XX. *Experimental Researches in Electricity.—Fourth Series.* *By* MICHAEL FARADAY, *D.C.L. F.R.S. M.R.I. &c. &c. &c., Fullerian Prof. Chem. Royal Institution, Corr. Mem. Royal Acad. of Sciences, Paris, Petersburgh, Florence, Copenhagen, Berlin, &c. &c.*

Received April 24,—Read May 23, 1833.

§ 9. *On a new Law of Electric Conduction.* § 10. *On Conducting Power generally.*

§ 9. *On a new Law of Electric Conduction.*

380. IT was during the progress of investigations relating to electro-chemical decomposition, which I still have to submit to the Royal Society, that I encountered effects due to a very general law of electric conduction not hitherto recognised; and though they prevented me from obtaining the condition I sought for, they afforded abundant compensation for the momentary disappointment, by the new and important interest which they gave to an extensive part of electrical science.

381. I was working with ice, and the solids resulting from the freezing of solutions, arranged either as barriers across a substance to be decomposed, or as the actual poles of a voltaic battery, that I might trace and catch certain elements in their transit, when I was suddenly stopped in my progress by finding that ice was a non-conductor of electricity; and that as soon as a thin film of it was interposed, in the circuit of a very powerful voltaic battery, the transmission of electricity was prevented, and all decomposition ceased.

382. At first the experiments were made with ordinary ice, during the cold freezing weather of the latter end of January (1833); but the results were fallacious, from the imperfection of the arrangements, and the following more unexceptionable form of experiment was adopted.

383. Tin vessels were formed, open at one extremity, five inches deep, one

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inch and a quarter wide in one direction, and of different widths, from three eighths to five eighths of an inch, in the other. Into these were fixed by corks, plates of platina, so that the latter should not touch the tin cases; and copper wires having previously been soldered to the plates, these were easily connected, when required, with a voltaic pile. Then distilled water, previously boiled for three hours, was poured into the vessels, and frozen by a mixture of salt and snow, so that pure transparent solid ice intervened between the platina and tin; and finally these metals were connected with the opposite extremities of the voltaic apparatus, a galvanometer being at the same time included in the circuit.

384. In the first experiment, the platina pole was three inches and a half long, and seven eighths of an inch wide; it was wholly immersed in the water or ice, and as the vessel was four eighths of an inch in width, the average thickness of the intervening ice was only a quarter of an inch, and the surface of contact with it at both poles equal to nearly fourteen square inches. After the water was frozen, the vessel was still retained in the frigorific mixture, whilst contact between the tin and platina respectively was made with the extremities of a well charged voltaic battery, consisting of twenty pairs of four-inch plates, each with double coppers. Not the slightest deflection of the galvanometer needle occurred.

385. On taking the frozen arrangement out of the cold mixture, and applying warmth to the bottom of the tin case, so as to melt part of the ice, the connexion with the battery being retained, the needle did not at first move; and it was only when the thawing process had extended so far as to liquefy part of the ice touching the platina pole, that conduction took place; but then it occurred effectually, and the galvanometer needle was permanently deflected nearly 70°.

386. In another experiment, a platina spatula, five inches in length and seven eighths of an inch in width, had four inches fixed in the ice, and the latter was only three sixteenths of an inch thick between one metal and the other; yet this arrangement insulated as perfectly as the former.

387. Upon pouring a little water in at the top of this vessel on the ice, still the arrangement did not conduct; yet fluid water was evidently there. This effect was found to be dependent on the cold metals having frozen the

water where they touched it, and thus insulating the fluid part; and it well illustrates the nonconducting power of ice, by showing how thin a film could prevent the transmission of the battery current. Upon thawing parts of this thin film, where it touched *both* metals, conduction occurred.

388. Upon warming the tin and removing the piece of ice, it was found that from a cork having slipped, one of the edges of the platina had been all but in contact with the inner surface of the tin vessel; yet, notwithstanding the extreme thinness of the interfering ice in this place, no sensible portion of electricity had passed.

389. These experiments were repeated many times with the same results. At last a battery of fifteen troughs, or one hundred and fifty pairs of four-inch plates, powerfully charged, was used; yet even here no sensible quantity of electricity passed the thin barrier of ice.

390. It seemed at first as if occasional departures from these effects occurred; but they could always be traced to some interfering circumstances. The water should in every instance be well frozen; for though it is not necessary that the ice should reach from pole to pole, since a barrier of it about one pole would be quite sufficient to prevent conduction, yet, if part remain fluid, the mere necessary exposure of the apparatus to the air, or the approximation of the hands, is sufficient to produce, at the upper surface of the water and ice, a film of fluid extending from the platina to the tin; and then conduction occurs. Again, if corks are used to block the platina in its place, and these corks being immersed, are damp or wet within, it is needful that the cold be sufficiently well applied to freeze the water within them, or else when the surfaces of their contact with the tin become slightly warm by handling, that part will conduct, and the interior being ready to conduct also, the current will pass. The water should be pure, not only that unembarrassed results may be obtained, but also that, as the freezing proceeds, a minute portion of concentrated saline solution may not be formed, which remaining fluid, and being interposed in the ice, or passing into cracks from contraction, may exhibit conducting powers independent of the ice itself.

391. On one occasion I was surprised to find that after thawing much of the ice the conducting power had not been restored; but I found that a cork

which held the wire just where it joined the platina, dipped so far into the ice, that with the ice itself it protected the platina from contact with the melted part long after that contact was expected.

392. This insulation exhibited by ice is not effective with electricity of exalted intensity. On touching a diverged gold-leaf electrometer with a wire connected with the platina, whilst the tin case was touched by the hand or another wire, the electrometer was instantly discharged (419.).

393. But though electricity of an intensity so low that it cannot diverge the electrometer, can still pass (though in very limited quantities (419.),) through ice; the comparative relation of water and ice to the electricity of the voltaic apparatus is not less extraordinary on that account, or less important in its consequences.

394. As it did not seem likely that this law of the assumption of conducting power during liquefaction, and loss of it during congelation, should be peculiar to water, I immediately proceeded to ascertain its influence in other cases, and found it to be very general. For this purpose bodies were chosen which, being solid at common temperatures, were fusible; and of such composition as, for other reasons connected with electro-chemical action, led to the conclusion that they would be able to replace water. A voltaic battery of two troughs, or twenty pairs of four-inch plates (384.), was used as the source of electricity, and a galvanometer introduced into the circuit to indicate the presence or absence of a current.

395. On fusing a little chloride of lead by a spirit-lamp on a fragment of a Florence flask, and introducing two platina wires connected with the poles of the battery, there was instantly powerful action, the galvanometer was most violently affected, and the chloride rapidly decomposed. On removing the lamp, the instant the chloride solidified all current and consequent effects ceased, though the platina wires remained inclosed in the chloride not more than the one-sixteenth of an inch from each other. On renewing the heat, as soon as the fusion had proceeded far enough to allow liquid matter to connect the poles, the electrical current instantly passed.

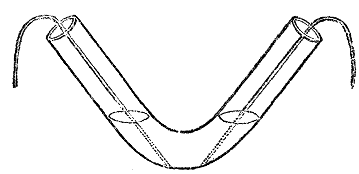
396. On fusing the chloride, with one wire introduced, and then touching the liquid with the other, the latter (being cold,) caused a little knob to con-

crete on its extremity, and no current passed; and it was only when the wire became so hot as to be able to allow contact with the liquid matter, that conduction took place; and then it was very powerful.

397. When chloride of silver and chlorate of potassa were experimented with, in a similar manner, exactly the same results occurred.

398. Whenever the current passed in these cases, there was decomposition of the substances; but the electro-chemical part of this subject I purpose connecting with more general views in a future paper*.

399. Other substances, which could not be melted on glass, were fused by the lamp and blowpipe on platina connected with one pole of the battery, and then a wire, connected with the other, dipped into them. In this way mixed carbonates of potash and soda, chloride of sodium, sulphate of soda, protoxide of lead, &c. &c. &c., exhibited exactly the same phenomena as those already described. Whilst liquid, they conducted and were decomposed; whilst solid, though very hot, they insulated the battery current even when four troughs were used.



400. Occasionally the substances were contained in small bent tubes of green glass, and when fused, the platina poles introduced, one on each side. In such cases the same general results as those already described were procured; but a further advantage was obtained, namely, that whilst the substance was conducting and decomposing, the final arrangement of the elements could be observed. Thus, iodides of potassium and lead gave iodine at the positive pole, and potassium or lead at the negative pole. Chlorides of iodine and silver gave chlorine at the positive, and metals at the negative pole. Nitre and chlorate of potassa gave oxygen, &c., at the positive, and alkali, or even potassium, at the negative pole.

401. A fourth arrangement was used for substances requiring very high temperature for their fusion. A platina wire was connected with one pole of

* In 1801, Sir H. Davy knew that "dry nitre, caustic potash, and soda are conductors of galvanism when rendered fluid by a high degree of heat," (Journals of the Royal Institution, 1802, p. 53,) but was not aware of the general law which I have been engaged in developing. It is remarkable, that eleven years after that, he should say, "There are no fluids known except such as contain water, which are capable of being made the medium of connexion between the metal or metals of the voltaic apparatus." Elements of Chemical Philosophy, p. 169.

the battery; its extremity bent into a small ring, in the manner described by Berzelius, for blowpipe experiments; a little of the salt, glass, or other substance, was melted on this ring by the ordinary blowpipe, or even in some cases by the oxy-hydrogen blowpipe, and when the drop, retained in its place by the ring, was thoroughly hot and fluid, a platina wire from the opposite pole of the battery was made to touch it, and the effects observed.

402. The following are various substances taken from very different classes, chemically considered, which are subject to this law. The list might, no doubt, be enormously extended; but I have not had time to do more than confirm the law by a sufficient number of instances.

First, *water*.

Amongst *oxides*;—potassa, protoxide of lead, glass of antimony, protoxide of antimony, oxide of bismuth.

Chlorides of potassium, sodium, barium, strontium, calcium, magnesium, manganese, zinc, copper (proto-), lead, tin (proto-), antimony, silver.

Iodides of potassum, zinc and lead, protiodide of tin, periodide of mercury; fluoride of potassium; cyanide of potassium; sulpho-cyanide of potassium.

Salts. Chlorate of potassa; nitrates of potassa, soda, baryta, strontia, lead, copper, and silver; sulphates of soda and lead, proto-sulphate of mercury; phosphates of potassa, soda, lead, copper, phosphoric glass or acid phosphate of lime; carbonates of potassa and soda, mingled and separate; borax, borate of lead, per-borate of tin; chromate of potassa, bi-chromate of potassa, chromate of lead; acetate of potassa.

Sulphurets. Sulphuret of antimony, sulphuret of potassium made by reducing sulphate of potassa by hydrogen; ordinary sulphuret of potassa.

Silicated potassa; chameleon mineral.

403. It is highly interesting in the instances of those substances which soften before they liquefy, to observe at what period the conducting power is acquired, and to what degree it is exalted by perfect fluidity. Thus, with the borate of lead, when heated by the lamp upon glass, it becomes as soft as treacle, but it did not conduct, and it was only when urged by the blowpipe and brought to a fair red heat, that it conducted. When rendered quite liquid, it conducted with extreme facility.

404. I do not mean to deny that part of the increased conducting power in

these cases of softening was probably due to the elevation of temperature (432. 445.); but I have no doubt that by far the greater part was due to the influence of the general law already demonstrated, and which in these instances came gradually, instead of suddenly, into operation.

405. The following are bodies which acquired no conducting power upon assuming the liquid state:—

Sulphur, phosphorus; iodide of sulphur, per-iodide of tin; orpiment, realgar; glacial acetic acid, mixed margaric and oleic acids, artificial camphor; caffeine, sugar, adipocire, stearine of cocoa-nut oil, spermaceti, camphor, naphthaline, resin, gum sandarach, shell lac.

406. Perchloride of tin, chloride of arsenic, and the hydrated chloride of arsenic, being liquids, had no sensible conducting power indicated by the galvanometer, nor were they decomposed.

407. Some of the above substances are sufficiently remarkable as exceptions to the general law governing the former cases. These are orpiment, realgar, acetic acid, artificial camphor, per-iodide of tin, and the chlorides of tin and arsenic. I shall have occasion to refer to these cases in the paper on Electro-chemical Decomposition.

408. Boracic acid was raised to the highest possible temperature by an oxy-hydrogen flame (401.), yet it gained no conducting powers sufficient to affect the galvanometer, and underwent no apparent voltaic decomposition. It seemed to be quite as bad a conductor as air. Green bottle-glass, heated in the same manner, did not gain conducting power sensible to the galvanometer. Flint glass, when highly heated, did conduct a little and decompose; and as the proportion of potash or oxide of lead increased in the glass, the effects were more powerful. Those glasses, consisting of boracic acid on the one hand, and oxide of lead or potassa on the other, show the assumption of conducting power upon fusion and the accompanying decomposition very well.

409. I was very anxious to try the general experiment with sulphuric acid, of about specific gravity 1·783, containing that proportion of water which gives it the power of crystallizing at 40° Fahr.; but I found it impossible to obtain it so that I could be sure the whole would congeal even at 0° Fahr. A ten-thousandth part of water, more or less than necessary, would, upon cooling the whole, cause a portion of uncongealable liquid to separate, and that remaining

in the interstices of the solid mass, and moistening the planes of division, would prevent the correct observation of the phenomena due to entire solidification and subsequent liquefaction.

410. With regard to those substances on which conducting power is conferred by liquidity, the degree of power so given is generally very great. Water is that body in which this acquired power is feeblest. In the various oxides, chlorides, salts, &c. &c., it is given in a much higher degree. I have not had time to measure the conducting power in these cases, but it is apparently some hundred times that of pure water. The increased conducting power known to be given to water by the addition of salts, would seem to be in a great degree dependent upon the high conducting power of these bodies when in the liquid state, that state being given them for the time, not by heat but solution in the water.

411. Whether the conducting power of these liquefied bodies is a consequence of their decomposition or not (413.), or whether the two actions of conduction and decomposition are essentially connected or not, would introduce no difference affecting the probable accuracy of the preceding statement.

412. This general assumption of conducting power by bodies as soon as they pass from the solid to the liquid state, offers a new and extraordinary character, the existence of which, as far as I know, has not before been suspected; and it seems importantly connected with some properties and relations of the particles of matter which I may now briefly point out.

413. In almost all the instances, as yet observed, which are governed by this law, the substances experimented with have been those which were not only compound bodies, but such as contain elements known to arrange themselves at the opposite poles, and also such as could be decomposed by the electrical current. When conduction took place, decomposition occurred; when decomposition ceased, conduction ceased also; and it becomes a fair and an important question, Whether the conduction itself may not, wherever the law holds good, be a consequence not merely of the capability, but of the act of decomposition? And that question may be accompanied by another, namely, Whether solidification does not prevent conduction, merely by chaining the particles to their places, under the influence of aggregation, and preventing their final separation in the manner necessary for decomposition?

414. But, on the other hand, there is one substance (and others may occur), the per-iodide of mercury, which, being experimented with like the others (400.), was found to insulate when solid, and to acquire conducting power when fluid; yet it did not seem to undergo decomposition in the latter case.

415. Again, there are many substances which contain elements such as would be expected to arrange themselves at the opposite poles of the pile, and therefore in that respect fitted for decomposition, which yet do not conduct. Amongst these are the iodide of sulphur, per-iodide of zinc, per-chloride of tin, chloride of arsenic, hydrated chloride of arsenic, acetic acid, orpiment, realgar, artificial camphor, &c.; and from these it might perhaps be assumed that decomposition is dependent upon conducting power, and not the latter upon the former. The true relation, however, of conduction and decomposition in those bodies governed by the general law which it is the object of this paper to establish, can only be satisfactorily made out after a far more extensive series of observations than those I have yet been able to supply.

416. The relation under this law of the conducting power for electricity to that for heat, is very remarkable, and seems to imply a natural dependence of the two. As the solid becomes a fluid, it loses almost entirely the power of conduction for heat, but gains in a high degree that for electricity; but as it reverts back to the solid state, it gains the power of conducting heat, and loses that of conducting electricity. If, therefore, the properties are not incompatible, still they are most strongly contrasted, one being lost as the other is gained. We may hope, perhaps, hereafter to understand the physical reason of this very extraordinary relation of the two conducting powers, both of which appear to be directly connected with the corpuscular condition of the substances concerned.

417. The assumption of conducting power and a decomposable condition by liquefaction, promises new opportunities of and great facilities in voltaic decomposition. Thus, such bodies as the oxides, chlorides, cyanides, sulphocyanides, fluorides, certain vitreous mixtures, &c. &c., may be submitted to the action of the voltaic battery under new circumstances; and indeed I have already been able, with ten pairs of plates, to decompose common salt, chloride of magnesium, borax, &c. &c., and to obtain sodium, magnesium, boron, &c., in their separate states.

§ 10. *On Conducting Power generally.*

418. It is not my intention here to enter into an examination of all the circumstances connected with conducting power, but to record certain facts and observations which have arisen during recent inquiries, as additions to the general stock of knowledge relating to this point of electrical science.

419. I was anxious, in the first place, to obtain some idea of the conducting power of ice and solid salts for electricity of high tension (392.), that a comparison might be made between it and the large accession of the same power gained upon liquefaction. For this purpose the large electrical machine (290.) was brought into excellent action, its conductor connected with a delicate gold-leaf electrometer, and also with the platina inclosed in the ice, whilst the tin case was connected with the discharging train (292.). On working the machine moderately, the gold leaves barely opened; on working it rapidly, they could be opened nearly two inches. In this instance the tin case was five eighths of an inch in width; and as, after the experiment, the platina plate was found very nearly in the middle of the ice, the average thickness of the latter had been five sixteenths of an inch, and the extent of surface of contact with tin and platina fourteen square inches (384.). Yet, under these circumstances, it was but just able to conduct the small quantity of electricity which this machine could evolve (371.), even when of a tension competent to open the leaves two inches; no wonder, therefore, that it could not conduct any sensible portion of the electricity of the troughs (384.), which, though almost infinitely surpassing that of the machine in quantity, had a tension so low as not to be sensible to an electrometer.

420. In another experiment, the tin case was only four eighths of an inch in width, and it was found afterwards that the platina had been not quite one eighth of an inch distant in the ice from one side of the tin vessel. When this was introduced into the course of the electricity from the machine (419.), the gold leaves could be opened, but not more than half an inch; the thinness of the ice favouring the conduction of the electricity, and permitting the same quantity to pass in the same time, though of a lower tension.

421. Fused iodide of potassium was then introduced into the course of the electricity from the machine. There were two pieces, each about a quarter of

an inch in thickness, and exposing a surface on each side equal to about half a square inch; these were placed upon platina plates, one connected with the machine and electrometer (419.), and the other with the discharging train, whilst a fine platina wire connected the two pieces, resting upon them by its two points. On working the electrical machine, it was possible to open the electrometer leaves about two thirds of an inch.

422. As the platina wire touched only by points, the facts show that this salt is a far better conductor than ice; but as the leaves of the electrometer opened, it is also evident with what difficulty conduction, even of the small portion of electricity produced by the machine, is effected by this body in the solid state, when compared to the facility with which enormous quantities at very low tensions are transmitted by it when in the fluid state.

423. In order to confirm these results by others, obtained from the voltaic battery, one of one hundred and fifty plates, four inches square, was well charged: its action was good; the shock from it strong; the discharge would continue from copper to copper through four tenths of an inch of air, and the gold-leaf electrometer before used could be opened nearly a quarter of an inch.

424. The ice vessel used (420.) was half an inch in width. The extent of contact of the ice with the tin and platina being nearly fourteen square inches, it was equivalent to a plate of ice having a surface of seven square inches of perfect contact at each side, and only one fourth of an inch thick. It was retained in a freezing mixture during the experiment.

425. The order of arrangement in the course of the electric current was as follows. The positive pole of the battery was connected by a wire with the platina plate in the ice; the plate was in contact with the ice, the ice with the tin jacket, the jacket with a wire, which communicated with a piece of tin foil, on which rested one end of a bent platina wire (312.), the other or decomposing end being supported on paper moistened with solution of iodide of potassium (316.): the paper was laid flat on a platina spatula connected with the negative end of the battery. All that part of the arrangement between the ice vessel and the decomposing wire point, including both these, was insulated, so that no electricity might pass through the latter which had not traversed the former also.

426. Under these circumstances, it was found that a pale brown spot of iodine

was slowly formed under the decomposing platina point, thus indicating that ice could conduct a little of the electricity evolved by a voltaic battery charged up to the degree of intensity indicated by the electrometer. But it is quite evident that notwithstanding the enormous quantity of electricity which the battery could furnish, it was, under present circumstances, a very inferior instrument to the ordinary machine; for the latter could send as much through the ice as it could carry, being of a far higher intensity, *i. e.* able to open the electrometer leaves half an inch or more (419. 420.).

427. The decomposing wire and solution of iodide of potassium were then removed, and replaced by a very delicate galvanometer (205.); it was so nearly astatic, that it vibrated to and fro in about sixty-three beats of a watch giving one hundred and fifty beats in a minute. The same feebleness of current as before was still indicated; the galvanometer needle was deflected, but it required to break and make contact three or four times (297.), before the effect was very decided.

428. The galvanometer being removed, two platina plates were connected with the extremities of the wires, and the tongue placed between them, so that the whole charge of the battery, so far as the ice would let it pass, was free to go through the tongue. Whilst standing on the stone floor, there was shock, &c. &c., but when insulated, I could feel no sensation. I think a frog would have been scarcely, if at all, affected.

429. The ice was now removed, and experiments made with other solid bodies, for which purpose they were placed under the end of the decomposing wire instead of the solution of iodide of potassium. For instance, a piece of dry iodide of potassium was placed on the spatula connected with the negative pole of the battery, and the point of the decomposing wire placed upon it, whilst the positive end of the battery communicated with the latter. A brown spot of iodine very slowly appeared, indicating the passage of a little electricity, and agreeing in that respect with the results obtained by the use of the electrical machine (421.). When the galvanometer was introduced into the circuit at the same time with the iodide, it was with difficulty that the action of the current on it could be rendered sensible.

430. A piece of fused common salt being introduced into the circuit was sufficient almost entirely to destroy the action on the galvanometer. Fused

chloride of lead produced the same effect. The conducting power of these bodies, when fluid, is very great (395. 402.).

431. All these effects, produced by using the common machine and the voltaic battery, agree therefore with each other, and with the law laid down in this paper, and also with the opinion I have supported, in the Third Series of these Researches, of the identity of electricity derived from different sources.

432. The effect of heat in increasing the conducting power of many substances, especially for electricity of high tension, is well known. I have lately met with an extraordinary case of this kind, for electricity of low tension, or that of the voltaic pile, and which is in direct contrast with the influence of heat upon metallic bodies, as observed and described by Sir HUMPHRY DAVY*.

433. The substance presenting this effect is sulphuret of silver. It was made by fusing a mixture of precipitated silver and sublimed sulphur, removing the film of silver by a file from the exterior of the fused mass, pulverizing the sulphuret, mingling it with more sulphur, and fusing it again in a green glass tube, so that no air should obtain access during the process. The surface of the sulphuret being again removed by a file or knife, it was considered quite free from uncombined silver.

434. When a piece of this sulphuret, half an inch in thickness, was put between surfaces of platina, terminating the poles of a voltaic battery of twenty pairs of four-inch plates, a galvanometer being also included in the circuit, the needle was slightly deflected, indicating a feeble conducting power. On pressing the platina poles and sulphuret together with the fingers, the conducting power increased as the whole became warm. On applying a lamp under the sulphuret between the poles, the conducting power rose rapidly with the heat, and at last the galvanometer needle jumped into a fixed position, and the sulphuret was found conducting in the manner of a metal. On removing the lamp and allowing the heat to fall, the effects were reversed, the needle at first began to vibrate a little, then gradually left its transverse direction, and at last returned to a position very nearly that which it would take when no current was passing through the galvanometer.

435. Occasionally, when the contact of the sulphuret with the platina poles was good, the battery freshly charged, and the commencing temperature not

* Philosophical Transactions, 1821, p. 431.

too low, the mere current of electricity from the battery was sufficient to raise the temperature of the sulphuret; and then, without any application of extraneous heat, it went on increasing conjointly in temperature and conducting power, until the cooling influence of the air limited the effects. In such cases it was generally necessary to cool the whole purposely, to show the returning series of phenomena.

436. Occasionally, also, the effects would sink of themselves, and could not be renewed until a fresh surface of the sulphuret had been applied to the positive pole. This was in consequence of peculiar results of decomposition, to which I shall have occasion to revert in the section on Electro-chemical Decomposition, and was conveniently avoided by inserting the ends of two pieces of platina wire into the opposite extremities of a portion of sulphuret fused in a glass tube, and placing this arrangement between the poles of the battery.

437. The hot sulphuret of silver conducts sufficiently well to give a bright spark with charcoal, &c. &c., in the manner of a metal.

438. The native grey sulphuret of silver, and the ruby silver ore, both presented the same phenomena. The native malleable sulphuret of silver presented precisely the same appearances as the artificial sulphuret.

439. There is no other body with which I am acquainted, that, like sulphuret of silver, can compare with metals in conducting power for electricity of low tension when hot, but which, unlike them, during cooling, loses in power, whilst they, on the contrary, gain. Probably, however, many others may, when sought for, be found.

440. The proto-sulphuret of iron, the native per-sulphuret of iron, arsenical sulphuret of iron, native yellow sulphuret of copper and iron, grey artificial sulphuret of copper, artificial sulphuret of bismuth, and artificial grey sulphuret of tin, all conduct the voltaic battery current when cold, more or less, some giving sparks like the metals, others not being sufficient for that high effect. They did not seem to conduct better when heated, than before; but I had not time to enter accurately into the investigation of this point. Almost all of them became much heated by the transmission of the current, and present some very interesting phenomena in that respect. The sulphuret of antimony does not conduct sensibly either hot or cold, but is amongst those bodies acquiring conducting power when fused (402.). The sulphuret of silver and

perhaps some others decompose whilst in the solid state; but the phenomena of this decomposition will be reserved for its proper place in the next series of these Researches.

441. Notwithstanding the extreme dissimilarity between sulphuret of silver and gases or vapours, I cannot help suspecting the action of heat upon them to be the same, bringing them all into the same class as conductors of electricity, although with those great differences in degree, which are found to exist under common circumstances. When gases are heated, they increase in conducting power, both for common and voltaic electricity (271.); and it is probable that if we could compress and condense them at the same time, we should still further increase their conducting power. CAGNIARD DE LA TOUR has shown that a substance, for instance water, may be so expanded by heat whilst in the liquid state, or condensed whilst in the vaporous state, that the two states shall coincide at one point, and the transition from one to the other be so gradual that no line of demarcation can be pointed out*; that, in fact, the two states shall become one;—which state presents us at different times with differences in degree as to certain properties and relations; and which diffeences are, under ordinary circumstances, so great as to be equivalent to two different states.

442. I cannot but suppose at present that at that point where the liquid and the gaseous state coincide, the conducting properties are the same for both; but that they diminish as the expansion of the matter into a rarer form takes place by the removal of the necessary pressure; still, however, retaining, as might be expected, the capability of having what feeble conducting power remains, increased by the action of heat.

443. I venture to give the following summary of the conditions of conduction in bodies, not however without fearing that I may have omitted some important points.

444. All bodies conduct electricity in the same manner from metals to lac and gases, but in very different degrees.

445. Conducting power is in some bodies powerfully increased by heat, and in others diminished, yet without our perceiving any accompanying essential

* Annales de Chimie, xxi. pp. 127, 178.

electrical difference, either in the bodies or in the changes occasioned by the electricity conducted.

446. A numerous class of bodies insulating electricity of low intensity when solid, conduct it very freely when fluid, and are then decomposed by it.

447. But there are many fluid bodies which do not sensibly conduct electricity of this low intensity; there are some which conduct it and are not decomposed; nor is fluidity essential to decomposition*.

448. There is but one body yet discovered† which, insulating a voltaic current when solid, and conducting it when fluid, is not decomposed in the latter case (414.).

449. There is no strict electrical distinction of conduction which can, as yet, be drawn between bodies supposed to be elementary, and those known to be compounds.

* See the next series of these Experimental Researches.

† It is just possible that this case may, by more delicate experiment, hereafter disappear.

Royal Institution,
April 15, 1833.