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/PP107/2/3/1-172

[1871-1873]

Working notes and rough drafts of hypotheses, methodological narratives, experimental observations and tables of test results compiled by Charles Wheatstone under the general heading of ‘electro-motive forces’, relating to the utility of employing combinations of elements in battery electrodes, 1871-1873; correspondence between Charles Wheatstone and Richard William Mellingford Higgs, chemist, on the analysis of acid solutions in battery experiments, with Higgs’ experimental observations.
List of experiments on electromotive forces, [1871-1873], page 1.
6. Ascertain whether the electromotive force of a Goniometer element is equal to that of the contrary electromotive force in a cell.

9. Ascertain the electromotive force of a cell, when sulphuric acid, hydrochloric, hydrocyanic acid are employed.

10. Ascertain the contrary electromotive forces when chlorine, iodine, bromine are employed.

11. Compare the elements

Chalk of Potassium - Sulphuric Acid - Zinc
Ammonia - Hydrochloric Acid - Zinc

The first gives the difference, the 2 the sum of the two elementary currents.

12. Measure the electromotive forces between the following pairs of elements:

Sulphuric acid, Potassium
Sulphuric acid, Nitric acid


should give precisely the same as

Pot. Copper, Con.
Feb 6, 1872

In the following paper experiment with sulphuric acid and hydrate of potash, ascertain after action when the potassium plate is wiped whether the action has not dropped from the plate in contact with it, when there is no reflection of the metal.

Try similar experiments with other acids as nitric, hydrobromic, &c.

Ascertain the electromotive force of the following combinations with sulphate of potash.

\[ \text{S} + \text{Z} \quad \text{S} + \text{C} \quad \text{S} + \text{P} \quad \text{Z} + \text{Al} \]

\[ \text{Pb} + \text{Z} \quad \text{Pb} + \text{C} \quad \text{Pb} + \text{P} \quad \text{Z} + \text{Pb} \]

Magnesium may be employed instead of potassium.

Place four pieces of zinc in the same liquid with which sulphuric acid, and contain the amalgams in tubes in the four different vessels. Deduce potash from the amalgams for the electromotive force.

Ascertain the electromotive force of the following.

\[ \frac{\text{S}}{\text{Z}} \frac{\text{S}}{\text{P}} \frac{\text{Z}}{\text{P}} \]

\[ \frac{\text{S}}{\text{Z}} \frac{\text{S}}{\text{P}} \frac{\text{Z}}{\text{P}} \]

and another the electromotive force.
Notes on experiments using a 'double plate rotating apparatus', [1871-1873].
It has been supposed that a certain amount of electrolytic force is required to decompose water, and that different bodies require different amounts of electrolytic force to decompose them. This can be shown not to be the case by a very simple experiment. The decomposing of the two rotating platinum electrodes is charged with water and a little connective by a little sulphuric acid, and connected with the rotating apparatus already described, after the latter has been built within. A circuit is found consisting of the decomposing cells, a ball single volunteer element, and a galvanometer; the circuit is not to be completed until after the apparatus is not in action. It will then be seen that with this single cell carbon is ready by the current paper readily and deflect the galvanometer easily strongly. But if the rotation of the plates be stopped, the current goes where the plates, and a contrary electromotive force is thereby given to the opposite direction. The electromotive force of the water element and under the current will.

If the water element be replaced by a single chlorine pair the current sets there be soon be felt.
When the plates are stationary, immediately after the circuit is closed the water is decomposed because, the current may be, but the decomposition occurs as soon as the opposition electromotive force attains equilibrium.

The removal of a current acts upon a decomposable body without decomposing it, if it is not because the electrolyte force is insufficient strong, but in consequence of faraday's electromotive force being called if the salt to conduct the original exciting one.

A much weaker current was put through a solution of a metallic salt than those so calculated earlier, this is because the hydrogen gas is removed as soon as found in the act of reducing the metal.
1. Two platinum electrodes one from the other resting. Observe if the current is from the resting to the fixed plate. After the resting plate has been a long time in solution ascertain if there is any effect of platinum in the solution, or if any black powder has been thrown down.

2. Two platinum electrodes in the same cell. One compartment charged with concentrated, the other with dilute nitric acid. Assemble either the current is from the concentrated to the dilute acid, and mannate, etc.

3. Assemble whether cadmium and lead can be rendered parnixe.

4. The carbonate and sulhide of copper given with copper electrodes for one 1700 for (6°6%) in the platinum chloride no current. Repeat them with copper electrodes, one in the same manner with other solutions (the same).

5. Try an element Zn and Alumina and ascertain the E.D.T.

6. Write your name thereupon (as before) soon. Copper plate white. The bulk of the matter of your is not being attacked by sulphuric acid.

7. The E.D.T. of ammonium carbonate, and any other form of Cadmum.
Notes describing measuring electromotive forces using a 'double rotating apparatus' with different salts, on reverse a note from Richard William Mellingford Higgs, [1871-1873], page 1.
K/PP107/2/3/12
Notes describing measuring electromotive forces using a ‘double rotating apparatus’ with different salts, on reverse a note from Richard William Mellingford Higgs, [1871-1873], page 2.
The Papers of Charles Wheatstone
K/PP107/2/3 - Papers relating to the development of the electric telegraph

K/PP107/2/3/13
List of 'electroscopic experiments', [1871-1873].

22nd July 1871

Electroscopic Experiments.

1st. Simulate each element. Connect one pole to the earth and apply the electrometer to the other pole. Repeat each experiment reversing the poles.

2nd. Let each pole remain unconnected with the earth. Apply the electrometer symmetrically to each pole.

3rd. Divide an element by removing one of the electrodes. Apply the electrometer symmetrically to the positive and negative electrode.

4th. Measure the electrometric force of metals only in contact.
K/PP107/2/3/15
List of experiments with pencil annotations in another hand, [1871-1873] Apr 2.

King’s College London Archives
Notes and rough diagram describing the use of a rheostat, [1871-1873], page 1.
Notes and rough diagram describing the use of a rheostat, [1871-1873], page 2.
Feb 27. 1872.

Experiments for tomorrow please.

Left early today.
R. Higgs

Try the films of Sulphuric, Selenic, and Bromide of Iron, also Gold on Platinum plates.
Notes and rough diagrams on experiments to measure electromotive forces, [1871-1873], page 1.


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List of 'compound substances in the liquid state by the pile, according to Faraday', includes rough diagrams, [1871-1873], page 1.
List of 'compound substances in the liquid state by the pile, according to Faraday', includes rough diagrams, [1871-1873], page 2.
June 19, 1871

1. Measure the electro motive force of a $0.5 \text{ mol} \text{ CuSO}_4 + 2 \text{ mol} \text{ H}_2 \text{SO}_4$ cell from 15° to 60°.
2. Substitute a platinum for a copper plate in the preceding experiment.
3. Try the electrolysis with different weight proportions of $\text{Zn} (\text{Cup was used})$ for the other plate and ascertain the changes in any of the electro motive force.
4. Heat the cell with a spirit lamp and ascertain if there is any change in the electro motive force.
5. Measure the electro motive force of a cell and of $0.5 \text{ mol} \text{ ZnSO}_4 + \text{CuSO}_4$.
6. Perform two standard cells $(\text{Alum + CuSO}_4)$ $(\text{Zn  + CuSO}_4)$ and measure their 1° with the same galvanometer between different degrees. 2° with different galvanometers between the same degrees. The note shows that the strength of the current does not affect the proportionality of the electro motive forces.
List of experiments to try and measurements to take, 1871 Jun 19, page 2.
List of observations related to electromotive forces, [1871-1873].
Calculations relating to various elements and a list including 'Faraday's Lecture printed,' 'office description of instruments,' and witnesses including Nathaniel John Holmes, [1824]-1888, electrical engineer, Warren de la Rue (1815-1889), chemist and astronomer, Edward Frankland (1825-1899), chemist, [1871-1873].
List of elements and associated figures [1871-1873].

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K/PP107/2/33
List of elements and associated figures [1871-1873].

King’s College London Archives
Conversion of Electricity into Heat

1st Experiment. A pair of metal plates.

These were insulated from each other, and connected respectively with the two contacts of a large charged or uncharged condenser, so as alternately touch the plates. The plates first received a charge from an uncharged condenser, by the charge from C, and the current operator may have one perfectly grounded hot metal, held by a delicate thermometer near to the plates.

2nd Experiment. To produce heat. The plate to be placed between the other plates A and B. A is charged positively and induces negative electricity on the opposite face of C, the positive electricity is then transferred to B, which is then charged negatively and induces positive electricity on the opposite face of C, which is also charged positive. The positive being insulated, many times the electricity being removed, set in in others. Instead of two insulated plates A, B, a single plate may be employed alternately charged with positive and negative electricity.

The electricity by containing less than their expansion forces.
Table showing various amalgams and chemical compounds together with related number of turns of the rheostat, [1871-1873].

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<th>Amalgam of Zinc</th>
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Table of chemical elements and their positivity when combined with other elements including sodium, potassium, and zinc, [1871-1873].
July 7th 1871.

My dear Sir,

You will find I have arranged the chemicals sent from Griffins. Anything further to-day they you will pardon: I found myself, by a letter this morning, involved in a legal affair relating to some money of my wife’s that requires immediate attention.

To-morrow, or this afternoon, I will remain later, should you desire it. Very this afternoon with the promise that I am able to return in time.

Yours truly,

Wm. Mellingford Higgs.
Mr. Becker tested the Thomson electric hygrometer before me and it worked admirably. He tells me that the wire of the galvanometer should not have more than half a B. A. unit resistance; those of hays are at least 14 to 15 units resistance. Mr. Becker will send the hygrometer.

The mercury was 3½ a pound. 5½ lbs. was all that could be opened and. 6 lbs. was charged for the bottle.

I will keep Griffins bill until to-morrow. They wished to send
at 8 o'clock this evening, I held them to send at 10 tomorrow morning.

Corry will send the last edition of Mr. Culley's book this evening.

K/PP107/2/3/51
Note possibly from Richard William Mellingford Higgs to Wheatstone including references to a Mr Becker testing a thermoelectric hygrometer, a bill from Griffins, the instrument makers, and a book by Richard Spelman Culley ([1819]-1901), telegraph engineer, [1871-1873], page 2.
Note by Richard William Mellingford Higgs outlining work completed that day on titanium and on tungsten to do the following day, [1871-1873] Feb 20.
K/PP107/2/3/55
Ink stained and possibly acid burnt sheet of notes, probably by John Rymer Jones (1851-[1919]), chemist and electrical engineer, [1871-1873], page 1.
Ink stained and possibly acid burnt sheet of notes, probably by John Rymer Jones (1851-[1919]), chemist and electrical engineer, [1871-1873], page 2.
Rough notes on zins by probably by John Rymer Jones (1851-[1919]), chemist and electrical engineer, page 1.
K/PP107/2/3/56
Rough notes on zincs by probably by John Rymer Jones (1851-[1919]), chemist and electrical engineer, page 2.
Copper Electrodes: February 29th

Decomposition of Sulphate of Copper. Modified Second method (see yesterday's experiment).

With copper electrodes the needle remains constantly deflected, and does not return to zero. (i.e. employed, no resistance in circuit).

The needle brought to zero by introducing the prime with one cell, 150 units, into circuit; 0.48 resistance in copper wire (as small as possible).

With a constant deflection (as before) successive dilutions of the sulphate of copper reduce the value of the deflection, but the a slight current continues to pass with only a trace of sulphate in water, the deflection...
The Papers of Charles Wheatstone
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The necessary precautions to be observed are, to approximate a constant cell, composed of zinc amalgam, copper, and sulphate of copper.

The Rheostat.

Before commencing experiments, the spring, attached to the binding screw & pressing against the axis of the cylinder of the Rheostat, should be thoroughly cleaned from all dirt, which causes the galvanometer needle to be oscillated in its movements.

Zinc amalgam.

The insolation of a cell was invariably found & to be insolate the porous pot & on investigation, the following were some of the defects to be eliminated.

The quantity of zinc in the amalgam does materially affect the electromotive force. If nothing is required, the amalgam must be concentrated & always have in it a piece of zinc to keep the mercury at the same point of saturation. Then really isolated the smallest quantity of amalgam in the porous cell will give as high an electromotive force as when full.

The most necessary precaution is to see that the amalgam is quite free from dirt, black deposit & (which accumulates either from the dirt & impurities in the zinc dissolved) which finely thickly forms on the sides of the porous pots during action & adheres to the zinc & greatly decreases the electromotive force.

Pure Mercury.

When replacing a zinc amalgam & copper cell against a pure mercury & copper cell, it is necessary to ascertain whether the mercury is positive or negative to the copper.
Paper outlining precautions to be observed with regard to the rheostat, zinc amalgams, porous pot and sulphate of copper by John Rymer Jones (1851-[1919]), chemist and electrical engineer at the India Rubber Gutta Percha and Telegraph Works (son of Professor Thomas Rymer Jones, King's College London), 1872 Dec 19, page 2.
List of meetings or appointments from Monday June 16 to Saturday June 28 1873.
The necessary precaution to be observed in order to approximate a constant cell composed of

Sulphate of Copper, in Sulphate of Copper, the Sulphate of Copper is attached to the binding screws pressing against the axis of the cylinder. When so attached, before coming of permanents, be thoroughly cleaned from oil or dirt which causes the inside to be constantly in movement. The Sulphate of Copper should be concentrated, otherwise the Copper plate will soon become porous.

The thickness of the porous pot does allow any slightest the electrical force, provided the porous pots are well saturated with clean water.

true amalgame, the means taying a cell
The amount of zinc in the amalgam does materially affect the electric force. If continuity is required, the amalgam nearly always having a free high to keep the necessary electric saturation. When saturated, the amalgam must be kept wet. The very necessary precaution is to see that the zinc amalgam is free from dirt. When the zinc amalgam is free from dirt, black deposit will form on the sides of the porous cell during its action, greatly increasing the electromotive force.

When0 containing zinc amalgam, it is necessary to ascertain whether the mercury is to be withdrawn, when the solution is taken up.
Draft of paper on precautions to be observed written by John Rymer Jones (1851-1919), electrical engineer at the India Rubber Gutta Percha and Telegraph Works (son of Professor Thomas Rymer Jones (1810-1880) at King's College London), [1872], page 3. See also K/PP107/2/3/58.
The electric current acts on the
outlines immediately decomposed by the
electric current. All the decompositions are
secondary, and are due to the ordinary chemical
actions of the united oxygen and hydrogen.
This in an element containing from the oxygen
and copper.

the same and vowels it into an oxide, the hydrogen
reverses the copper by combining with the oxygen of the
vapour of copper and forming water, and the substance
of the salt of copper combines with the zinc and forms
insoluble of zinc. Thus the hydrogen is consumed
in the solution of the copper as it remains on
the copper plate and consequently no precipitation
taken place; there is the same when the salt is
reduced in the perfect regular form.

The same also place when any other metals salt
are reduced.

That the united hydrogen is necessary for the
reactor of the metals, and that the nature
salt is not immediately decomposed by the
copper, can be proved by a very simple
experiment. If I immerse a cell of copper
or any other metallic salt immersed in a
 Cros is formed from the
metal, and the other with

K/PP107/2/3/87
Notes describing the decomposition of water, [1871-1873], page 1.
a solution of sulphate of copper; an insulating cork plate is fixed against the side of the case, and opposite to the sulphate. A circular platinum plate, which dips into the sulphate of copper, and by means of a setting place on the same axis connects it with a rotary apparatus. The plate may be put into rapid circular motion, while in motion it passes between the two plates of a conductor, which passes against the sides and feeds it of any substance gave on others above them. The apparatus having first set in rapid motion the circuit then completed by the plate is decomposed. The plates hydrogen may be obtained and water remain; the plate may be reduced, the copper; the plate may be thoroughly reduced, and no copper will be found on the water. Whereby the action may be continued as copper with oxygen, kept of the platinous plate, be allowed to rest, a new or twice, all the portion of it passes over the sulphate will be covered with the reduced copper.

Instead of the platinous plate being, when negative electrode of a voltaic circuit, or in the preceding experiments, it may be the electrode of a decomposing cell, the plate in an current until the solution be reduced. So this case, the same case as before may be employed, but both compartments are to be filled by the solution of
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K/PP107/2/3/88
Table of elements and their atomic weights, [1871-1873].
List of German terms relating to electricity and magnetism, [1871-1873], page 1.
List of German terms relating to electricity and magnetism, [1871-1873], page 1.
Table of chemical elements and figures relating to their amalgamation with sodium, potassium, zinc, copper, platinum and lead, [1871-1873], page 1.
Table of chemical elements and figures relating to their amalgamation with sodium, potassium, zinc, copper, platinum and lead, [1871-1873], page 2.
Table of chemical elements and figures relating to their amalgamation with sodium, potassium, zinc, copper, platinum and lead, [1871-1873], page 3.
Table of chemical elements and figures relating to their amalgamation with sodium, potassium, zinc, copper, platinum and lead, [1871-1873], page 4.
### Table of chemical elements and figures relating to their amalgamation with sodium, potassium, zinc, copper, platinum and lead, [1871-1873], page 5.

<table>
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<tr>
<th>Element</th>
<th>Sodium</th>
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Table of chemical elements and figures relating to their amalgamation with sodium, potassium, zinc, copper, platinum and lead, [1871-1873], page 6.
April 21, 1872

Two Mercury placed in a porous pot which had been for some time kept in common water, was made into a circuit with white sulphuric acid and copper. The cell was cooled only a few degrees, the mercury being in general negative. But when a porous pot filled with mercury was tied by paper, it went to the yin, or when cold mercury was placed in a dry porous pot, and then put in the circuit, the cathode became strong; and the E.M.F. was 39 (S. 1.77) the cathode being positive, the E.M.F. towards zinc and mercury was 158.

The zinc seems where to be affected, the E.M.F. with the cell zinc and copper was 100 when a dry porous pot was employed, 129 when a wet pot was employed.

It seems that the dry porous wets the amalgam more negative, it the same instance the cathode is so slanted, that it is positive and in the wet E.M.F. that with the dry or that with the wet porous pots.
Circumstances that may influence the accuracy of the measure.

1. If the resistance of the circuit changes while the measure is being taken, the measure will be inaccurate. The resistance should remain at the same level before and after the measure is taken.

2. Imperfect contacts in the opening of the circuit and in other parts of the circuit will influence the resistance of the circuit, and if these contacts should be variable, it will cause the measure to vary. When the measure is being taken, the contacts will be constant.

3. If the magnetic field of the room should be subject to changes, a measure made at one time will not agree with a measure made at another time. It is necessary to compare every new measure with a measure made with the standard element.
Letter from Richard William Mellingford Higgs largely regarding John Rymer Jones (1851-[1919]), chemist and later electrical engineer at the India Rubber Gutta Percha and Telegraph Works (son of Thomas Rymer Jones (1810-1880), Professor at King's College London), 1872 Jul 8.

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King's College London Archives
Letter from Richard William Mellingford Higgs relating to the results of analysis of acid solutions, 1872 Jul 5, page 1.

K/PP107/2/3/130

July 5th, 1872.

Sir Charles Wheatstone, F.R.S.

My dear Sir,

Analysis of the acid solution obtained in the purification of the mercury gives the following results:

Found:
- Copper (in small quantity).
- Mercury (do.).
- Iron (in small quantity).
- Lead
- Zinc,

Cadmium (traces only).
- Cobalt
- Nickel.
Not found:
Bismuth, Chromium, Platinum,
Palladium, nor any of the Alkali-
metals.

Remarks:
The spectrum is very complex,
and successive elimination is
too difficult to give satisfactory
spectra. The appearance of copper
is questionable.

From the excess of copper
(from the negative plate) there
may be a reflex action (since
copper is electric positive to mercury)
resulting in the formation of a very
dilute copper amalgam, instead
of pure mercury. Ordinary tests
for copper do not, however, show
this. But perhaps it would be
better to repurify the mercury
employing instead of copper a
platinum plate in the sulphuric
acid.

I am,

My dear Sir,

Truly and obediently,

Yours,

R. William Higgs

To S. Charles Wheatstone, F.R.S.
5, Cornwall Road.
Hammersmith, W.,
July 3rd, 1872.

Sir Charles Wheatstone, T. E.S.,

My dear Sir,

After leaving you this morning I saw Mr. Jones. He is I find a very good Chemist. Permit me to suggest that if he were with me on Thursday for portions of the day I might instruct him in several of your processes. I am preparing a series of instructions for your future assistant, but of course there are many practical points that it is very difficult to express in so many words. I shall however be pleased at any time to call upon you and state my
Lord Gladstone to Mr. Gladstone
June 1872

Dear Mr. Gladstone,

I am pleased to hear from you. I hope you are well. I have been working on a new project and I believe it will be successful. I am looking forward to hearing from you soon.

Sincerely,

William Higgs

2nd July 1872

Sir, Charles Wheatstone

K/PP107/2/3/131
Letter from Richard William Mellingford Higgs regarding John Rymer Jones (1851-[1919]), chemist and later electrical engineer at India Rubber and Gutta Percha and Telegraph Works (son of Professor Thomas Rymer Jones, King's College London), 1872 Jul 3, page 2.

King's College London Archives
1. An electro-motive exists at the contact of any two metals.

2. This electromotive force differs with the temperature.

3. In a circuit formed of two metals that at the same temperature, the contact must be an opposite direction at the alternate joints, and as they are made they must continue each other.

4. But if the alternate joints are kept at two different temperatures, then of the electro-motive force on one direction, and no longer be equal to the sum of the electro-motive force on the opposite direction, and a current the difference of these is equal to resultant current.

5. If three or more metals are in series at two temperatures equal before mouth, it is not necessary to admit that the electro-motive force of the distinct metals is equal to the sum of all the intermediate couples, but the same augmentation of temperature produces a proportional augmentation of the electro-motive force.
Consequences of the 1st hypothesis:

1. The state of the electric motion from according to other, or the view of the electric current, which is corresponds with the thermoelectric current. But this is not the case.

2. The same measures of temperature should produce a greater amount of effect, as the electric motion from due to contact or gradient, and absolute for wants should produce a more powerful current than Whistler's & Britain's, but the contrary is the case.

3. The hypothesis of proportion to one set of joints, which always assumes the thermal current, but Whistler and Remanent have shown that in certain events, the current at first appears, and these currents may be given.
On the relation between Chemical affinity and Electromotive force.

General remarks on chemical affinity.

General remarks on electromotive force.

Summation of chemical affinity according to Volta and Maranini.

General remarks on the relation between chemical affinity and electromotive force before their theory is spurious before and after their theory is spurious.

Distinct views of electromotive force and notion of measuring it.

Note: applicable only to the measure of the complex forces in various chemical arrangements.

In my paper in the *Phil. Trans.*
A very important question to be determined is whether a certain amount of electromotive force is required to overcome the affinity of each electrolyte, as Faraday and others have supposed, or whether the reaction be decomposition simply from the ordinary electric motive force generated by the action of the current. The following experiment will prove that when the galvanism, the want of decomposition, indicates a reaction, the liquid conduct as an ordinary conductor and that the decomposition which the current effects occurs in exact proportion to the strength of the current.

When a dissimilarity has been established for a whole twelve on a circuit, there is no development of gases and only a very slight galvanism. The employment of a very substantial galvanism is employed. Then in an absence of current it is attended to immediately after the completion of the circuit. Then no gas produced and that the galvanism shows a considerable amount of current for a moment when the development of gases occurs.

Employing the decomposing cell will by rotatory electricity by which the gauge are rendered as soon as formed, polarization is produced, and the current of a single cell then passes readily through the circuit, and currents measured under their conf may be made put through...
Notes relating to 'whether a certain definitive amount of electromotive force required to overcome the affinity of each electrolyte as Faraday and others have supposed ...' [1871-1873], page 2.