	Age.	Weight.	Occupation.	Efficiency.	No. of Experiments.
		kilos.			
W. M.	69	57·9	Laboratory work	0·191	7
R. B. F.	28	53·0	" "	0·176	19
E. R.........	29	80·4	" "	0·174	17
E. F.........	16	..	" "	0·181	16
M. (woman)..	47	..	Charwoman	0·193	7
			Mean	0·183	66

Therefore the maximum mean efficiency was 0·193 in the case of the woman from seven experiments, and the minimum mean efficiency was 0·174 for E. R. from seventeen experiments; the general mean from five different persons was 0·183.

The general results obtained from this inquiry can be summarised as follows :—

(1) There is no fixed relation per individual experiment between the oxygen absorbed under excercise and the corresponding heat emitted, although the mean for each person somewhat approximates a constant figure which is 1 to 3·246. Considering that in the state of rest we found the corresponding ratio to be 1 to 4·000, it may be concluded that the oxygen is better utilised for the production of heat in a state of rest than under exercise.

(2) There is a marked excess of heat over normal given out under exercise, this excess (+ theoretical heat) produced in doing a definite amount of work (say 1000 kilogram-metres) varies for each of the five persons under experiment.

(3) The efficiency, or economic coefficient, for the five persons under experiment varied from 0·193 to 0·174 with a mean of 0·183; or 18·3 per cent. of the excess heat produced + the theoretical heat corresponding to the work done. This is a little less than a fifth.

"Some Experiments bearing on the Theory of Voltaic Action."

By J. Brown. Communicated by Professor Everett, F.R.S.
Received February 4,—Read February 23, 1899.

In former papers on the "Theory of Voltaic Action,"* I have adduced evidence in support of the view that the difference of electric potential observed near the surface of two metals in contact is caused, or at all events mainly influenced, by the chemical activity of films

* 'Phil. Mag.,' vol. 6 (1878), p. 142; *ibid.*, vol. 7 (1879), p. 109; 'Roy. Soc. Proc.,' vol. 41 (1886), p. 294.

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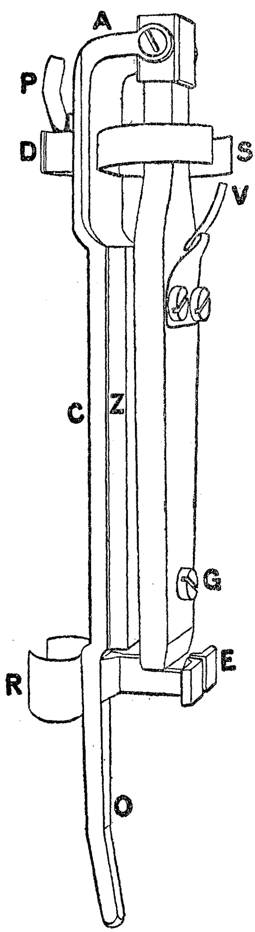
condensed on their surfaces from the atmosphere (vapour or gas) in which the metals are immersed. From this view it would naturally follow that, if all chemically active films and all atmosphere competent to produce them could be removed, the difference of potential would disappear also. This inference has been pointed out and acted upon by previous experimenters, as is well known; but it appeared to me that no certain test of the theory could be obtained in the way they suggested without elaborate precautions as regards details; and the experiments here to be described were undertaken in the hope that more definite results might follow greater care in the work.

The method adopted was to enclose a copper-zinc volta condenser in a glass tube containing nitrogen at a small pressure, together with metallic potassium and sodium, the expectation being that these metals would absorb any remaining water vapour or other agents (compounds of oxygen, &c.) that could exert chemical action on the zinc.



The condenser is represented in the figure. Its plates are 101 mm. long by 47 mm. wide. The copper plate C has prolongations at both ends, to which are attached the fittings D E, and the springs R S, for the support of the whole system in its glass tube. To the prolongation A of the copper plate is hinged, on pointed screws, a brass sleeve, into which is cemented the glass plate G, as an insulating support for the zinc Z. The free end of the glass plate hangs in a notch in the fitting E, and can move to the extent of the width of this notch, so as to separate the plates when the condenser with its tube is tilted over till the zinc falls away from the copper. Two curved springs of strip steel are placed between the glass and the zinc, to keep them apart; while they are held together by three screws, passing through the glass, and about half way through the zinc. These screws also serve to keep the copper and zinc, when in their position of nearest approach, at the uniform distance of about 0·03 mm.

The surfaces of the places were made true by careful filing, scraping, and testing by a surface plate. Platinum-tipped contact springs, P V, are provided to make connection with platinum wires sealed into the containing tube, which is of lead glass,

53 mm. diameter, and about 30 cm. long, with a leading tube attached on one side. The measurement of the difference of potential was made by a well-known zero method. The deflection given by a quadrant electrometer, on separating the condenser plates, was annulled by connecting the plates to points in a circuit of variable high resistance, containing a large gravity Daniell cell; the electromotive force required thus to annul being taken as equal and opposite to the difference of electrostatic potential at the plates. Three similar sets of measurements were made with this apparatus, continuing after it had been sealed up respectively six months, one and a half years, and seven and a half years. In the intervals between observations the plates remained out of metallic contact, and were kept, in Experiment I at their greatest distance apart; in III generally at their least. My notes of Experiment II are not clear on this point.

Experiment I, started December 12, 1888.—The plates having been cleaned with fine glass paper, the condenser was slipped into its tube. A small porcelain cup of phosphorus pentoxide was introduced, in order to dry out the interior, and the tube was then temporarily closed. The difference of potential was then found to be

0·74 volt.

The end of the main tube was then sealed at the blowpipe. The tube was exhausted through the side tube by a Sprengel pump, then filled with nitrogen, again exhausted, and then refilled with nitrogen. The condenser plates were now found to be in metallic contact, presumably due to the accidental sucking in of some minute globule of mercury from the pump. In three days this contact ceased. About 3 grams of potassium and 1 gram of sodium, in small pieces, were now inserted by the side tube. (My notes do not state that the capsule of phosphorus pentoxide was removed before closing the tube, but probably it was.) The tube was again, December 17, exhausted to 3 mm., and refilled with nitrogen, when the difference of potential was found to be about

0·64 volt.

The tube was finally exhausted to 4·5 mm., and the side tube was sealed off, the difference of potential being

0·61 volt.

The following observations were then made at the intervals noted in days after thus starting the experiment :—

Days...	13	25	27	30	61	106	173	181
Volt ...	0·56	0·52	0·55	0·51	0·47	0·34	0·32	0·33

It remained to ascertain whether the fall in potential-difference was due to the gradual absorption of chemically active matters by the potassium and sodium, or to the well-known effect of gradual tarnishing of the zinc surface. If, on admitting air and moisture to the tube, the potential-difference increased, the former alternative would be indicated, and the absence of such increase would indicate the other alternative.

Before testing this point, it was thought desirable to ascertain whether the pressure originally in the tube had changed. To measure the pressure, the sealed end of the leading tube was joined by a rubber tube and mercury seal to the Sprengel pump, which was worked till the pump gauge showed a pressure of about 2 mm. The end of the leading tube was then broken off in the inside of this rubber tube, a notch having previously been filed to facilitate breaking. The pump gauge then fell, and ultimately stood at 90 mm. pressure, showing that a considerable amount of gas had been evolved in the tube during its six months' trial.

The leading tube was now removed from the pump, and air admitted; air was also blown in by the mouth, to introduce moisture. The difference of potential at once rose to

0·39 volt, and later to 0·48 volt.

On taking out and examining the condenser, the zinc was found to be tarnished at the edges, but not much in the middle of its surface; the sodium was scarcely altered, but the potassium had a thick coat of, no doubt, oxide or hydrate, covering a core which burned on water.

Experiment II, started December 9, 1889.—This was intended to be practically a repetition of Experiment I. In closing the end of the main tube, a considerable amount of fumes and moisture from the gas blowpipe was observed to get into it, which may have affected the condition of the zinc surface. The moisture was removed by warming the tube and washing out with air. 8 grams of potassium were inserted, but no sodium. The nitrogen pressure before sealing off was 5 mm. After sealing off, the difference of potential was found to be

0·70 volt,

and fell thereafter more or less regularly for a year and a half, when, on June 9, 1891, it had diminished to

0·52 volt.

On opening the tube this value did not sensibly change. The fall in difference of potential was therefore probably due to tarnishing of the zinc merely. The potassium in the tube was very little altered.

Experiment III, started June 15, 1891.—The arrangement was the

same as in Experiment I, except that, after the tube had been exhausted and finally sealed off, the 9 grams of potassium and 3 grams of sodium which had been introduced, were fused together, forming the alloy that is liquid at ordinary temperatures. The difference of potential was at first about

0·75 volt.

During the first year, the whole tube (except when being examined) was kept immersed in a bath of petroleum, to prevent leakage of air, in case of minute imperfections at the sealed-in wires or elsewhere. The difference of potential on July 22, 1892, was about

0·67 volt.

The tube, no longer kept in petroleum, was examined occasionally for the next six and a half years, till November 4, 1898, when it was opened. The pressure had risen to about 59 mm. of mercury. The difference of potential just before opening was about

0·49 volt;

and after opening and blowing in there was little appreciable change in this value. If anything, it seemed rather lower; though the rapid tarnishing of the potassium-sodium alloy, when a new surface of it was exposed, indicated the presence of an ample amount of oxidising medium. The decrease of potential difference, in this case also, was therefore probably due to tarnishing of the zinc surface. The zinc was almost as bright as when enclosed seven and a half years before; but polishing a small portion of its surface with glass paper showed that a slight film had formed.

Of the three experiments, the first is the only one that lends any support to the hypothesis they were designed to illustrate. The laboratory notes show no difference between the first experiment and the other two, beyond what may be gathered from the foregoing account. It seems unlikely that the three days of accidental metallic contact in the first experiment or the distance apart of the plates in intervals between observations can have affected the result; and I am unable to suggest any other explanation except the possibility that the phosphorus pentoxide was left in the tube as well as the potassium and sodium. I found on a previous occasion,* that when this substance was enclosed with a copper-zinc pair, so as to dry the air surrounding the pair, the difference of potential fell in 134 days by one-sixth of its first value, and rose to its original amount immediately on admission of the ordinary atmosphere. In No. III certainly no phosphorus pentoxide was enclosed, and there is no mention of it in my notes of No. II.

* 'Roy. Soc. Proc.,' vol. 41 (1886), p. 305.

Though the experiments cannot be quoted as confirming the chemical hypothesis, which I still think to be supported by an overwhelming weight of evidence, it has been thought worth while to describe them, if only to show the extreme difficulty of eliminating the last traces of active matter from the gas employed. That this is the real difficulty in the way of obtaining positive results is well illustrated by the ingenious experiments of C. Christiansen.* He found, among other things, that when the metal (of a pair) near which positive potential is usually observed is exposed, for a minute fraction of a second, to an inactive gas, such as hydrogen, the observed potential difference is very much smaller than when the exposure lasts for a considerable time. The metal exposed by Christiansen was a jet of liquid amalgam, flowing from a drawn out glass tube. Its surface was thus perfectly clean, and the time of exposure to the surrounding gas was merely the interval between the instant at which the amalgam left the nozzle and that at which it broke into drops. The difference of potential observed, when carbon was opposed to a jet of zinc amalgam in hydrogen in this manner, was only 0·15 volt; while in air it was 0·89 volt. If more time had been allowed, the impurities in the hydrogen would have diffused in larger quantity towards the zinc, and given a larger effect, similar in character to that observed in my experiments, where the metals are exposed to the gas for a period amply sufficient for all such action.

"Deposition of Barium Sulphate as a Cementing Material of Sandstone."

By Frank Clowes, D.Sc., Emeritus Professor, University College, Nottingham. Communicated by Professor H. E. Armstrong, F.R.S. Received February 7,—Read February 23, 1899.

Some years ago I described the occurrence of a peculiar sandstone over a large area in Bramcote and Stapleford, near Nottingham.† The sandstone was remarkable for its high specific gravity, and chemical analysis, supported by microscopical examination, proved that the high specific gravity was due to the existence in the sandstone of a large proportion of highly crystalline barium sulphate. In the rock itself the percentage of the sulphate varied from 33·3 to 50·1: and it evidently served as the binding or cementing material which held the sand grains together. The occurrence of this sandstone was stated by geologists to be unique in the United Kingdom.

Mr. J. J. H. Teall made an examination of a portion of the sandstone, and stated that after breaking up a portion of the rock, he easily

* 'Wied. Ann.,' vol. 56 (1895), p. 644.

† 'Roy. Soc. Proc.,' vol. 46, p. 363.