but rather qualitative.

Summary.

With platinum electrodes, immersed in a dilute iron trichloride solution, the effect of a magnetic field on the potential difference between the electrodes was especially noticeable when it was applied to the cathode. The diminution of the potential difference between the electrodes was less when a cobalt- or nickel-salt solution was employed.

With the iron electrodes the effect was more complex. When a weak magnetic field was applied to the anode, the potential difference between the electrodes increased, and when it was applied to the cathode, it diminished. But with a strong magnetic field, whether applied to the anode or cathode, a decrement of the potential difference was always observed.

With a relatively strong electric current in the battery circuit, the magnetic field caused the diminution of the potential difference between the electrodes when it was applied to either of the electrodes. But with a weak current, a small increment of the potential difference was observed in the case of the anode.

Mechanical stirring of the electrolyte near one electrode affected the potential difference between the electrodes similarly as in the case of the application of the magnetic field to that electrode. With a weak current in the battery circuit, the potential difference diminished when the electrolyte near the cathode was stirred, and increased when the electrolyte near the anode was stirred. When the current in the bat-

tery circuit was made stronger the effect at the cathode was especially remarkable compared with that at the anode.

A mere stirring of the electrolyte near one electrode gives rise to a new electromotive force between the electrodes of the same metal immersed in its own, or other salt solutions. When the electrolyte in the neighbourhood of the metal was stirred, the latter became anode or cathode, according to the nature of the metal and the solution used.

On the potential difference arising between a magnetized iron and unmagnetized one immersed in an electrolyte, Th. Gross,[1] H. A. Rowland and L. Bell,[2] G. O. Squier,[3] E. L. Nichol and W. S. Franklin,[4] Hurmuzescu[5], Bucherer[6], U. Lala and A. Fournier[7] and Paillot[8] have already made investigations.

From the present experiment it will be seen that such potential difference as is caused by the magnetization of one electrode surely has a certain effect on the change of the potential fall between the electrodes. This is however not sufficient to explain experiment V.

Bucherer found that, when a magnetic field was applied to one of the iron electrodes immersed in an electrolyte, a potential difference was set up between them; and a mechanical stirring of the electrolyte round the same electrode had the same effect as that due to a magnetic field. This phenomenon was observed by the writer also.

Procopiu[9] observed a change of the potential difference between the electrodes caused by a movement of one of the electrodes of the cell. This phenomenon is somewhat analogous to that described in experiment VI, which may at present be explained in a following rather premature way.

At the contact surface of a metal and an electrolyte a potential difference due to the solution pressure of the metal takes place, the metal and the solution being oppositely charged. By stirring the electrolyte in the neighbourhood of the metal, this potential difference will

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1 Sitzungsber. der kais. Ak. der Wiss., **92**, Dec. (1885).
2 Jour. of Sc., (3) **36**, 39 (1888).
3 Am. J., **45**.
4 Sill. Jour., (3) **35**, 290 (1888).
5 C.R., **119**, 1006 (1894).
6 Wied. Ann., **58**, 564 (1896).
7 C. R., **123**, 801 (1896).
8 C. R., **131**, 1194 (1900).
9 Bull. d. la Sect. Scintif. d. l'Acad. Roma, **3**, 187 (1915).

be disturbed, and tends to become neutralized; whilst as, at the other electrode, the potential difference due to the solution pressure remains the same, a potential difference will be set up between the electrodes.

If we admit this mode of explanation, experiment VII also seems to be explanable. When the external electromotive force was applied to the electrodes of the cell, the potential difference between the iron anode and the solution due to the solution pressure of the metal diminished. On the contrary, the potential difference between the iron cathode and the solution due to the solution pressure of the metal was strengthened. Consequently the effect of the stirring of the electrolyte near the electrode was more conspicuous at the cathode than at the anode, in the case of a strong current. With a weak current, however, as the external electromotive force applied to the electrodes of the cell is small, the stirring effect naturally appears on the same scale at both electrodes.

As is well known in physiology, when one part of the tissue is put in action it becomes electronegative with respect to the other resting part. The cause of this phenomenon may be ascribed to some electrochemical changes and other more complicated ones; but the disturbance of the double layer, formed between a cell or other living particle and the body juice, in consequence of a stirring of the latter may, perhaps, also play a part in it.

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