Extracts from the papers of Sir Charles Wheatstone

WHEATSTONE 2: Material relating to experiments designed to measure electromotile forces and electric potential, [1834-1875]

K/PP107/2/1

1834-1843

Observations upon electromotive force drafted by Charles Wheatstone, consisting of proposals for experiments to test the electro-motive force of combinations of electrode elements and electrolytes; the means for transforming weak currents; summary entitled ‘new theory of voltaic decomposition’, with sketches and diagrams.
King's College, June 27th, 1843.

Resistance coils.
30 feet = 45 hours
50 feet = 44
100 feet = 97
200 feet = 194
400 feet = 391
600 feet = 639

Large Resistance Coils

\[ \frac{1}{3} \]
\[ \frac{1}{5} \]
\[ \frac{1}{10} \]
\[ \frac{1}{20} \]
\[ \frac{1}{40} \]

\[ \times 500 \text{ yards} \] = all the small resistance coils + 99 hours
\[ = 1688 \text{ hours} \]

The thermo-electric element of brass and copper, the joints at 32° and 21/2° required 60 hours (exactly) to raise the metal from 10° to 15°. (Parameter stood at 29.77).

The second certain element required 757 hours (500°-400°). To raise the metal from 10° to 5°.

The electromotive force of the thermo-electric element is therefore to that of the second certain element as 1 : 94.5

\[ \text{Rule: } \text{by graph: } \text{if different graph has maintained this proportion, } \text{it is } 1:95 \text{ the Clin. de Physique} \]
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Notes on resistance in the electromagnetic telegraph including calculations, [1834-1843], page 1.
with 100 pairs $A = \frac{1000}{300}$. With 1000 pairs $A = \frac{10000}{2800}$.

4. If the size of the plates and the diameter of the wire be subsequently increased, the force of the current will be increased in the same proportion. With 1 pair $A = \frac{100}{1000}$; the size of the plate and the diameter of the wire, but $\theta = \frac{10}{501}$. The force of the current is then for 1 pair

with 100 pairs $A = \frac{1000}{1200}$; the size of the plate and the diameter of the wire becomes $\frac{1000}{500}$.

5. If the number of pairs, and the length of the wire be increased in the same proportion, the force of the current will increase in the same proportion; for then the total resistance will increase in the same proportion as the ohmic force.
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Notes on experiments to measure electromotive forces undertaken at King’s College London, 1840 Jun 29.
In a voltaic series the effective current of electricity is furnished by the calomel element alone, and if the
it consists of 20 pairs there is \( \frac{12}{20} \) the of the electricity generated absolutely lost, that it is neutralized between the
adjacent plates without doing any work. If the electricity could be lost usefully to work without injuring the insulating
power of the battery, a great advantage would be obtained.

Let us suppose the work to be done is the decomposition of
water, and the pile employed consists of 9 pairs. If a resistance
be placed in one of the metallic circuits the insulating power of
the mass will be equal to 9 pairs.
Notes describing the decomposition of water and on reverse a timeline of related events between 1831-1833, [1834-1843], page 2.
Electro-motive Force.

In certain arrangements, it is of the utmost consequence, if great intensity of electromotive force be required, that the number of elements be great. In others again, if a moderate intensity of electromotive force is sufficient, the number of elements may be small, but the intensity of the electromotive force of a single element, may be very great.

If the electromotive intensity of copper and platinum be required to produce a certain decomposition (e.g. of a 1% solution of copper), a pile of copper and platinum of however many elements it may consist will not be this hundred. The number of elements will always have the intensity of the electromotive force the proper degree, but no pile of so many elements will have the effect of it.

The decomposition of a substance.

Instead of saying as we now do that such and such substances are decomposed and that other substances are not decomposed by electricity, it would be more correct to say that they are decomposed or non-dissociated by the electricity. However, it is not always true that they are decomposed or non-dissociated by the electricity. Therefore, the index by which we are arrived by our ordinary methods of measurement, which is usually given to copper, cannot be given to platinum with respect to this.

Advantages will be obtained if we use the electromotive force of a single element in all the methods as the same proportion, except that of requiring a large number of elements to produce the same effect. Thus, as one element represented by $\frac{1}{2}$ will produce double the effect of one element represented by $\frac{1}{4}$; but if the amount of the intensity of the electromotive force is the same.

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Notes describing methods of measuring electromotive forces, [1834-1843], page 1.
The maximum limit of the action of a pole of electromotive force may consist in that of a single element without any resistance in the circuit, this is \[ \frac{E}{L} = \frac{3}{10} \]

The maximum limit of a single element is that of the electric motive force. Thus the thousand elements of copper of that, each a thousand square feet, can never equal a single pair of battery, and the number is indefinitely increased.

Hence the other expedients of escaping the produce energy to decomposition in the chosen electric arrangement.
Means of multiplying the effects of very weak currents

Suppose we have a current which produces a permanent division of 5° towards A of Nollin’s galvanometer. The needle being first at rest at 0° and one of the poles placed in the case, connection must be made for an instant with the other case, the needle will spring between A and return into zero beyond 5° towards B; at the instant it is about to return from B. Here there may occur an equal and opposite effect, the magnitude of the indication will be increased, and repeat the same operation again twice the needle will return from B. The indications may thus succeed, the needle striking against the stop, and the number of indications may be taken as the measure of the force.

To reduce the indications, let the needle be returned, connection must be made at every instant the needle is at the extreme limit towards A; it requires greater force to return the indications of the needle than to make them the same again.

In the first case the current is made to act with the moment of the needle, in the second case against it.

Currents which would produce division only of a fraction of a degree may be thrown very sensible; this method can be extremely applicable in some of their circumstances.
Notes describing methods of measuring electromotive forces, [1834-1843].
What does Faraday mean when he says that heat exalts the chemical affinities between a metal and the liquid? If he means that a new chemical action is produced by the application of heat, and that the current is proportional to the energy of action, then he makes the affinity be equal to the energy of action, a proposition which is by no means true.

If two platinum electrodes be placed in sulphuric acid, and one of them be heated, no current is produced. What is the chemical action in this case? And yet the same thing would happen here if produced by the current, whereas it is happening also with other metals.
Notes, formulas and calculations relating to the measurement of resistance on reverse of a letter from the Royal Society including Wheatstone's rough diagrams, [1843], page 1.
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Notes, formulas and calculations relating to the measurement of resistance on reverse of a letter from the Royal Society including Wheatstone's rough diagrams, [1843], page 2.
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Notes, formulas and calculations relating to the measurement of resistance on reverse of a letter from the Royal Society including Wheatstone's rough diagrams, [1843], page 3.
Notes, formula and calculations relating to the measurement of resistance, 1843 Sep 9.
Experiments to be made with Faraday's circuit with Iodide of Potassium and Sulphuric acid.

Exp 1. Measure the electromotive force with the Iodide alone.
Exp 2. Measure the electromotive force of the sulphuric acid alone.
Exp 3. Measure the difference of the electromotive forces.
Exp 4. Measure their sums.

Platinum, Mercury, Platinum, Analogue of zinc gave 147.90 hours of light between 15th & 16th.
Copper, Electrode of copper, Analogue of zinc — 60 hours.
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Notes on ‘Electro-motive forces of the metals as measured by volta’ on reverse of envelope from the social reformer Edwin Chadwick (1800-1890), [1834-1843], page 1.
Notes on 'Electro-motive forces of the metals as measured by volta' on reverse of envelope from the social reformer Edwin Chadwick (1800-1890), [1834-1843], page 2.
Notes and sketch diagrams describing how to make a mercury battery, written on the back of an envelope, [1834-1843], page 1.
Notes and sketch diagrams describing how to make a mercury battery, written on the back of an envelope, [1834-1843], page 2.
Notes and sketch diagrams on an experiment using a twelve cell battery, 1841 Sep 3.
The resistance of a conductor of any form, provided its section be regular or irregular, is inversely as the weight, when the length and material of which it is composed remains the same; or \( R = \frac{1}{W} \). Therefore the resistance of any shaped conductor is equivalent to the resistance of a cylinder of the same weight. This rule may be useful in determining the conductivities of liquids without deducing the regularities of the forms of the tubes which contain them.
Faraday has proved these simple and remarkable laws that the same quantity of electricity is required to effect the decomposition of one atom (of the proper kind) of any substance. Now let us consider one case. If the quantity of electricity is doubled, it is the same as the destruction of half the compound, and it is in the same proportion because the other compound must be taken into consideration. If it is a necessary consequence of these two laws that the decomposition of any substance, much too on account of the conducting power, is no more properly in the resistance of the passage of electricity. The law which Faraday has now them from direct experiment, by which he found that the electricity was the best conductor.

It has been observed, particularly by [singed] in a recent paper of his, that those elements which are combined with the greatest energy, are also those which are most readily decomposed by the current, and that these elements which are combined in virtue of their affinities, are also those which the least obey the accompanying action of dynamic electricity; and that it hence appears that all compound bodies separate under the influence of a current, in proportion to the affinity which under the same conditions. Thus it is generally true if follows that the form of affinity and the substance is the passage of electricity combined with each other, or in other words that the force of affinity is increased as the conducting power.
Notes describing the law of electrolysis proposed in 1834 by Michael Faraday (1791-1867), natural philosopher, [1834-1843], page 2.
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Notes describing different electromotive forces, [1834-1843].
Notes describing a 'New Theory of Voltaic Decomposition', [1834-1843].
List of measurements of electromotive forces in different elements, [1834-1843].
Notes describing the 'Solubility of Metallic Salts', [1834-1843], page 1.
According to the experiments of Bunsen, 1 part of metallic lead

deposits at the temperature of 120° in 172 parts of nitric acid,

359 parts of nitric acid and 57 parts of water.

Not 50.0% deposits in 99.3 parts of 7 parts of nitric acid and 3 parts of water,

92 deposits in 99.3 parts of nitric acid.
Assuming that the quantity of electricity evolved is in exact proportion to the quantity of zinc depolarized, the augmentation of power by adding more energetically one of the gases by bringing the plate closer together, increasing the quantity of negative surface exposed to the fluid, can be effected not by producing additional power, but merely by increasing the rapidity of the decomposition, i.e., by producing the effect in less time.

It would be interesting to measure the time a certain quantity of zinc requires for its dissolution under different circumstances.

I have no doubt that the constancy of the electrical current produced will be found exactly in the inverse proportion to the duration of the action.

Experiments. The zinc to dissolve a gram of zinc in a 1:10 solution of sulphate of copper. Do, when an equal weight of copper is opposed, twice, then three times.
If a crah of copper is more engaging as grain in a bath of water, sulphuric acid and lead, it may be explained in the following way:

Sulphuric acid in a given time decomposes a grain of copper and in the same time with a grain of zinc, when lead and zinc are in presence of the solutions. The intensity of the reaction may be measured difference of the two effects. (This must be true, for if it were, increasing the quantity of copper would diminish the action.)
The experiments of Marianini, Rogers & Daniell, seem to prove that the force of a current is increased by heating the battery; and is this increase of effect owing to the increase of the electromotive power, or to the diminution of the resistance of the conducting liquid? The question, of course, of course, of course; in accordance with the law of Ohm, if it is then the electromotive power, which is earth, the force of the current is should be varied in the same proportion as the earth, if the effect is due to the diminution of the resistance, then the augmentations of the current should be left in proportion to the height of the conducting wire.

It also follows from the same law that the heating effect and the current of the current by wire increases. The current of the wire increases in the same proportion as the heating effect increases while the current of the wire remains the same, the height of the current wire increases in a higher proportion than the heating effect, and the difference between the force of the current and the heating power, acts the greater as the height of the wire increases.

It equally follows that increasing the number of plates, when the wire is very short, no difference of effect on the next wire be observed beyond that caused by one pair of plates; but a difference will become more and more as the length of the wire increases.

In fact, augmenting the temperature of the liquid produces precisely the same effect as increasing the size of the plates. It is easy therefore to see that because the magnetic effect may be augmented by the application of heat, we cannot expect to neutralize the chemical effects of a pole in any very eminent degree by this means; for the use of salt in any extreme climate is not to be increased as to the power of the current, with such an arrangement of plates.
Description of experiments by Stefano Giovanni Marianini (1790-1866), Italian physicist, William Barton Rogers (1804-1882), American physicist, and John Frederic Daniell (1790-1845), Professor of Chemistry at King's College London, proving that the force of a current is increased by heating the battery, written on the back of an envelope, [1838], page 1.
Experiments to be tried.
June 1840.

1. Ascertain the electromotive force of amalgams of potassium, 1st with sulphate of copper and copper,
   2nd with muriate of platinic and platinic.

2. Ascertain the electromotive force of iron, employing successively sulphate, acetate and nitrate of iron, with amalgams of zinc.

3. Increase the power acting on the neele by presenting a magnet to it. Observe the number of coils necessary to reduce 10 to 35°. Will they be proportional to the intensity?

4. Ascertain the electromotive force of copper, sulphate of copper and amalgam of zinc, at the temperatures of 0° and 212°.
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Notes on the variability of electromotive force, [1834-1843].
Phenomena of the Electrical Current

21. According to what has been proved in No. 12, the strength of the electrical current in a metallic body, for each point, being in general will be expressed by the following equation

\[ S = \omega \frac{dx}{dx} \]

where \( S \) is the strength of the current and \( \omega \) is the electrical power at the point of the circuit, the abscissa of which is \( x \), \( x \) representing the resistance of the metallic body, and \( \frac{dx}{dx} \) the connecting power at the same point. To express this condition, we have the same general equation as No. 109, for each circuit composed of a certain number of parts, we write it thus:

\[ S = x^2 \frac{dy}{dx} \]

we have for the values derived from the general equation \( \frac{A}{L} \)

and for the values \( \frac{A}{L} \) to be derived from the same number of parts, which values are good for every point passing between two existing points, then we very simply obtain

\[ S' = \frac{A}{L} \]

in which \( L \) signifies the whole circuit length of the circuit, and \( A \) the sum of all its divisions. By means of this equation is obtained the strength of the electrical current of a simple circuit composed of one or many parallel parts, which has always been permanent.

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Notes describing phenomena observed in electric currents, [1834-1843], page 1.
occurring cases are contained, on which account we have most

completely analyzed the result.

Because \( A \) represents the sum of all the tensions occurring in
the circuit, and \( L \) the sum of the reduced lengths of all the
single parts, the following general properties of the galvanic current
consuming the electrical current, are immediately deduced by the

same equation.

I. The electrical current is at all points of a galvanic
circuit of equal strength throughout, and independent of the values
of the constant \( c \), which, as we have seen, varies the strength of
the electric current at a deflected point. In the open

circuit the electric current entirely ceases, for in this case the reduced
length \( L \) of same is infinite, and it vanishes.

II. The strength of the current is in an electric circuit remains
unchanged, when the sum of all the tensions and the entire reduced
length of the current is altered, or in the same proportion as

the sum of the tensions, and the sum of the tension remains, and the sum of the tension remains. The same, when
the reduced length of the current decreases. From this general law we will

deduce the following particular.

III. A difference in the arrangement and distribution of the
crop existing points through a transporting of the parts of which
the sum \( c \) remains, has no influence on the strength of the current,

if only the sum of all the tensions remains the same. Thus, for

example, a current found according to the order of copper, zinc, silver,
lead, zinc, and a liquid will remain unchanged, if copper and

lead exchange their places with each other, because according to the laws

King's College London Archives

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Notes describing phenomena observed in electric currents, [1834-1843], page 2.
The strength of the galvanic current remains the same, when even a part of the circuit is removed from it and another prismatic conductor is placed at that point, only the parts have the same raised lengths and the sum of the distances must in both cases remain the same. Generally, if the current of an circuit is not changed by exchanging a part thereof for a prismatic conductor, and we can be assured that the sum of this distance has remained the same, the raised lengths of both must be in the exchange conductor.

If we represent to ourselves a galvanic current always of an equal number of parts, of the same materials and placed in the same order, so that the single lengths may be considered as invariable, the strength of the current of this circuit remains, while the lengths of its parts remain unchanged, in the same proportion in which the sections of all its parts increase in the same manner, and whilst the sections are made on the same proportion in which the length of the parts equally increase. When the length of the current is a part of the same conductor, and of the other part, the strength of the current depends principally on the dimensions of its single part, as the law has engaged with a mere new simple form, when when the previous consideration on the companions made the single part.

The proportion stated in II. 2 affords a convenient means to determine the conducting power of various bodies. Let us assume, for instance, two prismatic bodies of the length of each, which may be $l$ and $L$. The sections are $w$ and $W$ and the conducting powers $x$ and $X$, and that both bodies possess the property of not changing the current of a galvanic circuit, when it passes through a part $l$, and have both the same density of the circuit unit, there

$\frac{x}{l} = \frac{X}{L}$
Therefore

\[ x : x' = \frac{a}{a'} \]

The conducting power of both bodies was therefore in exact proportion to their lengths and unevenly as their areas. And the relation he used to determine the conducting powers of various bodies, and proportion of bodies of the same material be shown for the explanation, which is already agreed without this or with some accuracy, the longer is not nearly as one of their relative conducting powers.

25. We have in the preceding number defined the strength of the current from the general equation in No. 10.

\[ u = \frac{A}{L} = \theta + c \]

And found that it is expressed by the coefficient \( \frac{A}{L} \) belonging to it, to determine the value of the current, knowing all the other parts of the circuit and from opposite known to it, suppose that one general equation, the actus as means to show the value from the other, of any single part of the current, which we will do, suppose in this case it will make no good sense. Therefore, if we measure for instance in the above equation of currents by a given magnitude \( \Delta v \) ad instead by \( \Delta \theta \), the corresponding change of \( \theta \), and by \( \Delta u \) that of \( u \), it follows from this equation that

\[ \Delta x = \frac{A}{L} \Delta \theta - \Delta \theta \]

and hence we find

\[ \frac{A}{L} = \frac{\Delta x + \Delta \theta}{\Delta u} \]

If we find therefore the strength of the electric current, when we add to the difference of the electric arcs, of any two parts of the circuit the sum of all the electric lines between these points, and divide this sum by the length of any of the parts of the circuit which he between the same points.