ELECTRO-MAGNETISM;

BEING

AN ARRANGEMENT

OF THE

Principal Facts

HITHERTO DISCOVERED IN THAT SCIENCE;

WITH PLATES OF THE APPARATUS.

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Ornari res ipsa negat—contenta doceri. Hor.

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PREFACE

has been changed but little; for it would be worse than useless to alter that which can neither be condensed to advantage, nor translated into our own peculiar manner of expression, without injury.

ELECTRO-MAGNETISM:

MAGNETISM and ELECTRICITY are comparatively modern sciences, and though they have always constituted two distinct departments of physical knowledge, it has been impossible entirely to overlook many marked analogies, subsisting between their respective phenomena. Thus it has been long known that lightning on some occasions, renders the iron or the steel it meets with in its passage, magnetic. In the London Philosophical Transactions, it is recorded that a stroke of lightning passing through a box of knives, converted most of them into powerful magnets. It has also been noticed that when magnetic compass needles, were subjected to the discharge of an electrical battery, their power was often weakened, sometimes destroyed, and sometimes their poles were reversed. Similar effects have also been known to result from lightning, when it passed near a ship's compass, and many stories are related of disastrous accidents arising from such an event.

The agencies, whatever may be their real nature, which give rise to electrical and magnetic effects,* are distinguished from all the other agencies or powers of nature, by the association of two analogous, but opposite forces; for almost all their phenomena result, from the predominance of one or other of two contrary influences, attraction and repulsion—which act only when separate, and which become neutralized or inefficient when combined. Electricity, for example, is either positive or negative; and the natural state or point of zero, is intermediate between these two opposite conditions. The agency of magnetism in like manner,

* For a compendious statement of magnetic phenomena, see Appendix, Letter A.

is referable to one of two contrary polarities, called the southern or austral, and the northern or boreal polarity. These opposite magnetic and electrical influences, have in either case the very same relations with regard to each other; thus, two bodies positively electrified, repel each other; two negatively electrified, also repel; and a body positively electrified, attracts one that is negatively electrified; in other words, like electricities repel, unlike attract. In like manner, attraction takes place between the north and south poles of a magnet, but repulsion between poles of the same character. It is a well known fact that electrified bodies render most substances in their vicinity also electrical; and the very same kind of influence is likewise exerted by magnets, on all ferruginous matter— these phenomena are termed *induction*, and each kind of electricity, as well as each kind of magnetic polarity, tends to *induce* in the bodies on which it exerts its influence, an electricity or a polarity of the opposite kind. In all these particulars, and some others which might be mentioned, the parallel we have drawn, is exact; but there are many facts in electricity, which not only have no analogy in magnetism, but they are entirely opposed. Thus we can obtain the two electricities in separate states, so that the properties of each may be examined without the interference of the other; but if a magnetic bar, of which the poles are at the two extremities, be broken across in the middle, we find that each fragment will become a complete magnet with two poles. It will, however, be foreign to our purpose to pursue this inquiry further; suffice it to say, that the identity or the independence of electricity and magnetism, has attracted much attention among philosophers from a very early period; and in following the laborious investigations which were undertaken to resolve the problem, it is often amusing to perceive how near an approach was sometimes made to the truth, which was lurking as it were close to the very path of the inquirer. An unexpected result would sometimes startle the philosopher in the midst of his experiments, and afford him a momentary glimpse of some new region of science, into which he had not power to penetrate, and which, after fruitless efforts to repeat, he ended in persuading himself was a mere illusion.

Numerous facts sufficiently demonstrated the tendency of electricity to produce magnetism—but Ritter appears to have been the first who had any correct views respecting the identity or intimate relation of these two powers; the full and clear discovery of the fact of their true connexion belongs, however, to Dr. Oersted, professor of chemistry at Copenhagen; his first experiments were published in 1821, though they were performed some time before. The name which has been given to this new branch of philosophical inquiry, has been called by some, electro-dynamics, but the more preferable term is electro-magnetism.*

In exhibiting the facts connected with

* For directions how to prepare and use the galvanic battery, see Appendix, Letter B.

cited, and the conjunctive wire being closely united to the poles of the instrument, on bringing some iron filings on a paper under the wire, they will be immediately attracted, and will adhere in considerable quantities, forming a mass round the wire of ten or twelve times its thickness. On breaking the communication between the poles of the battery, or on removing it from the exciting fluid, the iron filings instantly fall off. Thus we see that the magnetic effect depended entirely on the passage of the electricity through the wire. The length of the conjunctive wire in this experiment seems to influence but little its magnetic properties, for iron filings will be attracted by *all parts* of the wire, whether it be eight or ten *inches*, or eight or ten *feet*, long. If, however, the conjunctive wire be twisted into a series of consecutive rings, one inside of the other, so as to form a *flat spiral*, the quantity of iron filing taken up will then be enormous, and the attraction being the strongest at the centre of the spiral, will cause them to assume a conical figure. The electricity produced by a common electrical machine, will, also, cause a metallic wire to take up iron filings.

It may here be remarked that when a magnetic bar is made to act on steel filings, these filings arrange themselves in curves round the poles, but diverge in right lines; and in their adherence to each other form right lines, appearing as spicula. In the attraction of the filings round the conjunctive wire, on the contrary, they form one coherent mass, which would probably be perfectly cylindrical were it not for the influence of gravity.

Our two next experiments will be to show, that when a current of electricity passes through a conjunctive wire, the wire itself possesses all the properties of a common magnetic bar. The different parts are attracted and repelled by the north and south poles of a magnet; and under favourable circumstances it will arrange itself in a plane perpendicular to the magnetic meridian, one end turning towards the north, and the other towards the south pole of the earth.

TO EXHIBIT THE ATTRACTIVE AND REPULSIVE PHENOMENA OF A CONJUNCTIVE WIRE.

The apparatus for showing this, was constructed by M. De la Rive, of Geneva. (See Plate 1, figure 1.) It consists of a small voltaic combination or battery, attached to a piece of cork; the zinc plate is half an inch wide and three inches long, and passes through the middle of the cork, two and a half inches being below, and half an inch above it; the slip of copper is the same width as the zinc, but about twice as long; it passes through the cork on both sides of it, and being thus opposed to both surfaces, it forms a little battery, on the principle of Dr. Wollaston's. A piece of copper wire, covered with silk thread, is rolled five or six times, and tied together so as to form a ring about an inch and a half in diameter; the ends of the wire are connected, one with the zinc, and the other with the copper slip or plate, above the cork. Now when this little battery is placed in water slightly acidulated with the sulphuric or nitric acid, the ring becomes highly magnetic, and on presenting a magnetic bar to it, which is strongly charged, it will be attracted and repelled, according as one or other of the poles is opposed, or as one or other side of the ring is presented to the bar. When the result of the application is attraction, the cork will advance towards the end of the bar; and if this latter be held horizontally, and in a line with the centre of the ring, it will continue to advance till the pole of magnet is within the ring, and then the ring will proceed with considerable velocity till it reaches about the middle of the magnet, where it will remain stationary. If now the magnet be withdrawn and changed end for end, and re-introduced into the ring, the ring will move off from the magnet, turn itself round, when quite free from it, then advance, and settle in the middle as before.

Of this very simple apparatus, Mr. Barlow remarks: "It throws great light upon electro-magnetic action, and proves most satisfactorily, that notwithstanding the intimate relation between the electro-magnetic and the magnetic fluids, they are not identical; for no possible arrangement of simple magnets can be made that would lead one of them beyond the pole of another to find its state of equilibrium in the middle of the latter." Whatever the fact may be in regard to the identity of the two fluids, we think that this is rather a hasty conclusion of Mr. Barlow.

Besides the motion of the ring when influenced by an artificial magnet, it has also a tendency to arrange itself in a plane perpendicular to the magnetic meridian. This property will, however, be best illustrated by the next experiment.

TO EXHIBIT THE TERRESTRIAL DIRECTIVE QUALITY OF A CONJUNCTIVE WIRE; OR, THE VOLTAIC NEEDLE.

The little apparatus used in this experiment, and represented in Plate 2, figure 11, is precisely like the last, except that the zinc and copper strips are connected together not by a *ring*, but by a helix of copper. This helix is made by twisting a thin copper wire in regular turns round a glass tube about one-third of an inch in diameter. The helix is to be made about four inches long, and after it is removed from the glass, the two *ends* of the wire, are to be bent and returned through the centre of the helix, till near the middle, where they are made to pass to the outside between the spirals, then being connected, one to the zinc, and the other to the copper strip, the helix reposes on the cork, with the two ends equally distant from the centre. When this little instrument is floated on acidulated water, the helix becomes magnetic;

its extremities act like the opposite poles of a magnetic needle, being attracted or repelled by the opposite ends of a magnetic bar, and settles in a north and south position, in the same manner as a common magnetic needle. Both of the contrivances last mentioned, have had their original construction much improved by Mr. James Marsh, of Woolwich. Instead of floating them in a large vessel containing the acidulated fluid for their excitement, a small light glass tube, filled with this liquid, is fastened to the under side of the cork, as represented in the drawings. They may then be floated on common water, and all the facts be exhibited as above described. The magnetic qualities of the last instrument, may then also be shown by suspending the whole on a fine silk thread.

The voltaic needle appears to have been first suggested by Arago, of whom La Place once remarked to a friend, "*he is the hope*" of the French Institute. He was led to this suggestion by reflecting, that whatever action the turns of the spiral part of the wire may have in a longitudinal direction, that is in a line parallel to the axis of the wire, this would be neutralized by the contrary action of the returning wire; and the only force operative would be that of the circular currents moving in planes perpendicular to the axis. Experience seems to have fully confirmed this conclusion. This voltaic or electrical magnet, may have its poles instantly reversed, by altering the connexion of the helix, with the copper and the zinc plates. But to show this satisfactorily, we must have *Ampére's spiral*, which little apparatus is as follows: A spiral brass wire surrounds two glass tubes, bent a little at one end, as in Plate 1, figure 2, and being prolonged on both sides, the ends of the wire are returned through the interior of the tubes; the extremities coming out at the curved ends; one of them descends vertically, while the other rises vertically, and perpendicularly to the first, from the second tube, and is bent twice at right angles as shown in the figure. Both the wires are terminated by steel points, which are plunged in mercury contained in the cups, one above and the other below, as in the drawing; the upper point resting solely on the bottom of its cup, on the upright mahogany pillar fixed into the bottom board of the instrument. Now upon connecting the mercury in the cups with the galvanic battery, one extremity of this little spiral will present the phenomena of the north pole of a magnetic compass needle; and the other, those of the south pole.

It may here be mentioned, that we are, perhaps, indebted to Ampére, for our most ingenious and elaborate treatise on electro-magnetism. In our opinion, he has mingled too much theory and mathematics with his beautiful experimental details. He maintains that all the phenomena usually referred to the operation of magnetism, are mere electrical effects; in other words, that instead of two agencies, there exists but one. After reading Ampére's essay on this subject, Sir Humphrey Davy remarks, "without meaning to offer any decided opinion on that gentleman's ingenious views, I shall beg permission to mention two circumstances which seem to me unfavourable to the idea of the identity of electricity and magnetism. 1st. The great distance to which magnetism is communicated by common electricity. I found that a steel bar was made magnetic at fourteen inches distance from a wire transmitting an electrical shock from about seventy feet of charged surface. 2nd. The effect of magnetizing at a distance by electricity, takes place with the same readiness through air and water, glass, mica, or metals, i. e. through conductors and non-conductors." Both of the facts here mentioned by Sir Humphrey, we shall illustrate presently by easy experiments; but as far as we can comprehend their bearing, they are not incompatible with Ampére's theory, and are not entitled to the same weight as most of the opinions of this illustrious man. Sir Humphrey would be very unwilling to consider light and heat as two distinct fluids; because the rays of light from a burning body readily pass through a plate of glass or mica; whereas those of heat, are either wholly stopped, or greatly retarded by the same substances.

M. Erman has also contrived a little electro-magnetic apparatus, to show the attraction and repulsion of the conjunctive wire, when influenced either by terrestrial magnetism, or by an artificial magnet; we notice it merely on account of its simplicity. Having placed a watch glass in a silver or copper crucible, and a small piece of zinc in the glass, he fastens a strip of zinc or tin to the mass of zinc, which extending upwards and outwards over a paste-board band, in which the cup rests, it is fastened at the other end to the cup itself; a complete galvanic circuit being thus formed, electricity is set in motion by filling the cup with acidulated water. Now if the whole apparatus be suspended by a thread, and a magnet be brought near it, either attraction or repulsion takes place according to the direction of the current in the apparatus, and the magnet current in the bar. If the instrument be made with great delicacy, it will also be influenced by the magnetism of the earth. A little contrivance very similar to this, was constructed in the laboratory of Jefferson College, without any knowledge of that of Professor Erman.

After attraction, repulsion and polarization, the next fact in the order of simplicity, appears to be electro-magnetic *induction*. It is a well known fact, when a rod of soft iron is presented to a magnetic bar, the bar not only takes up the rod, but the rod itself, as long as it is in contact with the bar, exerts a magnetic influence; this is done by *induction*. Each pole of the magnet tends to induce in all ferruginous bodies, a polarity of an opposite kind, within a certain distance.

The conjunctive wire presents us with the same phenomena.

TO EXHIBIT ELECTRO-MAGNETIC INDUCTION.

Take a piece of unmagnetized iron, bent in the form U, and twist a piece of copper wire eight or ten times round it, a few inches of the wire are to be left projecting on each side of the instrument. (See Plate 1, figure 3.) Now upon connecting the extremities of this wire with the opposite poles of a galvanic battery, the curved iron bar will act as a horse shoe magnet, and attract by its inductive force, any ferruginous body within its influence. The quantity of iron lifted by an apparatus similar to the above, is astonishingly great.

It might be very readily imagined that from the powerful magnetic induction produced by the conjunctive wire on soft iron, as exhibited in the last experiment, a permanent magnetism might be imparted to steel also. Accordingly, steel needles have been rendered permanently magnetic, either by fastening them to the conjunctive wire, or by bringing the conjunctive wire near them; for mere juxta position is all that is necessary. The magnetic induction in such an experiment, is instantaneous; for a needle which has been placed near the wire, but for a moment, is made as powerfully magnetic, as one that has been for a long time under its influence. The position, however, of the needle, with respect to the conjunctive wire, is of great consequence. Sir H. Davy discovered the remarkable fact, that by fastening steel needles to a conjunctive wire in different directions, some parallel, and others in a transverse position, or at right angles to it, on breaking the connexion between the conjunctive wire and the galvanic battery, those needles only which were in a *transverse direction*, retained their magnetism, and exhibited each a north and south pole. He also observes, that when the battery was placed with its positive and negative sides in different directions, as to the poles of the earth, the positive side being on the *right hand*, in all situations those needles placed transversely *under* the conjunctive wire, had their north poles turned towards the face of the operator; those *above* the *wire*, their south pole toward the face; and those arranged vertically on one side the wire, had their north and south poles opposite to those arranged vertically on the other side. These facts are well illustrated by the little model exhibited at figure 4, Plate 1. The straight line, which represents a brass rod fourteen inches long, is the conjunctive wire; the arrow which is fastened by a rivet to the middle of it, and crosses it at right angles, is the magnetic needle. When this rod is held by its ends, in the right and left hand, the end in the right hand, is the positive end of the battery; the arrow, when *under* the rod, will have its head turned *towards* the experimenter, when *above* the rod, it will be turned *from* him. When on the *east* of the rod, the arrow will be turned vertically *upwards*, and when on the *west*, vertically *downwards*.

The magnetic induction in these experiments, seems to be in proportion to the *heat* produced in the *conjunctive* wire. When a fine platinum wire was heated so intensely as to be near the point of fusion, it exhibited the strongest magnetic effects.

Electricity, from a common Leyden battery, discharged through a wire, will also give permanent polarity to a steel needle placed transversely across it. If the needle be *under* the wire, the positive conductor being on the right hand, the north pole will be that end which is to the face of the operator; and if the needle be above the wire, it exhibits the opposite polarity, according to the same law as in the galvanic circuit.

This singular method of giving magnetism to steel, has suggested a simple mode of making powerful magnets, namely, by fixing hard steel transversely across lightning rods, which are attached to buildings in elevated and exposed situations.

Our next experiments will be, to exhibit the curious fact, that the conjunctive wire, contrary to the ordinary effects of electricity, exerts its inductive effects through both non-conductors and conductors, such as plates of glass, resin, paper, metal, &c. The sudden interposition of any of these substances does not sensibly diminish its magnetic influence.

TO EXHIBIT ELECTRO-MAGNETIC INDUCTION, THROUGH NON-CONDUCTORS OF ELECTRICITY.

Sprinkle some steel filings on a glass plate, or a sheet of paper, placed either in contact or within an inch above the conjunctive wire, and they will be found to arrange themselves at right angles to the axis of the wire. In this experiment let it not be expected that any very powerful effect on the filings will be produced. It is only on close inspection, at least so far as our own experience goes, that the filings immediately above the conjunctive wire, will be found to cross it at right angles. On the principle of induction, Arago succeeded in communicating magnetism to needles in a different manner from any which has hitherto been stated.

ELECTRO-MAGNETIC EFFECTS OF THE HELIX.

On twisting a copper wire round a rod of glass, or any other substance, the spiral thus produced is called a helix; and it is easy by passing the wire round the rod in one or the other direction, to form a right handed or dextral helix, or a left handed or sinistral helix. On making a helix the conjunctive wire, by properly fastening its opposite extremities to the poles of a galvanic battery, and on introducing a steel needle surrounded with paper into its cavity or axis, Arago found that the needle very soon acquired a very high charge of magnetism.

This experiment may be varied by putting a needle, guarded with paper, *within* the helix, and by attaching another needle, surrounded with paper, to the *outside* of the helix; then on transmitting the electrical current through the helix, both needles will be found magnetic; but their poles will be inversely situated. This curious fact was first noticed by some Italian philosophers.*

In another experiment a double helix was formed with a single wire; by twisting it on a rod, first, for about two inches from the left towards the right, and then the same distance from the right to the left. Within each of these spirals, a needle, properly guarded with paper, was included, and the double helix was then

* M. Van Beck and Professor Van Rees, of the University of Liege, and Professor Moll, of Utrecht, have made some interesting experiments on the electro-magnetic properties of the helix, but it would carry us too much into detail to repeat them. We are also indebted to Major-General Baron Van Zuylen Van Nyevelt, for some similar ingenious researches. Vide Bib. Univ. Aug. 1823.

made the conjunctive wire, by fastening it to the two ends of a galvanic battery. The result was, that both the needles were magnetized, but in directly opposite *senses*; the end of the needle in the right handed or dextral helix, which had been placed towards the negative pole of the battery, pointed towards the north, and the other end south; but the needle in the left helix, had its north pole towards the positive end of the battery; thus the south poles were in the middle, and the north poles at the ends. In another experiment where the conjunctive wire is twisted into three consecutive helices, the middle one differing from the other two, when a single piece of steel wire, long enough to pass through them all, was placed in a glass tube, which also passed through them, on examination it was found to have acquired six poles; first a north pole, a little farther on, a south pole, then another south pole, then two north poles, and at the further end, a south pole.

The electricity of a common machine

when passed along a helix, either in sparks from the prime conductor, or in discharges from a battery, will render an included needle magnetic as in the above cases.

In all the experiments we have hitherto noticed, we have exhibited the effect of the conjunctive wire on ferruginous substances not previously magnetized. We shall now examine some of the phenomena produced by the conjunctive wire on the *magnetic* needle, or a steel needle already magnetized. These experiments were first made by Dr. Oersted, Professor of chemistry at Copenhagen, in 1819; and first drew the attention of philosophers to this interesting subject.

TO EXHIBIT THE EFFECT OF THE CONJUNCTIVE WIRE ON A MAGNETIC NEEDLE.

To produce these new phenomena, a strongly magnetized needle, about a foot in length, is to be balanced horizontally on a finely pointed pivot; and when it has settled in a north and south direction, resulting from the magnetic force of the earth, we take the conjunctive wire, which, for this purpose, is best made of lead or tin, and having extended it in a parallel direction *over* the needle, and about an inch or two from it, the needle will be moved from its north and south position; the end of it next to the positive pole of battery, will be turned towards the east. But if the wire be brought *under* the needle, the end next the positive, will be west. Again, if the wire be placed on the right side of the needle, its north pole will be thrown vertically downwards, and if on the left side, it will be raised vertically upwards. These different positions are well illustrated by the model we have already shown at Plate 1, figure 4. The following instrument will be found convenient to exhibit the horizontal positions of the needle. Here the conjunctive wire is fixed permanently, in the form of a parallelogram, about the needle. See figure 5, Plate 1.

This drawing represents a cylindrical foot of mahogany, supporting by means of a metallic point, a powerfully magnetic needle, about ten inches long, and which turns freely on its pivot. A strong brass wire passes through the foot of the instrument, and is bent as represented in the figure. At the point near where the wire crosses, it is surrounded by silk, and tied with a thread of silk, in order to insulate the ends at that place. On the ends of the wire, two thimbles are soldered to contain mercury; another thimble with mercury is fastened at the upper angle, as shown in the figure. Now when a wire communicating with the negative side of a galvanic battery is put into the mercury of the thimble on the angle, and another wire from the positive side, is put into the upper thimble on the other side, the current of electricity will pass *over* the needle; but when the positive wire is placed in the lower thimble, then the current will pass *under* the needle. In experimenting with the above little instrument, if the needle be highly charged with magnetism, and the power of the battery be strong, the declination will be 90°, which is the maximum. Under ordinary circumstances, however, it does not decline so much. If the wire connected with the positive end of the battery be dexterously managed, by placing it rapidly and alternately in the two thimbles last mentioned, the needle may be made to perform a quick circular motion.

The best contrivance to show the vertical motions, is a common dipping needle, with a piece of tin foil folded round the south pole to balance it.

In the very early stage of electro-magnetic experiments, it had been suggested, that an instantaneous telegraph might be constructed by means of conjunctive wires, and magnetic needles. The details of this contrivance are so obvious, and the principles on which it is founded so well understood, that there was only one question which could render the result doubtful. This was, whether by lengthening the conjunctive wires, there would be any diminution in the electrical effect upon the needle. It is the general opinion, that the electrical fluid, from a common electrical battery, may be transmitted without any sensible diminution, instantaneously through a wire three or four miles in length. At the philosophical dinner, as it has been called, got up a number of years ago by some gentlemen of Philadelphia, on the banks of the Schuylkill, it may be recollected that Dr. Franklin killed a turkey, with the electric shock, transmitted across the river; a distance of more than half a mile; and Dr. Watson, who was also at the pains of making some experiments of this kind, asserts that the electric shock was transmitted instantaneously through the length of 12,276 feet. Had it been found true that the galvanic fluid could be transmitted in a moment through a great extent of conducting wire without diminishing its magnetic effect, then no question could have been entertained as to the practicability and importance of the suggestion adverted to above, with regard to the telegraph. Mr. Barlow, of the Royal Military Academy, who has made a number of successful experiments and investigations in electro-magnetism, fully ascertained that there was so sensible a diminution with only 200 feet of wire, as to convince him at once of the impracticability of the scheme.

There are some other motions produced by the conjunctive wire on a nicely balanced magnetic needle; we shall, however, only mention two. Thus when a uniting or conjunctive wire, is perpendicularly opposite to the north pole of a suspended needle, and the *upper* extremity of the wire is connected with the negative end of the battery, the pole, when brought near the wire, will move towards the east; but when the wire is opposite to a point between the pole and the middle of the needle, the pole moves west. When the upper end of the wire is made to receive the positive electricity, these phenomena are reversed.

To exhibit these facts, in addition to the stand for supporting the common needle, let two brass wires, curving upwards, project from its foot, to confine the motions of the needle to a small space.

Before we pass to a different series of electro-magnetic phenomena, we shall here notice an experiment made by Sir H. Davy, in which a quantity of mercury is set in motion by this wonderful agent. When two copper wires are placed in a basin of mercury, perpendicular to its surface, and in the voltaic circuit of a battery with large plates, the pole of a powerful magnet being held either above or below the wires, the mercury will immediately begin to revolve round the wires, as an axis; the velocity may be greatly accelerated by bringing the opposite poles of two magnets, one above, and the other below, the wires. Masses of mercury, several inches in diameter, were set in motion, by Sir Humphrey, and made to revolve in this manner, whenever the pole of the magnet was held near the perpendicular of the wires; but when the pole was held above the mercury, between the two wires, the circular motion ceased; and currents took place in the mercury in opposite directions; one to the right, and the other to the left of the magnet. Sir Humphrey then inverted the form of the experiment. He took two copper wires about one-sixth of an inch in diameter, the ends of which were flat and carefully polished, and passed them through two holes three inches apart, in the bottom of a glass basin, and perpendicular to it; they were cemented into the basin and made non-conductors by sealing wax, except at the polished ends; the basin was then filled with mercury to the height of one-eleventh of an inch above the wires. The moment the contacts were made, the mercury was seen in violent agitation; its surface became elevated into a small cone above each of the wires; waves f·wed in all directions from these cones, and the only point of rest was apparently where they met in the centre of the mercury between the two wires. On holding a powerful magnet some inches above one of these cones, its apex was diminished, and its base extended; by lowering the pole farther, these effects were increased, and the undulations became feebler.

We shall now exhibit a number of experiments which prove that when properly adjusted, the conjunctive wire and the magnetic needle, or bar, have a tendency to revolve round each other. In all the preceding facts, we have purposely avoided any theoretical details, that we might not perplex the subject; and we shall now only state two or three opinions which are admitted by all, and which seem necessary to the clear understanding of the experiments.

First, then, in the hypothetical language of the electricians, when a wire or other conductor connects the opposite extremities of a voltaic or common electrical battery, during the discharge, a *current* of electricity passes from the positive to the negative side.

Second. When the conjunctive wire becomes magnetic, there is a revolution of magnetism round the wire, forming a kind of vortex or cylinder, depending for its direction upon the position of the negative and positive sides of the electrical battery. In consequence of this *vertiginous* motion, as Dr. Wollaston has called it, there can be no fixed magnetic poles in this revolving current which is supposed to move at right angles to the wire. But let us illustrate this by a model. Figure 6, plate 1, represents a cylinder with a rod representing the conjunctive wire at its axis. The cylinder is intersected with a number of circular parallel lines, all at right angles to the conjunctive wire; imagine these circles to be composed of an infinite number of small lines touching each other. Now suppose these small lines to represent magnetic particles with the northern polarity of each turned in one invariable direction as we follow them round the cylinder. Then will these imaginary magnets, indicate the nature and direction of the magnetic forces which emanate from the wire as long as a current of electricity passes through it. The particular direction of this transverse, or, as it has been termed, this *tangential* magnetic force, will depend, as we have just hinted, upon the electrical current in the wire. If the wire be vertical, in which case the planes of the tangential forces will be *horizontal*, and if the current descends along the wire, then a magnetic needle or the imaginary magnets will have the north pole impelled towards the east, in the circumference of a circle—the motions will be like those of the hands of a watch.

When Dr. Wollaston first suggested to Sir Humphrey Davy, that the above phenomena of the conjunctive wire might be explained, by supposing a kind of revolution of magnetism round its axis, Sir Humphrey performed a variety of ingenious experiments on the subject, which he communicated to the Doctor in a letter, from which we make the following extract.

"To gain some light on this matter, and to ascertain correctly the relations of the north and south poles of steel magnetized by electricity, to the positive and negative state, I placed short steel needles round a circle made on pasteboard of about two inches and a half in diameter, bringing them near each other, though not in contact, and fastening them to the pasteboard by thread, so that they formed the sides of a hexagon inscribed within the circle. A wire was fixed within the centre of this circle, so that the circle was parallel to the horizon, and an electrical shock was passed through the wire, its upper part being connected with the positive side of a battery, and its lower part with the negative. After the shock, all the wires were found magnetic, and each had two poles; the south poles being opposite to the north pole of the wire next to it, and *vice versa*. A similar experiment was tried with six needles arranged in the same manner, with only this difference, that the wire positively electrified was *below*. In this case the results were precisely the same, except that the poles were reversed."

"A number of needles were arranged as polygons in different circles round the same piece of pasteboard, and made magnetic by electricity; and it was found that in all of them, whatever was the direction of the pasteboard, whether horizontal, or perpendicular, or inclined to the horizon, and whatever was the direction of the wire with respect to the magnetic meridian, the same law prevailed. It was perfectly evident from these experiments, that as many polar arrangements may be formed as chords can be drawn in circles surrounding the wire; and so far these phenomena agree with your idea of revolving magnetism; but I shall quit this subject, which I hope you will yourself elucidate."

The hope here expressed by Sir H. Davy, has been disappointed. Dr. Wollaston, we believe, has entirely abandoned these interesting investigations, to the great regret of all who are acquainted with his profound experimental skill, the extent of his philosophic views, and the ingenuity and clearness of his inductions.

The experiments we shall now exhibit, appear all to depend on the tendency of the magnetic and electrical fluids to produce a transverse rotatory motion when freely acting on each other. This transverse or tangential action, is one of so extraordinary a character, that it cannot be assimilated to any other principle in nature of which we have any knowledge. It is, therefore, not surprising that it eluded the observation of former inquirers; although, in the keenness of research, they almost stumbled on the discovery. The experiment performed by Beccaria, of producing transverse magnetism in an iron bar, by the discharge of an electrical battery had, in fact, pointed out the precise direction of this inductive force, and the hint, if pursued, would have infallibly led to the discovery which Professor Oersted made fifty years afterwards, and which thus seems to have been reserved for our own times. The idea of magnetic rotation, and which has since given rise to such a multiplicity of amusing apparatus, certainly first occurred to Dr. Wollaston; who, after convincing himself of its truth by an experiment, dropped the inquiry. The subject, with regard to rotatory movement, was then taken up by Mr. Faraday, and has been pursued by him with great ingenuity and success. Mr. F.'s first and simplest contrivance is to show the revolution of a conjunctive wire round the pole of a magnet, it is as follows:

TO EXHIBIT THE MOTION OF A CONJUNCTIVE WIRE ROUND THE MAGNETIC POLE.

Take a glass tube four or five inches

long, and about half an inch in diameter, the bottom part of which is to be closed by a cork; through this is passed a short piece of soft iron wire, so as to project a little above and below the cork. A little mercury is then poured in, so as to form a channel between the wire and the tube. The upper orifice is also closed by a cork, through which a piece of platinum wire passes, terminated within by a loop; from which, another piece of wire hangs, the lower end of which just touches the mercury; and being amalgamated, it is preserved from adhering either to the iron wire or the tube. The moving joints of this little contrivance, and those of all other electro-magnetic apparatus, should be amalgamated, and a small drop of mercury, whenever practicable, should always be placed between them. Plate 2, figure 9, is a representation of this instrument. When a *small* galvanic battery is connected with the upper and under ends of this apparatus, and the pole of a magnet is brought in contact with the external part of the iron wire below, the moveable wire within, rapidly revolves round the magnet thus formed at the moment, by induction. By changing either the connexion, or the pole of the magnet in contact with the iron, the motion is reversed.

Thus we see, that a wire through which a current of electricity is passing, has a tendency to revolve round a magnetic pole, and a still more remarkable conclusion follows from the experiment, viz. that there is no *attraction* whatever between the conjunctive wire and either poles of a magnetic bar.

It was natural to expect, that as a conjunctive wire would rotate about a magnetic pole, so a magnetic bar would revolve round a conjunctive wire. This experiment is readily effected by fastening one end of a small magnet in the bottom of a cup of mercury, the other end being above the surface of the mercury; then by connecting the quicksilver with one end of the battery, and then bringing a wire from the other end perpendicularly into it, in another part near, the floating magnet, the magnet will move round the wire.

TO EXHIBIT THE ROTATION OF A CONJUNCTIVE WIRE, ROUND A MAGNET, AND OF THE MAGNET ROUND THE WIRE.

Mr. Faraday, to whose ingenuity we are indebted for the following contrivance to illustrate the above facts, appears to have been the first person who produced decisive electro-magnetic rotatory movements, though Dr. Wollaston first suggested their probability.

A delineation of this apparatus, is given at Plate 3, figure 17. It consists of two glass vessels placed side by side, with their appendages, on a rectangluar piece of mahogany. In the glass on the left of the figure, the motion of a magnetic pole round the conjunctive wire, is produced. That a current of electricity may be established through this glass cup, a hole is drilled at the bottom, and into this, a copper pin is ground tight, which projects upwards a little way into the cup, and below is rivetted to a small round plate of copper, forming part of the foot of the vessel. A similar plate of copper is fixed to the turned wooden base, on which the cup is intended to stand, and a piece of strong copper wire, which is attached to it beneath, after proceeding downwards a little way, turns horizontally to the left hand, and forms one of the connexions, with the poles of a galvanic battery. The surfaces of these two plates, intended to come together, are tinned and amalgamated, that they may remain longer clean and bright, and afford better contact. A small cylindrical and powerful magnet, has one of its poles fastened to a piece of thread, which, at the other end, is attached to the copper pin, at the bottom of the cup; and the height of the magnet, and length of the thread, is so adjusted, that when the cup is nearly filled with clean mercury, the free pole shall float almost upright on its surface.

A small turned pillar of mahogany, rises from the stand behind the glass vessels; an arm of brass comes forward from the top of it, supporting at its extremity, a cross wire, which, at the place on the left hand where it is perpendicularly over the cup just described, bends downwards, and is continued till it just dips into the centre of the mercurial surface. The wire is diminished in size, for a short distance above the surface of the mercury, and its lower extremity amalgamated, for the purpose of ensuring good contact; and so also is the copper pin in the bottom of the cup. When the poles of a galvanic battery are connected with the brass wire on the top of the pillar, and with the lateral copper wire proceeding from the copper plate below the cup, the upper pole of the magnet immediately revolves round the wire which drops into the mercury, in one direction or the so that no

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lower extremity hollowed into a cup, the inner surface of which is well amalgamated. A smaller piece of copper wire has a spherical head fixed to it, of such a size that it may play in the cup in the manner of a ball and socket joint, and being well amalgamated, it, when in the cup, retains sufficient fluid mercury by capillary attraction, to form an excellent contact with freedom of motion. The ball is prevented from falling out of the socket, by a piece of fine thread, which being fastened to it at the top, passes through a small hole at the summit of the cup, and is made fast on the outside of the thick wire. The small wire is of such a length, that it may dip a little way into the mercury, and its lower end is amalgamated. When the connexions with the battery are so made with the brass wire supported by the pillar, that the current of electricity shall pass through this moveable wire, it immediately revolves round the pole of the magnet, in a direction dependent on the pole used, and the manner in which the connexion is made.

Instead of using the circular copper plates to secure the metallic contact between the polar wires of the battery, and the interior of the cups, as in the above plan originally proposed by Mr. Faraday, a small portion of fluid mercury may be placed in a cavity made in the turned wooden base, which supports the cups. The magnets from above, and the connecting wires from below, may thus be surrounded by mercury, and a perfect communication between them formed. The first trials with this instrument, are apt to fail; but a little experience in its manipulation will ensure success.

As it is not easy always to remember the direction in which the poles of a magnet tend to revolve round a conjunctive wire, or in which the wire tends to move round each magnetic pole, the following contrivance, the invention of Dr. Roget, will be found useful, not only in studying the circumstances of an experiment, but also in anticipating almost any new combination: Figure 7, Plate 2, represents a slip of pasteboard or tin, two inches wide, and eight inches long; on each side of which, a line is drawn along the middle, nearly the whole of its length: the upper end is marked -|- positive, and the lower end — negative; the centre of the line is crossed by an arrow at right angles to it: through the centre of the line, and at right angles to the plane of the slip, there passes a small wire, as seen in the figure, at the ends of which, are fixed in planes parallel to the slip, two arrows, marked N and S, and which point in a contrary direction from the one on the slip. Now suppose the line to represent the conjunctive wire, the direction of the current of electricity being denoted by the signs -|- and — at the ends of the wire, the arrow at the middle of the conjunctive wire, will point out the direction in which it tends to move when under the influence of the north pole of a magnet, placed at the upper end, or of the south pole placed at the other end. And vice versa, the arrows N and S, will indicate the direction in which the north and south poles will revolve round a conjunctive wire, with relation to the direction of the electrical current passing through it. It must be observed that the poles N and S are here not considered as in connexion with each other, or as forming part of one magnet; their operations are exhibited singly, and entirely independent of each other.

TO EXHIBIT THE REVOLUTION OF A MAGNET, ON ITS OWN AXIS.

The instrument for showing this fact, was devised by my friend, the late Dr. Dana, professor of chemistry in the university at New York; hê constructed it without knowing of the previous contrivances of Ampére and Barlow, for the same purpose; and to both of which it is decidedly preferable. See Edin. Journal, v. viii. p. 371.

Figure 18, Plate 3, represents a magnetic bar about eight inches long, in a perpendicular position; it is preserved in this situation by steel points projecting from its upper and lower ends, and which act as pivots. The lower point turns in a little cup of mercury, on the base of the instrument. From the middle of the bar, a small curved piece of steel wire projects and dips into some mercury in a circular trough or channel, through the centre of which, the magnet passes, and is permitted freely to revolve. This little circular trough is supported by a strong wire, fastened into an upright from the foot of the instrument. On connecting this wire with the positive pole of a galvanic battery, and the mercury in the cup below with the negative pole, the magnet revolves on its axis with an astonishing velocity. In this experiment, it is essential that the mercury in the channel should be clean, and that the perfect contact of the curved wire, from the middle of the magnet, be ensured by amalgamation.

given at figure 14, Plate 3. A magnetic bar is placed vertically in the centre of a block of wood, which serves as a foot to the apparatus, and in which a circular channel is cut for the purpose of containing mercury. A hollow cylinder of copper is then provided, having a steel point projecting downwards, from its semicircular support, into an agate cap fixed on the top of the magnet, as represented in the figure. The lower edge of the copper cylinder just dips into the mercury, in the circular channel. The top of the steel point is hollowed to contain a drop or two of mercury, into which the point of a wire, proceeding from the top of a wooden support, is immersed. A galvanic circuit being now formed by connecting this wire, and the mercury in the circular channel, with the opposite poles of a battery, the copper cylinder will thus form a part of the conjunctive wire, and will revolve with great velocity on its axis.

Mr. W. Sturgeon has a contrivance

for showing the rotation of the conjunctive cylinder on its axis, in which a compound motion is produced. Two copper cylinders, similar to the one above described, are placed on the poles of a horseshoe magnet; and by using two galvanic batteries, one revolves to the right, and the other to the left. By making a little variation in his contrivance, the same effect may be produced with one battery. Those who wish for further information respecting this instrument, will find his communication on this subject in the Annals of Philosophy, vol. xii. New Series.

There is another experiment similar to the above, devised by Ampére, and improved by Mr. Marsh of Woolwich, in which the galvanic power is produced by the apparatus itself, instead of having recourse to a separate galvanic battery; and this is, perhaps, one of the most pleasing and convenient electro-magnetic instruments.

AMPERE'S ROTATING CYLINDERS.

To form this apparatus, which is figured at number 10, Plate 2, provide two cylinders of thin sheet copper, about two inches high; one of the cylinders must be about two inches and a half in diameter, and the other, two inches; these are to be soldered at the bottom to a circular plate of copper, in the centre of which, there is a hole two inches in diameter, to permit a large bar magnet to pass through and through the interior of the smaller cylinder. The two copper cylinders thus arranged, form a kind of cup to contain diluted sulphuric or nitric acid. At opposite points on the upper edges of the interior or small cylinder, is soldered the ends of a brass wire, bent in the form of a high narrow arch, as represented in the figure; having at its upper part a small steel point projecting downwards, and on which the cylinders are made to revolve on the pole of the perpendicular bar magnet, which passes through their axis. A hoop or cylinder of zinc, nearly two inches high, and large enough in diameter to turn easily in the space between the concentric copper cylinders, is next to be obtained, and at opposite points on its upper edge is to be soldered a wire, larger in curvature, but similar to the one attached to the copper; at its upper part, a point projects and is received into a small cavity made in the upper part of the lower wire; thus the zinc hoop is made to revolve within the copper cylinders. If now this little circular galvanic battery be suspended on the magnet, as is shown in the figure, the cylinders will begin to revolve, one from right to left, the other from left to right, and the rotations, under favourable circumstances, will sometimes amount to 120 in a minute.

When the north pole of the magnet is upward, the motion of the zinc cylinder will be from left to right, and that of the copper one, in the opposite direction; the motion of this last, however, will not be so rapid as the other, in consequence of the weight of the acid, &c. When the south pole of the magnet is uppermost, the motions will be reversed.

TO SHOW THE EFFECT OF A HORSE-SHOE MAGNET ON A FREELY SUSPENDED CONJUNCTIVE WIRE.

The drawing at figure 13, Plate 2, represents part of the conjunctive wire freely suspended from another wire fastened into the top of a support, as shown in the figure. Its lower extremity is to be amalgamated, and slightly immersed in a little reservoir of mercury below. A horse-shoe magnet is then placed as in the drawing. Contact being now made between the wire above, and the mercury below, the hanging part of the wire will be thrown out of the mercury, and will then instantly fall back into the mercury, by its own gravity; then be projected again, and so on, with much rapidity. The motion of the wire may be produced in the opposite direction, by the ordinary means.

This singular motion may be explained, by supposing the wire not only to have a tendency to pass round the north pole to the right hand, but also an equal tendency to pass round the south pole to the left hand; and being thus urged by equal forces in opposite directions, it moves in a straight line, till the electrical contact is broken. This experiment is due to Mr. Marsh, and by using a copper star or wheel with teeth, instead of the moveable wire as above, a wheel and axle rotation may be produced on the same principle.

A WHEEL AND AXLE ROTATION BY MEANS OF A HORSE-SHOE MAGNET.

The apparatus represented at figure 15, Plate 3, is the contrivance in question. A rectangular piece of mahogany is to be provided for the base of the instrument. A small cavity about an inch deep, an inch and a half wide, and three inches long, is to be hollowed out from the upper surface near the middle, for the purpose of containing some mercury. Near one end of this little channel, there is a small wooden pillar, on the top of which is fixed a brass wire, which, after rising perpendicularly an inch or two, proceeds in a parallel direction over the channel, and when about the middle of it, bends downwards till within about two inches of the mercury. The lower end of this wire is to be split with a fine saw upwards about three inches, so as to permit a thin copper wheel to turn freely between the divided parts, near the ends of which, small pivot holes are drilled a little way into the brass, to receive the axis of the wheel. Mercury being poured into the reservoir till the tips of the wheel are slightly immersed in it, and the proper connexions with the galvanic battery being made, the wheel will rotate with surprising velocity. If the contact be changed, or if the magnet be inverted, the motion of the wheel will be reversed. If the tips of the wheel should be amalgamated, and the surface of the mercury in the cavity covered with weak diluted nitric acid, the motion may be produced with less galvanic power.

This experiment, as well as the preceding and following, appears to have originated with Mr. Marsh, though from the account given by Mr. Barlow of this instrument, in the Philosophical Magazine, vol. lix. p. 241, this is somewhat doubtful. It always affords us peculiar pleasure to notice the efforts of genius and intellect in those of obscure origin, or when labouring under the pressure of external disadvantage. The brilliant career of Scheele, his difficulties and discouragements, his successes and rewards, will always be a model of emulation for those who are either highly endowed by nature, or favoured by fortune. Mr. Barlow thus speaks of the person alluded to. "The name of the young man, is James Marsh, a very ingenious work-man, employed in the laboratory of the Royal Arsenal, who has constructed for me my calorimoter, and most of the other apparatus I have occasion for, in my experiments. It is much to be regretted that he is not in a situation to allow of a further and more profitable exercise of his ingenuity."

A COMPOUND WHEEL AND AXLE ROTATION WITH TWO HORSE-SHOE MAGNETS.

The drawing, number 20, Plate 4, represents this instrument. Provide a rectangular piece of board, having two grooves about half an inch deep cut in it, parallel to its length, and which are to be filled with mercury. Into each of these reservoirs of mercury, is slightly immersed the tips of a wheel similar to the one in the last experiment. These wheels are soldered to the ends of a wire, which serves as an axle, and which rests on two supports as shown in the figure. The notches in the supports on which the axle turns, are brought to a fine edge, in order to reduce the friction as much as possible, and to give the greater freedom of motion. The horse-shoe magnets are placed at the grooves, as in the figure.

The apparatus being thus prepared, and the mercury in the grooves being connected with the opposite ends of a battery, the wheels will begin to revolve, and in a very short time will acquire a velocity considerably greater than any produced by the contrivances hitherto mentioned. We need scarcely say that by changing the contact, or by inverting the magnets, the direction of the rotation will also be changed. The usual precaution of covering the surface of the mercury with very dilute nitric acid, will increase the rapidity of the motion, but it is not necessary for its satisfactory exhibition.

REVOLVING STARS.

Figure 12, plate 3, represents a little instrument of our own, in which a compound motion takes place; the wheel connected with the zinc end of the battery revolving in one direction, and that connected with the copper end in another, according to the position of the magnets, and the polar wires. Provide a rectangular piece of hard wood, on the surface of which there are two grooves or channels cut about an inch deep, and on a line with each other; these are to be filled with mercury. Between these grooves and a little behind them rises a pillar of wood supporting a strong brass wire, bent twice at right angles, as seen in the figure; the lower ends of this wire are split upwards, so as to permit a thin copper wheel to turn freely between each; two horse-shoe magnets are placed as in the figure, and then upon making a connexion between the mercury in the grooves and the opposite ends of the battery, the wheels will revolve in different directions.

It is not essential that the revolving wheels in the two last experiments should be cut in stars with rays, as plain circular discs of copper will also rotate; but the stellar form is, perhaps, the most preferable, as it is much lighter, is more readily moved, and the motion can be more satisfactorily seen, than when a plain metallic disc of the same diameter is used. In repeating the wheel and axle experiments, care should be taken to place the magnet with its poles near a line perpendicular to the axis of the wheels, and a small distance above the surface of the mercury in the grooves. It was found that a magnet with a feeble charge was incapable of producing the revolutions of the wheels, even where the galvanic power was considerable; but a rapid rotation was effected with a higher charge of magnetism and a feebler one of electricity. This fact we find has also been noticed by others, and it has been suggested to construct all the electro-magnetic apparatus on a much larger scale than that in common use, in which the magnets should be exceedingly powerful, and the galvanic battery comparatively small.

There must, however, be some point at which the relative proportions, between the magnetic and electrical influences, produce the greatest effects.

In all the movements of the conjunctive wire hitherto noticed, except De La Reve's ring, the action has been produced by an artificial magnet. We shall now mention two experiments of Mr. Faraday, in which the motion of the galvanic wire is produced by terrestrial magnetism.

MOTION OF THE CONJUNCTIVE WIRE, BY TERRESTRIAL MAGNETISM.

To form this contrivance, which is drawn on the second plate, figure 8, a rectangular piece of hard wood is obtained, in which two parallel grooves are sunk for containing mercury; a small wire bent twice at right angles, is supported in the middle by a *long* piece of silk, from the ceiling or other high support, and the amalgamated ends are just immersed in the mercury in the grooves. A connexion being now made between the grooves, and the opposite ends of a battery, the wire will be thrown out of the mercury in the direction of the grooves; if the connexion be changed, the motion will be in the opposite direction.

To prove that the motion proceeds from this cause, let the south pole of a strong magnet be placed under the board between the ends of the rectangular wire; and the wire will be projected with much greater force than before. Now, the *effect* being precisely of the same character, but much more powerful in the latter than in the former case, we are authorized to conclude that the *cause* of motion is of the same nature in both cases; the one proceeding from a southern polarity artificially produced by the magnetic bar, and the other from the natural magnetic action of the earth, which in all northern latitudes we know to be of the same kind as that exhibited by the south pole of a magnet.

TO PRODUCE A ROTATION OF THE CONJUNCTIVE WIRE BY MEANS OF TERRESTRIAL MAGNETISM.

To exhibit this, a very light copper or platinum wire six inches long, is to be freely suspended from, and in close contact with, the conjunctive wire, connected with one end of a galvanic battery; at the lower end of this moveable wire, a small piece of cork is attached in order to keep it buoyant in a basin of mercury about ten inches in diameter. The moveable wire is then to be depressed so as to slope at an angle of 40° to the horizon; in this state the circuit of the battery is to be completed through the mercury in the basin, when immediately the wire commences a rotation as it would do about the south end of a magnet, but of course with less velocity, in proportion to the weaker directive magnetism of the earth.

When the moving wire is placed at an angle equal to the dip of the needle, no motion is produced, which proves, conclusively, that the motion proceeds from the influence of terrestrial magnetism.

A number of curious speculations cannot fail, Sir H. Davy remarks, to present themselves to every philosophic mind, in consequence of the facts which are here developed; such as whether the magnetism of the earth may not be owing to its electricity, and the variations of the needle, to the alterations in the electrical currents of the earth in consequence of its motions, internal chemical changes, or its relations to solar heat, and whether the luminous effects of the auroras at the poles, are not shown by these new facts to depend on electricity.* This is evident, that if a strong electrical current be supposed to follow the apparent course of the sun, the magnetism of the earth ought to be such as it is found to be.

* See appendix for some remarks on Auroras, Letter D.

The last electro-magnetic experiment we shall notice in this department of the subject is one discovered by Ampére.

TO EXHIBIT THE ACTION OF TWO CONJUNCTIVE WIRES ON EACH OTHER.

For a representation of this apparatus, see figure 16, Plate 3. Two conjunctive wires are freely suspended parallel to each; the points of suspension being in little cups of mercury, to secure perfect contact.

These cups and wires are supported by two cross pieces fastened on the tops of the upright little pillars, as seen in the drawing; the perpendicular ends of the wires are elevated in order to bring the points of suspension to correspond as nearly as possible, with the centre of gravity, by which means the wires are moved with the least force. The conjunctive wires from the extremities of the battery, are divided at their ends into two branches, or forks, so that when they are brought each into their respective cups of mercury, the current of electricity from the positive pole of the battery, will pass through both of the moveable wires to the negative pole; one of these divided wires is represented on the left of the figure. Sometimes the cups of mercury in which the moving wires are supported, are made so that they can be placed at different distances from each other, in order to have strong or feeble effects.

Now, suppose a current of the same kind of electricity to be moving through both wires in the same direction, for instance, from right to left, the two wires attract and adhere to each other, and they manifest this attraction, whether the two currents are obtained from separate galvanic batteries, or from portions of the same current in different parts of its course. But on the other hand, if the current in one wire is moving in a direction opposite to that in the other wire, then the wires repel each other. These

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...HE ELECTRO-MAGNETIC MULTIPLIER.

One very important acquisition to the ...paratus of chemical research, derived ...m electro-magnetical investigations, is, ...instrument by which we are enabled ...tect the smallest stream of electrici-... ...y means of the magnetic needle; and this, whether the electrical current arises from the ordinary operations of the galvanic apparatus, or from the chemical action, which bodies reciprocally exercise on each other. The instrument is called the electro-magnetic multiplier, and was invented very shortly after the discovery of electro-magnetism, by M. Schweigger, Professor at Halle. The effect of this multiplier is founded on the equal action exercised on the needle by all parts of a conjunctive wire, when it transmits a current of electricity.

The drawing at figure 19, Plate 3, represents this apparatus according to the form which Dr. Oersted has given it, which, however, differs from that of the original inventor, merely in parts which are not essential. The foot of the instrument is a stout rectangular piece of wood, supporting four uprights, very much like a small table with four feet, in an inverted position. These uprights carry a small rectangular wooden frame, in the border of which there is a groove, where the successive turns of the conjunctive wire are lodged. In the middle of the hollow square formed by the rectangular frame is suspended, by a fine silk thread, a delicate magnetic needle. This thread at its upper extremity, is fastened with wax to a piece of wire, which moves with difficulty through a hole in the cross piece of a little gallows, as shown in the figure; to the lower extremity of this thread, is attached a small triangle of paper folded double, in which reposes the magnetic needle. Where this suspension thread crosses the upper folds of the multiplying wire, there is a hollow tube of glass placed, through which, the suspension thread passes freely, and is thus prevented from touching the multiplying wire. Below the needle, there is a graduated circle for measuring its deviations. The multiplying wire, which should be silvered copper, should be long enough to make four or five turns in the groove of the frame supported by the foot of the instrument; its thickness is about 0.01 of an inch, and is to be wrapped or wound round throughout its whole length, in silk thread. Thus all electric communication is avoided between the different parts of this wire, the turns of which are wound one over or above the other, as it is placed in the groove of the frame. The two extremities of the multiplying wire come out on opposite sides of the instrument, as shown in the drawing.

The manner of using the multiplier, will readily be understood. Let us suppose that the two extremities of the wire are in connexion with the opposite poles of a galvanic pile in very feeble action; it is manifest that the current of electricity will pass through the whole length of the multiplying wire, since the silk in which it is wrapped, hinders any communication from one part to another. It is evident that the four sides of the rectangular frame surrounded by the first turn of the wire, through which a stream is passing, acts in the same direction, or in the same *sense*, and of course causes the needle to turn in one direction; and thus with but one single convolution of the wire, the action is quadruple that of a single stream passing in a parallel direction to the needle. If, therefore, the multiplying wire should make one hundred revolutions round the rectangular frame, its action on the needle will be four hundred times as great as that of a single stream from the pile passing a simple wire which unites its poles. The same prodigious increase of power will also take place whenever the two extremities of the multiplying wire are brought into contact with any two substances, one of which is positive, and the other negative. A stream of electricity thus established in the wire of the multiplier, will move the magnetic needle, and the particular direction in which these movements take place, will show the direction of the stream, and consequently the species of electricity, whether positive or negative, which is liberated at each extremity of the wire. The multiplier is so exceedingly sensible, that when one extremity of the wire, should it be formed of copper, is made to touch a plate of zinc, and the other extremity, having a sheet of blotting paper moistened with pure water, attached to it, and which is at the same time spread over the surface of the zinc, the needle will be immediately turned at right angles to the plane of the wire, and this even when the action of the earth's magnetism is diametrically opposite to this position.

Electricity has for a long time been supposed the principal agent in chemical phenomena, and experiments have been made by Sir Humphrey Davy, and others, to ascertain its presence during certain chemical combinations. Most of the experiments, however, which were performed, were insufficient to afford any very satisfactory results; for though, in some few instances, we were able to obtain sensible electricity, yet in many others, not the smallest indication of it could be perceived. The facts discovered in electro-magnetism, have carried us at least one step farther in this interesting inquiry; and if we still cannot fully explain the precise action of electrical forces in chemical combinations, we are at least able to demonstrate, that these forces are actually developed. Mr. Avogrado seems to be entitled to the merit of first applying the electro-magnetic multiplier for the purpose of rendering sensible the electrical phenomena produced by chemical action. Thus he discovered that metals plunged in nitric acid disengaged electricity, and that the current thus established through the multiplying wire, depended on the concentrated state of the acid, and on the duration of the chemical action.

After this, Dr. Oersted performed a number of experiments on this subject, from which he drew the following conclusions.

First. When the two extremities of the multiplying wire are immersed in an acid or an alkaline solution, capable of acting on them, the needle is always effected; and consequently a current of electricity must be supposed to pass through the whole length of the wire.

Second. The direction of this current is very variable. Sometimes the positive electricity seems to proceed from one end of the wire, and then again from the other end, and that this change in the direction of the current, occurs several times during the course of the same experiment.

Third. There are two methods of establishing the current in one direction. The first method is to keep one end of the multiplying wire at a higher temperature than the other. The second is to hold one of the wires still, while the other wire is continually kept in motion; this last method is so effectual, that if the wire which has been kept in motion, is suffered to remain at rest, and then by slightly agitating the other, the current of electricity is instantly reversed.

When a metal is to be acted upon which is different from that which composes the multiplying wire, a piece of the metal to be tried is soldered to both extremities of the wire, and great care is taken that the parts soldered should be perfectly cool; then the metal to be experimented with, is used in the same manner as the ends of the multiplying wire itself.

We are indebted to Mr. Becquerel for some further observations on this subject, which he derived from an ingenious apparatus of his own construction. The following are the principal results which he obtained.

When an acid combines with an alkali, a current in one uniform direction is established; the acid furnishes the positive, and the alkali the negative, electricity. When nitro-muriatic acid acts upon gold, the acid is positive and the gold negative. When concentrated nitric acid acts upon copper, the acid is negative and the copper positive; but this condition is reversed when the acid is a good deal diluted with water. In general, an acid during its action on a metal, is either negative or positive, according to its concentration or dilution. The exception which seems to be furnished, when iron is acted on by concentrated acid, is no doubt occasioned by an oxide which adheres to its surface, and which produces complication in the phenomena. Dilute nitric acid, holding in solution a small portion of a *nitrate*, is positive, like the concentrated acid; but this is no doubt in consequence of its thus becoming a much better conductor of electricity than before.

A mixture of a concentrated solution of an acid, with a dilute solution of the same acid, produces electrical effects, the concentrated acid liberates the positive, and the dilute acid the negative electricity. With alkaline solutions these effects are reversed.

If into a filtered solution of the nitrate of iron, two leaves of platinum foil be immersed, these leaves at the same time communicating with the two ends of the multiplying wire; under such circumstances, if one of the leaves be suffered to remain in the solution, and the other be withdrawn, and again immersed, a current of electricity is produced, and the leaf which is re-immersed will always liberate the positive electricity. The nitrates of copper and lead give sensible results at first, but they gradually lose this property. The nitrate of zinc, even when newly prepared, shows no signs whatever of electricity. All the above phenomena take place in the air, but in an atmosphere of hydrogen gas they do not occur. We have been the more particular in noticing the above experiments, because they appear to us to throw considerable light on the mutual relations which subsist between chemical and electrical attractions, relations which seem to govern the union and combination of all material substances.

Messrs. Prevost and Dumas have employed the electro-magnetic multiplier, in a series of experiments of a very different, and, perhaps, of a more interesting character than those we have just mentioned; they have endeavoured to ascertain if electricity was not sensibly liberated during muscular contractions. As solutions of acids or alkalies produced currents of electricity by their action upon metals and other unorganized conductors, it was, therefore, probable that they would occasion like effects upon animal substances. Indeed, this very fact, we know, takes place whenever a portion of muscular fibre, or brain, or of nerve, is brought into contact with any of the acids, with aqueous solutions of the alkalies, and, especially, with the metallic chlorides. These very agents were employed by Haller and his friends to excite muscular contractions; in addition to which they made use of red hot metal. Messrs. Prevost and Dumas have fully demonstrated, that whenever red hot metal touches the muscular fibre, and contractions are produced, at the same moment there is also a very considerable development of electricity. These physiologists have rendered it exceedingly probable that

CHEMICAL CHANGES PRODUCED BY MAGNETISM.

Before we describe another class of electro-magnetic experiments, it will here be proper to say a few words respecting certain chemical changes supposed to be produced by magnetism. Mr. J. Murray, of Edinburgh, has performed a variety of experiments on this subject, and which he thinks unequivocally prove the influence of magnetism in the decomposition of metallic salts; we shall here select a few of the numerous experiments repeated in the course of his researches.

DECOMPOSITION OF METALLIC SALTS BY THE MAGNET.

A solution of permuriate of mercury (corrosive sublimate) was by the magnet soon reduced to fluid or metallic mercury, and the supernatant liquid was not affected by the albumen of the egg; and hence, fine steel filings magnetized, have been suggested as an admirable antidote for this active poison.

Nitro-muriate of platinum was rapidly decomposed with a brisk effervescence distinctly audible, and with a visible spray between the eye and the light.

Fine Dutch steel wire, ascertained to be not magnetic, was thrown into nitrate of silver, where it remained fourteen hours without being affected. It was then made the uniting wire between the north and south poles of two bar magnets, when it became speedily plumed with crystals of silver.

The magnetic bar was coated with copal varnish, and placed in a solution of muriate of mercury; the mercury was reduced precisely as if the bar had not been varnished.

Two magnetic bars were left for two days in phosphorus acid. The acid was decomposed; the north pole of one of the bars was scarcely affected, but the south pole of the other was deeply corroded, and developed the foliated structure described by Mr. Daniel.

A portion of platinum wire, which suffered no change in a solution of nitrate of silver, was made the uniting wire between the poles of a powerful horse-shoe magnet; one that would support twelve pounds weight. When this was immersed in a solution of the nitrate of silver, it was soon acted upon by it, and became discoloured. When magnetic bars are plunged in this solution, the silver is deposited much more rapidly round the north pole than round the south pole.

After performing a variety of other experiments, much of the same character as those above described, Mr. Murray remarks, "I have succeeded in decomposing every metallic salt in this way, to which I have applied the magnet.

VEGETABLE COLOURS CHANGED BY THE MAGNET.

A small magnetic bar was placed by Mr.

Murray in a vessel containing the blue tincture of red cabbage, and after two or three days, the blue colour was found to be completely destroyed. The same experiment was tried by substituting the tincture of litmus for that of the cabbage, and the colour of this also was destroyed in about the same time, by the magnet.

Notwithstanding the above experiments, which, to a superficial observer, may appear quite satisfactory, and the strong probability that at no very distant period, magnetism will be found capable of producing striking chemical changes, there can be but little doubt that Mr. Murray has been too hasty in his conclusions from the above details. The precipitation of one metal in a state of combination and solution by another metal is a very common chemical occurrence. This phenomenon depends on a variety of circumstances, wholly unconnected with their magnetic state; on the relative affinities of the two metals for oxygen; on the affinity of the two metals for each other; on the state of saturation and concentration of the solution, and on many other particulars. But independent of these general laws, most of Mr. Murray's experiments have been repeated with unmagnetized steel, and the same results have followed as when it has been magnetic; thus fluid mercury has been produced from corrosive sublimate, &c.

In the experiment with the nitro-muriate of platinum, an unmagnetized steel bar will produce all the phenomena supposed by Mr. Murray to be peculiar to the magnetic bar. With regard to the use of the nitrate of silver, a correspondent, in the third volume of the Annals of Philosophy, N. S. remarks: I divided a dilute solution of nitrate of silver into three portions. In one I placed a steel bar hardened at the ends, but which did not attract iron filings, and consequently was not magnetized. In the two other solutions of nitrate of silver, I put magnets formed of similar bars, the north pole of one and the south pole of the other being immersed, their opposite poles projecting above the edges of the glasses containing the solution; the poles were then connected by an unmagnetized steel wire. Several hours elapsed before any sensible precipitation occurred in either of the three glasses; at length a few fine flakes of metallic silver appeared in all of them; and I did not observe that they were formed sooner in one solution than the others. These flakes increased very slowly, till a certain quantity had collected, when the action increased rapidly, and an abundant precipitate of reduced silver was seen in each of the three glasses. I could perceive no difference in the quantity of silver thrown down.

It is evident from the above statement, that the magnetism of steel bars has no power whatever in modifying, increasing, or reversing the mutual action of steel and the solution of the nitrate of silver. When this mysterious agent shall be found capable of decomposing metallic salts, the order of affinity will probably be reversed by its influence; a fact which occurs in the action of the galvanic battery, as when copper is precipitated on silver wire in a negative state of electricity. Sir H. Davy has made a number of experiments with the hope of effecting chemical changes by magnetism, but without any successful results.

The following is also an experiment on the influence of magnetism in hastening crystallization. It was first made by Professor Marchmann, of Christiana, and confirmed by Professor Hanstein, of the same city. We mention it principally to show how easily even judicious persons may be led into error, by a favourite hypothesis. A glass tube bent in the form of a syphon, is to be placed with the curve downward, and in the bend a small portion of mercury, not sufficient to close the communication between the two legs, is to be put. A solution of the nitrate of silver is then to be introduced, until it rises in both limbs of the tube. The precipitation on the mercury in the figure of an arbor Dianæ will then ensue; slowly when the syphon is in a plane perpendicular to the magnetic meridian; but if placed in a plane coinciding with that meridian, the action is rapid and the crystallization particularly beautiful; taking place principally in that branch of the syphon towards the north. Again, if the syphon be placed in a plane perpendicular to the magnetic meridian, and a strong magnet be brought near it, the precipitation will recommence in a short time, and be most rapid in the leg nearest the south pole of the magnet.

ELECTRO-MAGNETIC LIGHT.

Mr. Leopold de Noboli, by means of a flat spiral covered with silk in the usual way, produced a very vivid light, something resembling artificial fire works, by passing the charge of a large Leyden jar through it. The light from the spiral is very peculiar in colour and vividness; he therefore calls it electro-magnetic light, because of its relation to the magnetic state of the spiral, and thinks that it might be

[illegible] a [illegible]
[illegible] battery [illegible]
[illegible] that the [illegible]
[illegible] produced by the magnet [illegible]
[illegible] We regret [illegible]
[illegible] doubt but that [illegible]
[illegible] ment was merely [illegible]
[illegible] the passage of electricity [illegible]
[illegible] the spiral to another. [illegible]
[illegible] simulated.

[illegible] FROM ELECTRO-MAG-
[illegible] PHENOMENA.

[illegible] marks of a practical bear- [illegible] we have already incidentally [illegible] following particulars will [illegible] interesting. Unusual deviations [illegible] needles produced by local and [illegible] causes, may occasion very ser- [illegible] both in surveying and naviga- [illegible] Lieutenant Johnson of the British [illegible] seems first to have noticed a very [illegible] variation of the magnetic [illegible] in the compass-box, by simply wiping the dust from the glass cover, with a silk handkerchief or other soft substance; the rays of the sun in their passage through the glass, will also affect its electrical state. Now, although the Lieutenant appears to have been rather hasty in concluding, that the deviations of the needle, which might have been produced by mere electrical attraction, were occasioned by a true electro-magnetic current, yet his observations are not the less important. The real or apparent deviations of a needle, may be alike injurious in their consequences. When the glass cover of a compass needle is rubbed with a silk handkerchief, the south pole is attracted. This may be accounted for on the principle, that as the upper surface of the glass is rendered positive by the friction of silk, the lower surface will of course be negative; and then if negative electricity and austral magnetism, bear the same relation to each other, as positive and negative electricity, the attraction is what we should expect. Some experiments seem to show that the boreal fluid, and the positive electricity, also attract each other. But to return to the practical part of our subject. In many instances after cleaning the glass cover of a compass needle, one pole of the needle will adhere to it for more than a minute, and then dropping off will make a number of oscillations before it assumes a state of rest; and as several observations might be made in this interval, it is proper always to attend to this circumstance, and as a caution, to remove when practicable, the glass cover of the instrument altogether. We do not wish to attach more magnitude to this error to which the needle is liable, than it deserves, but every suggestion which is calculated to produce accuracy on such a subject, is important.

From an extensive series of experiments, performed with apparent accuracy by Mr. Abraham, it is supposed, that magnetized steel bars, possess a much better conducting power for electricity, than the same bars in their ordinary state, and consequently that they are better adapted for the preservation of buildings from lightning. In the course of his experiments, he observed that on bringing one point of a magnetic discharging rod to the negative side of a charged jar, and then presenting the other to the positive ball, a deep red light passed between them; this he ascribes to the contact of the condensed magnetic and electrical atmospheres surrounding the ball and the point.

THERMO-MAGNETISM.

In this department of our subject, we propose to arrange a series of magnetic phenomena, which may be produced in solid conductors of electricity, without the interposition of *any liquid*, and through which a current appears to be established by merely disturbing the equilibrium of temperature. It has been proposed to call these new kind of electrical circuits, *thermo-electrics*, to distinguish them from the ordinary galvanic circuits, which are now denominated *hydro-electrics.*

No one conversant with modern science, can have observed without surprise and admiration, the extent to which the discoveries in this branch of philosophy have already reached, and the rapidity with which they have succeeded each other, since the period when Oersted first decisively ascertained the intimate union existing between a series of phenomena until then considered as almost entirely distinct. These facts furnish a new instance of the justice of the observation, "that even in those sciences with respect to which we are most inclined to think that we approach perfection, the truths unknown to us, are still greater than those of which we can render a reason." Before entering immediately on the subject, we shall notice some of the relations subsisting between heat, and the phenomena of electricity and magnetism, and which will not be found irrelevant.

The thermo-electricity of minerals, or the electricity produced in certain crystals by the alteration of their temperature, was a discovery accidentally made by the Abbé Haüy, and seems to be closely connected with our present inquiries. The circumstances which led to the discovery, took place while the Abbé was examining some crystals of the oxide of zinc. Having placed a fragment of one of these crystals in a very cold window for a few moments, it was found on examination to be electri-

... its poles were ascertained. The ... being placed in a milder temperature, the electricity soon vanished; but afterwards on being gently heated, the electrical power was gradually revived, and now its poles were found to be reversed. These results have been verified on other crystals, especially those of the tourmaline, and taking these for examples, the Abbé has endeavoured to ascertain their precise electrical state in the interval comprised between those limits of temperature beyond which the electrical action disappears without return. He has given the name of *ordinary electricity* to that produced by heat, and *extraordinary electricity* to that produced by cold. If, therefore, commencing at the point where the excess of heat destroys in the tourmaline the effects of ordinary electricity, the mineral be left to cool, it will soon give signs of ordinary electricity. The action of the poles first feebly augments to a certain degree, beyond which, it gradually diminishes, and at last disappears. With a temperature a little lower, however, the extraordinary electricity is manifested and the poles resume their power, but in an inverted order; so that the pole first positively electrified, becomes negative, and the negative pole becomes positive.

Sir Humphrey Davy has recently made some very curious experiments on the properties of electrified bodies in relation to their conducting power, their temperature, and their magnetic phenomena. Metals, it is well known, readily transmit large quantities of electricity, and their limit, in this respect, seems to be their fusibility or volatilization, by the heat which the electricity produces, in its passage through them. The intensity of this heat, however, is connected with the nature of the medium by which the metal is surrounded. Thus a wire of platinum which may be readily fused with a certain charge from a galvanic battery, when in the exhausted receiver of an air pump, will acquire in common air a much lower degree of temperature. A wire of platinum of

$\frac{1}{220}$, and three inches in length, was fused in the air, and upon trying the magnetic power of a similar wire in water, under equal galvanic excitement, it was found to be very great. The quantity of iron filings which it attracted, was such as to form a cylinder round it of nearly the tenth of an inch in diameter. It would be foreign to our present purpose to enumerate all the curious researches of Sir Humphrey on this subject; the most remarkable general result obtained, was, that the conducting power of metallic bodies is lower in some inverse ratio, as the temperature is higher. This fact may be exhibited by the following highly curious experiment. Let a fine wire of platinum, four or five inches in length, be placed in a strong galvanic circuit, so that the electricity passing through it, may heat the whole to redness, and let the flame of a spirit lamp be applied to any part of it, so as to heat that part to whiteness; the rest of the wire will then instantly become cooled below the point of visible ignition. For the converse of this experiment, let a piece of ice, or a stream of cold air, be applied to a part of the wire; the other parts will immediately become much hotter, and from a red, will rise to a white heat. Thus we see, that the quantity of electricity which can pass through that part of the wire, submitted to the changes of temperature, is much smaller when it is hot, than when it is cold; that the absolute temperature of the whole wire is diminished by heating a part of it, and on the other hand, is increased by cooling a part of it.

Mr. Children, in his account of the experiments made in heating wires, with his battery of large plates, has ingeniously referred the heat produced by the passage of electricity through conductors, to the resistance it meets with, and has supposed, what proves to be the fact, that the heat is in some inverse ratio to the conducting power. The greatest heat, however, is produced when the conductor is surrounded with air, where there is great reason to suppose much less resistance, than when the conductor is immersed in water, which is so bad a conductor, that in experiments of this kind, its effect in this respect, may be neglected altogether. Now, therefore, as the presence of heat renders bodies worse conductors, a different view from that of Mr. Children may be taken, namely, that the excitation of heat occasions the imperfection of the conducting power. But till the causes of electricity and heat are known, and of that peculiar constitution of matter which excites the one and transmits or propagates the other, all our reasoning on this subject must be inconclusive.*

Sir H. Davy found that when equal portions of wires of the same diameter, but of different metals, were connected together in the circuit of a powerful galvanic battery,

* When occupying the chair of chemistry, and experimental philosophy, at Nassau Hall, Princeton, N. J., we made a series of experiments on the heat produced by different metals, when under galvanic excitement. Those who may be curious on this subject, will find an account of them in the Medical Review, vol. iii.

acting as two surfaces, the metals were heated in the following order: iron most, then palladium, then platinum, then tin, then zinc, then gold, then lead, then copper, and silver least of all. If a chain be made of wires of platinum, and of silver soldered together in alternate links, the silver wire being four or five times the diameter of the platinum, and then placed in a strong galvanic circuit, the silver links will scarcely be heated, whilst all those of the platinum become intensely and equally ignited. This is a very important experiment for investigating the nature of heat. If heat be supposed a substance, it cannot in the above instance be imagined to proceed, or be expelled from, the platinum; because an unlimited quantity may be generated from the same platinum wire, provided it be not fused, as long as the electricity is excited in it.* The magne-

* See some able remarks of Professor Olmsted, of Yale College, in reply to Dr. Hare, of the University of Pennsylvania, who argues with considerable ingenuity, that heat is material. We may also refer to

tism produced by electricity, though with the same conductors, it increases with the heat, as we have already mentioned; yet with different conductors, it follows a very different law—it seems directly as the quantity of electricity which the conductors transmit. Upon this principle Mr. Arago has contrived a very exact process, by which the electro-conducting power of different metals may be ascertained. Suppose a conducting wire to be continued from the external coating of a battery, in a rectilineal direction, for a certain length, and then ramifying in a certain number of branches of the same metal, all equal in diameter, form, and length, and reuniting in one common point. Steel needles are to be placed transversely across the straight part of each wire before and after the ramification, and the electric discharge is to be passed through the system.

a pamphlet just published at Cambridge, Mass., in which it is maintained that heat, light, electricity, and magnetism, are all material, and the different developments of one elementary body.

It will pass undivided through the first conductor, but be separated into equal proportions in the different branches. The magnetization of the needles placed on the first wire, will be the measure of the effect produced by the whole quantity of electricity; the magnetization of those placed on the ramified wires will measure the effect produced by a certain fraction of that quantity, as the third, if there be three branches, or the tenth, if there be ten. A scale will be thus formed of magnetic intensities, corresponding to a fraction of any given discharge. If, afterwards, instead of using different branches of the same metal, similar wires of different metals be used, and a second discharge be passed through this new system, equal to one of known effect, it will be divided unequally between the wires, and the steel needles placed transversely across them, will indicate by their degree of magnetization, whether a particular metal has transmitted a third, another a fourth, another a tenth, or any other proportion of the whole quantity of electricity discharged.

Some of the relations subsisting between magnetism, and certain changes of temperature, have long been known. Thus, if wire be heated until red hot, and then by suddenly cooling it in water, when held in a particular direction, it will for some time show signs of magnetism. Heat and cold also affect the declination of the needle. In navigation, we are told that the approach of an island of ice, has often been found very sensibly to affect the ship's compass. Some very recent experiments show that even the heat of the hand will produce a notable declination in a delicately suspended needle. From 3° below zero on Fahrenheit's thermometer, and even lower, up to 127°, the intensity of magnets decrease as the temperature rises; this fact, noticed by Mr. Christie, seems to contradict the notion of destroying magnetism by intense cold; yet both may be true. Beyond the temperature of 100°, a portion of the power of the magnet is permanently destroyed; and a magnetic bar, whether of steel, nickel, or cobalt, looses its virtue when brought to a white heat. We might farther enlarge on this subject, but we must hasten to the immediate object of our inquiries.

SEEBECK'S ELECTRO-MAGNETIC BAR.

Dr. Seebeck, of Berlin, appears to have been the first person who entertained any very precise or correct ideas as to the production of electro-magnetic effects by the application of heat to metallic bodies; in other words, that an electrical current or circuit might be established in metals, by merely disturbing their equilibrium of temperature. The apparatus for exhibiting this action is exceedingly simple, and may be seen at Plate 4, figure 25. A bar of antimony, about eight inches long and half an inch thick, is there represented, suspended from a thin copper wire in the form of a loop, and which is connected with the extremities of the bar, by twisting it round several times; thus each end of the bar will have several coils of the thin wire in contact with it. Now, if one extremity be heated for a short time with a small spirit lamp, electro-magnetic phenomena will be exhibited in every part of the bar. The heated end will be negative and the other end positive. Though the mere twisting of the copper round the antimony will be a sufficient contact to produce evident effects, it is best that the two should be soldered together. The effects will continue as long as a difference of temperature is preserved at opposite ends of the bar. Any two metals whatever, formed into arcs, and submitted to the same process, will exhibit similar phenomena in a stronger or weaker degree; some will attract iron filings, some merely affect a delicately suspended needle, and in many cases we must increase the energy by the multiplier; an instrument we shall presently notice. It was at first supposed that the two metals should be fastened together in the form of an arc, or that of a circle, but a continuous arrangement, of any figure, will answer the purpose.

Some philosophers have imagined that the effect of Dr. Seebeck's circuit which we have just described, ought not to be considered as a power, possessed by the heterogeneous metals, of developing electricity by contract, and of their various conducting powers, as to heat. Dr. Yelin being induced to consider the mere rupture of temperature as the principal cause of the electro-magnetic action, endeavoured to obtain similar effects with a single piece of metal, and he seems to have obtained very decided effects. In his experiments he used exceedingly delicate needles, and suspended them by the single film or thread of a spider.

If a band of any single metal be formed into a circuit of any figure, by riveting one of its ends near the other, and the projecting end be heated by a flame, whilst the circuit is plunged in cold water, this band will become electro-magnetic, and its properties may be easily ascertained. The several times; thus each end [illegible] will have several coils of [illegible] contact with it. Now, [illegible] acc[illegible] be heated for a short [illegible] spirit lamp, electro-mag[illegible] will be exhibited in eve[illegible] the [illegible] The heated end will be [illegible] other end positive. [illegible] ment being [illegible] twisting of the copp[illegible] principle will be a sufficient [illegible] dent effects, it is b[illegible] to their [illegible] be soldered toge[illegible] be ranged continue, as long as [illegible] those which ture is preserved at [illegible] degree; [illegible] bar. Any two me[illegible] silver, platinum into arcs, and sub[illegible] lead. cess, will exhibit [illegible] only on the needle stronger or weak[illegible] the cold part of [illegible] attract iron filing[illegible] needle. The follow- delicately suspended [illegible] with cast bars cases we must incr[illegible] inch in thick- multiplier; an ins[illegible] cylinders, or [illegible] sently notice. It [illegible] six sides; [illegible] the two metals sho[illegible] also employed— in the form of an [illegible] bar of bismuth is

e bar being placed in the direc-
of the magnetic needle, with its cold
the north, and the hot end be
ght under the needle, the north point
he needle will turn towards the east.
If the direction of the bar being preserv-
it be moved towards the south until its
old end is under the needle, the needle will
turn towards the west. 3. The inverse effects
are obtained when the hot end of the bar is
towards the north. 4. When the bar is heat-
in the middle, and the ends preserved
ld, the same effects are obtained for each
lf of the bar. 5. The magnetic effects are
nsible when one part of the bar is heated
rely by the hand, and the other cooled
snow.

III. The magnetic action of metals un-
ually heated depends on the form given
em in casting, and in this it differs from
he action of Oersted's conjunctive wire. 1.
If an equilateral triangular prism of bismuth
be used as in the former experiments, and
its faces be turned upwards successively,
one of its faces will make the needle de-

viate to the east, the next face (that towards the east) brought into the place of the first, will make the needle deviate to the west; the third face has so uncertain an effect that it may be considered as null. 2. If a square or four-sided prism of bismuth, antimony, or zinc, be used in a similar manner, it will be found that two contiguous faces, when turned upwards, will make the needle move eastward, whilst the other two faces will move it westward, so that this prism may be considered as composed of two triangular prisms, of which the unmagnetic faces are in contact. 3. With a regular hexagonal prism three of the faces move the needle eastward, and three move it westward. 4. Cylinders present peculiar effects; a cylinder of bismuth had been thrown with its mould into cold water immediately after being cast, another was suffered to cool slowly; when these cylinders were used in place of the prisms, the ends which were uppermost in the moulds being placed under the needle, one part of the curved surface urged the needle to the east, and the other part to the west; these parts were equal in the first cylinder, but unequal in the second. When the other extremities of the cylinders were placed under the needle, then the curved surface of the first cylinder presented four nearly equal portions, which successively turned the needle to the east and west: the second bar presented six similar portions.

The differences remarked between the extremities of the cylinder, and also between the cylinders themselves, when cooled slowly or rapidly, induces M. d'Yelin to conclude there is some relation between the crystallization of metals and their magnetic properties.*

Should the above results be confirmed, they will have a very important bearing on the theory of magnetism. Whatever may be the fact in regard to the experiments just mentioned, it is no less true that the most decided and striking effects are produced when dissimilar metals are used,

* Vide Bibliotheque Universelle, xxiv. 253.

and when their conducting power in rel-
tion to heat, differs considerably.*

The experiments of Becquerel suppo
some of those of Dr. Yelin, and therefo
as the same metal at different temperatur
produces electro-motion, we might in th
way form an electric pile, by having t
opposite ends of a metallic bar heated a
cooled to very different degrees.

* Dr. Yelin has executed a number of exceedin
delicate experiments on the electro-magnetic eff
of alkalies, acids, and salts. The needle used,
nearly one-fifth of an inch long, 008 in diameter,
weighed about half a grain. It was suspended
spider's web, from a rod passing through the to
a glass cylinder, so that it could be raised or low
at pleasure. The bottom of the instrument w
circular card divided into degrees, to indicate
amount of the motion of the needle. The condu
whose state was to be indicated, was sometin
band of tin 0.4 inches broad, and 24 inches
sometimes a brass wire helix, which being bro
up close beneath the needle, formed a kind of
denser, and thus rendered the action more sen
We regret that our confined limits will not p
us to detail some experiments of great in
which were performed with this little contriva

Professor Cumming of the university of Cambridge, England, who has cultivated with much success, the study of thermo-magnetism, has remarked the following curious property when iron is used as one of the metals, in Seebeck's circuit. The deviation of the magnetic needle, when the spirit lamp is applied to the joining or solderings of the two metals, gradually attains a maximum, then returns through zero, and at a red heat, assumes an opposite direction. Antimony and bismuth, exhibit the same thing. With regard to iron, the effects took place when it was connected with silver, copper, gold, zinc, and brass; but not with platinum, or lead, and has not been observed in other cases when neither of the wires or metals were of iron.

We are indebted to Professor Cumming, for the following table of thermo-electrics. When used together, each substance is positive to all below, and negative to all above. The voltaic series, and the order of the conductors of electricity and heat, are added merely to show that the thermo-electric series has no accordance with either.

Thermo-Electric.	*Voltaic Series.*	*Electricity.*
Galena	Charcoal	Silver
Bismuth	Platinum	Gold
Mercury }	Gold	Tin
Nickel }	Silver	Copper
Platinum	Copper	Platinum
Palladium	Lead	Iron
Cobalt	Tin	Lead.
Tin	Iron	——
Lead	Zinc.	*Conductors of Heat.*
Rhodium	——	Silver
Brass		Gold
Copper		Tin
Gold		Copper
Zinc		Platinum
Silver		Iron
Iridium }		Lead.
Osmium }		——
Charcoal		
Plumbago		
Iron		
Arsenic		
Antimony.		

THERMO-MAGNETIC ROTATION.

Professor Cumming in his account of "Thermo-electric phenomena," appears first to have suggested a small combination of silver and platinum wires for exhibiting a rotatory movement about a magnet, somewhat in the same manner as Messrs. Faraday and Ampére had before done, in the case of a galvanic wire, in their experiments on electro-magnetism—instruments which certainly threw more light on the inquiry than any experiments which had till then been contrived. Though the apparatus suggested by Professor Cumming has certainly a tendency to revolve, yet it is so feeble that it would be difficult, if not impossible, to exhibit the effect to a sceptical inquirer, by means of it. The small success attending the use of the contrivance, seems to have been owing to the position of the magnet; for it has been found to produce a much more decided effect when applied to the *exterior* part of the moving apparatus, than when placed in the *interior* of it, as in Ampére's revolving cylinders. This fact seems due to Mr. Marsh, who noticed it while constructing one of Professor Cumming's combinations for his learned, ingenious, and liberal patron, P. Barlow, Esq.* Marsh, to whose ingenuity

* Appended to Mr. Barlow's highly important Essay on Magnetic Attractions, &c. there is a very interesting tract on electro-magnetism. Not having access to this work, we have been obliged to content ourselves with some copious extracts made from it, in our Periodical Journals. The Royal Military Institution at Woolwich, of which colonel Mudge is, we believe, the present lieutenant-governor, and of which Mr. Barlow is a distinguished ornament, is already well known in this country. The lovers of sound science, and genuine piety, will recollect this place, as the residence of Dr. Olinthus Gregory, a man whose extraordinary attainments in the severer sciences, have not chilled the ardour of his devotion, and who, in the midst of pursuits which are not always found to have a propitious effect on the religious character of their votaries, has secured the means of preserving his holy faith in its original purity. We feel no small gratification in thus noticing this bright example of the union of genius, science, and piety, though in doing it, we may have subjected ourselves to the charge of wandering from the subject before us.

we are indebted for our most pleasing experiments illustrating electro-magnetic rotation, has also constructed a variety of apparatus for the exhibition of rotatory motion by thermo-electricity. The first instrument we shall mention, very aptly illustrates the fact first noticed by him, which we have just alluded to.

MARSH'S MOVING RECTANGLE.

The drawing represented on Plate 4, figure 21, will afford a very good idea of the instrument, without much description. The thick or double line represents the silver wire, and the single thin line the platinum wire. They are soldered together and made into a rectangle; a ring being formed below to admit the support on which it is to revolve. A fine steel point is brazed to the upper part of the rectangle, and rests in an agate cap on the top of the support. A bar magnet is then to be placed as near as possible to one side of the rectangle; in the drawing this is represented [illegible] for the sake of ex- [illegible] making the experiment [illegible] should be strong, ought [illegible] placed horizontally. Now, [illegible] being applied to the rec- [illegible] soldered ends of the silver [illegible] opposite to the magnet, the [illegible] will move round, till the heated [illegible] opposite the magnet, it will [illegible] back again, and after a little, will [illegible] position at right angles to the [illegible] lamp. When a second mag- [illegible] to the side where the lamp is [illegible] the first experiment, and then [illegible] be made to heat one angle of the [illegible] continued rotations will begin, [illegible] amount to about thirty revolu- [illegible] a minute. The motion will be [illegible] changing the poles of the mag- [illegible] the magnet is employed as [illegible], and the exterior one is re- [illegible] no case has any strong tendency [illegible] been observed.

MARSH'S COMPOUND RECTANGLE.

The most pleasing exhibition of thermo-electro-magnetic rotation is shown by Marsh's compound rectangles. This instrument is represented on Plate 4, figure 20. The double lines at the upper part of each of the frames, are two silver wires, bent twice at right angles and soldered together in the middle; the lower thin lines are platinum wire, soldered to the ends of the silver wires, and having a ring in the middle through which one of the poles of a horse-shoe magnet is to pass. A point attached by soldering to the centre where the silver wires cross, rests in an agate or cornelian cap placed on each pole of a horse-shoe magnet, as shown in the figure. Now when a spirit lamp is applied between those two rectangular frames, so as to heat their lower angles, the frames begin to move in opposite directions, and will continue to revolve as long as the lamp burns.

Compound rectangles with six branches have also been tried, but there appears to be little or nothing gained by increasing the number beyond four, as in the above arrangement. The length of the rectangles is about two inches, and the depth an inch. In general, the lighter they are made, the greater will be their velocity; yet in no wire is the motion as rapid as that produced in the last experiment.

The motion which is thus produced may be explained on precisely the same theory as that which is applied to electric-magnetic rotation, being reducible to one *simple* effect, and subject to one general law.

THERMO-MAGNETIC MULTIPLIER.

We have before mentioned that in some cases of feeble thermo-electric action, it is necessary to resort to the multiplier in order to render the effect sensible. The multiplier invented by Schweigger, and which we have already described, may, with a little alteration, be applied for this purpose. Suppose, for example, the multiplying wire is of copper, and we wish to try this metal with silver: we take a short piece of thin silver wire, and solder one end of it to one of the multiplying wires, and the other end to the other wire; the whole is then suffered to get perfectly cool. Now, upon altering the temperature of one of the solderings, the needle will instantly decline. So sensible is the combination, that even the heat of the hand is often sufficient to produce the effect. Again, the wire of the above apparatus being still of copper, suppose we desire to ascertain the thermo-electric effects of any two other metals, zinc and antimony, for instance, a short piece of zinc wire is to be soldered to each extremity of the multiplying wire; the apparatus thus prepared will show all the phenomena, as when the whole multiplying wire is of zinc. Now, between the two extremities of the zinc, the bar or wire of antimony is then to be soldered, and the effect is to be estimated as in the last instance. Professor Cumming has made a number of experiments with a multiplier of his own construction;

and on reading the account of his instrument, the self-taught Marsh contrived a very simple and sensible instrument, in which the great inconvenience which always must attend the soldering and unsoldering of the different wires, as in the experiments with the multiplier, is avoided.

MARSH'S GALVANOMETER.

This little machine is represented on Plate 4, figure 23. Two pillars of mahogany rise to the height of about eight inches from the opposite sides of a rectangular block of hard wood, through the top of each pillar a strong brass wire passes horizontally; having each, at its outward extremity, a small brass cup; and to the other extremity of each, is attached, by good contact, the square helix cage shown in the figure. On a line with, and midway between, the two first pillars, there is another, on the top of which there is a fine steel point, carrying a very light and delicate compass-needle, with a card below. From the front of the instrument, there rises a stand for holding a bar of bismuth, antimony, or other metal; and from the extremities of this bar, proceed to the two brass cups, wires of different metals, which are either bound round or soldered to the bar. The brass cups being now rubbed with a little nitrate of mercury, and pure mercury being poured into them, the contact is made or broken at pleasure, by placing the wires in or taking them out of the cups, and the effect thus produced, is shown in the most sensible manner by the needle in the helix. In very delicate cases, the needle may be neutralized by small magnets placed below the foot of the instrument, when east or west, or by inserting them in holes made for the purpose in the mahogany pillars when it is in the meridian. Now by applying the lamp first at one end of the bar, then at the other, then changing the bars, and wires, or altering the size of the wires, &c. all the variety of experiments so judiciously arranged and combined by Professor [illegible] may be [illegible] at pleasure. Mr. C.'s [illegible] communication [illegible] found in the Cambridge Philosophical Transactions, for 182[illegible]. From [illegible] made with the multiplier [illegible] we have arrived [illegible] conclusion, that the [illegible] by different metals as [illegible] by Volta, is not a [illegible] the energy of which [illegible] changes of temperature.

[illegible] has also contrived a [illegible] which appears to be more [illegible] the above instrument. [illegible] them in the use of two needles instead of one; these are equal in size, parallel to each other; magnetized in opposite directions; delicately suspended [illegible] each other, and so managed, that their [illegible] ends may point in opposite directions when under the influence of the multiplying wire.

THE METALLIC PILE OR BATTERY.

Baron Fourier, and Professor Oersted, have instituted a series of experiments to ascertain whether thermo-electric effects might not be increased by the alternate repetition of bars of different metals, so as to construct a true metallic battery, and the result has been fully equal to their expectations. The apparatus first employed, was composed of three bars of bismuth, and three others of antimony, soldered alternately together, so as to form a hexagon, constituting a thermo-electric circuit, which includes three elements. The length of the bars was about four-sevenths of an inch, their breadth 0.59 of an inch, and their thickness about 0.16 of an inch. This circuit was put upon two supports, and in a horizontal position, observing to give to one of the sides of the hexagon the direction of the magnetic needle. A compass needle was then placed below this side, and as near to it as possible. On heating one of the solderings with the flame of a lamp, they produced a very sensible effect on the needle. On heating two solderings, not contiguous, the deviation became considerably greater. When, lastly, the temperature of the three alternate solderings was heated, a still greater effect was produced. They likewise made use of an inverse process, that is to say, they reduced to 32°, by melting ice, the temperature of one or more solderings of the circuit. It is readily conceived that, in this case, the solderings which are not cooled, must be regarded as heated, in reference to the others. This manner of operating allows the different experiments to become comparable; otherwise the laws of this class of phenomena could not be discovered. By combining the action of the ice with that of the flame, namely, by heating the three solderings that are not refrigerating, they arrived at a very considerable effect indeed; the deviation of the needle amounted then to 60°.

They afterwards continued these experiments with an apparatus composed of twenty-two bars of bismuth, and twenty-two of antimony, much thicker than those of the hexagon; and became convinced that each element contributes to the total effect. Having opened the circuit in one point, they soldered to the separate bars, small brass cups, which were subsequently filled with mercury, in order to establish at pleasure a sure communication between their extremities by means of metallic wires. A copper wire, a decimetre in length, and a millimetre in thickness, was nearly adequate to restore the complete communication. With two similar wires placed along side of each other, the communication was perfect. A wire of the same diameter, but more than a metre long, transmitted the current pretty well; while a wire of platinum, half a millimetre in diameter (about $\frac{1}{50}$ of an inch,) and four decimetres long, established the communication so imperfectly, that the deviation of the compass-needle did not amount to 1°. When the interposed body was a slip of paper moistened with a saturated solution of soda, no appreciable effect was observed. It is worthy of remark, that an apparatus capable of affording electro-magnetic effects of such magnitude, produced no sensible chemical action or ignition. They further add, that the effect of the complex electro-magnetic circuit, is much inferior to the sum of the insulated effects, which the same elements could produce when employed in the formation of simple circuits.

Some of the experiments performed by Fourier and Oersted, were made with the two following instruments, and which will afford a very correct idea of all similar contrivances. Figure 26, Plate 4, which for convenience we have placed in the interior of figure 22, represents a small parallelogram, formed by four metallic bars soldered together at their ends; these bars are about five inches long, and about 10.6 of an inch square; the opposite sides are of the same metal; for example, the plane sides are bismuth, and the sides marked with fine transverse lines, are of antimony. This little rectangular circuit being now arranged horizontally on supports with two of its sides in the direction of the magnetic meridian, a delicate needle is to be placed on one of them. The apparatus is then put into action by applying a piece of ice to its opposite angles, and it will be found to occasion a deviation in the needle of from 30° to 31°. In a rectangular circuit formed of the same bars, in different situations, that is, the two adjacent sides of antimony, and two of bismuth, the ice being put on the soldering joining the different metals, the deviation of the needle was only 22 or 23. The temperature of the air must be attended to in these experiments, the higher that temperature is, the greater will be the deviation.

The last instrument to be noticed, is the large parallelogram, figure 22, which surrounds figure 26. Here the metallic bars used are of the same length as the others, but from alternations are made, or from thermo-electric elements, the bars of antimony and bismuth are represented in the drawing as in the last figure. This apparatus was made active by ice being placed on the solderings at every two intervals. The deviation of the magnetic needle was in this case 31¾°. When a rectangular circuit of the same *length* and size with this last was formed, by making two adjacent sides entirely of bismuth, and the other two of antimony, then the deviation was only 13° 15 under the same circumstances in which the compound circuit produced 31¾°. Hence we perceive that the deviations of the needle, produced by the thermo-electric circuit, augment with the number of elements when the length of the circuit remains the same, but that they become feebler in proportion as the length is increased. It is seen, moreover, that these two effects counterbalance each other. Hence the effect of a circuit does not change when the length of its circumference augments in the same proportion as the number of its elements; or in other terms, that elements of equal length, form circuits which produce equal deviations, whatever may be the number of these elements.

These results were confirmed, by comparing the effects of circuits of one, two, three, four, six, thirteen, and twenty elements. In order to form complex circuits capable of producing a very great effect on the magnetic needle, very short elements must be employed. One inconvenience, it is true, will thence arise; the equilibrium of temperature will be rapidly restored in the circuit, unless with regard to the alternate solderings, one be put in communication with a continual source of heat, and the other, with a continual source of cold. The thermo-electric action may be rendered sensible by means of the electro-magnetic multiplier, but the effect is not so good as by the preceding simple arrangement. Hence it is inferred that the thermo-electric circuit contains electrical forces in much greater *quantity* than any hydro-electric circuit of equal size; while, on the other hand, the *intensity* of the forces in the latter circuit is much more powerful than in the other. In the first electro-magnetic experiments it was seen that the deviation of the compass-needle, produced by the electrical current, was regulated by the *quantity* of the electrical forces, and not by their *intensity* (*action électro-métrique.*) The considerable deviation, therefore, which the thermo-electric current produces, is an indication of the great quantity of force which it contains. MM. Fourier and Oersted tried the effect of the complex circuit on the needle of the multiplier, and found that it increased considerably with the number of the elements of the circuit, even in cases where this multiplication of the elements added nothing to the effect on the simple compass-needle. It appears, therefore, that the intensity of the forces increases, in the circuit, with the number of its elements, precisely as happens in the pile of Volta. The circuit had no sensible effect, however, on the needle, when the communication was established by the wire of the multiplier. The thermo-electric circuit afforded no sensible taste, when it was made to act on the tongue; but on a prepared frog, it exhibited the effect of two metals slightly dissimilar. This result shows the electroscopical delicacy of the nerves of the frog.

These philosophers conclude, that the thermo-electric circuit will afford a quantity of electricity incomparably greater than could be derived from any other apparatus hitherto invented.

To sum up the whole, as by means of the common voltaic circuit, water, acids, and alkalies have been decomposed; it is not beyond the limits of probability, to imagine, that by thermo-electric circuits, the metals themselves may also be reduced to simpler forms of matter. Thus the great revolution in chemistry, commenced with the Pile of Volta, may be completed by these new arrangements first suggested by Dr. Seebeck.

DIURNAL VARIATION OF THE NEEDLE PRODUCED BY THERMO-MAGNETISM.

An exceedingly interesting paper on the

variation of the needle, was read to the Royal Society of London in June 1827, by S. H. Christie, Esq. The author having been led to doubt the validity of the moving easterly variation, adopted by Canton, but at the same time having observed that the changes in direction and intensity, appear always to have reference to the position of the sun with regard to the magnetic meridian, was led to connect these phenomena with Professor Seebeck's discovery of thermo-magnetism, and Professor Cumming's subsequent experiments; and to refer the phenomena of diurnal variation, to the effect of partial heating, modified, perhaps, by that of rotation and by peculiar influence in the sun's rays.

In support of this opinion he cites passages from papers by Professor Cumming and Dr. Traill, whom a similar idea appears also to have impressed. But in place of looking to the stony strata of which the earth's surface consists, as the elements of the thermo-magnetic apparatus which this doctrine requires, the author regards them as rather consisting of the atmosphere, and the surfaces of land and water, with which it is in contact. Thermo-magnetic phenomena, he remarks, have hitherto only been observed in metallic combinations; but this may be owing merely to the small scale on which our experiments are conducted.

To put to the test of experiment, whether thermo-magnetism could be excited when the surfaces of two metals instead of touching at one point were in symmetrical contact throughout, the author first employed a compound ring of bismuth and copper, the copper outwards; and he found that to whatever point heat was applied, magnetic powers were developed; a needle being affected differently according to the different positions in which the ring was placed with regard to it. After a lapse of two years from this first experiment, the author resumed the inquiry with an apparatus consisting of a flat ring of copper, having its inner circumferences grooved and united firmly by soldering and fusion to a plate of bismuth cast within it; the whole forming a circular plate twelve inches in diameter, weighing 119 ounces Troy, which was made to revolve in its own plane.

Heat was applied by a lamp to a given point in the circumference of this plate, and a delicately suspended needle, partly neutralized, was placed near it, and the deviations observed in all positions of the heated point, which was made to revolve; the lamp being withdrawn. These experiments led him to conclude that the effect of so heating a portion of the circumference, was to create a temporary polarity in the plate, the law of which he explains. He then details a set of experiments by which he assured himself that a uniformity of action obtained wherever in the circumference the heat was applied. He next instituted a series of observations for determining the laws which govern the magnetic phenomena resulting from the application of heat as above described; the results of which are stated in the form of tables.

Four poles appear to be produced, two north and two south, the north both lying in one semicircle, and the south both in the other, and not in alternate quadrants, and all the poles lying rather nearer to the centre than the line of junction of the two metals. The experiments were pursued in a variety of positions of the plate with respect to the meridian and horizon, and with a similar general result.

From these experiments the author concludes that uniformity of junction of the two surfaces of a thermo-magnetic combination, is no obstacle to the development of transient polarity. Regarding the earth and its atmosphere as such a combination, and limiting our views to the intertropical zone alone, we should have two magnetic poles produced on the northern, and two on the southern sides of the equator, the poles of opposite names being diametrically opposite to each other.

To apply this to the earth, it is necessary to know the times of greatest heat in the twenty-four hours: this may be assumed and minimum variation, which could not but be expected.

The author then considers the manner in which the distribution of land and sea over the globe modifies the point of greatest heat, and in consequence the place of the diurnal poles. He next observes, that at the commencement of the experiments, he had no idea of being able to reduce the deviations of the needle to so simple a law as that resulting from a polarity in a particular direction communicated to the plate; but that he considered it of the greatest consequence, to ascertain whether the deviations on the outer edge of his plate, had the same general character with those within, at the time of junction of the metals; since these situations of the needle would correspond to great elevations in the atmosphere, and points near the earth's surface, respectively, the character of the deviations turns out to be the same in both cases, so that in this respect the hypothesis, so far as is known, agrees with observation.

One general effect of some experiments

with a hollow copper shell filled with bismuth, afforded a striking correspondence with nature. The whole equator being heated, and one part more than the rest, he uniformly found that the elevated pole being towards the north, the north end of the needle deviated when the place of heat was on the meridian above the horizon, and south when below, which is precisely the character of the diurnal variation in north latitudes.

APPENDIX.

A—MAGNETIC PHENOMENA.

I am indebted to the late Dr. J. F. Dana, Professor of Chemistry in the University of New York, for the following clear and concise view of the phenomena of magnetism. Professor Dana was perfectly familiar with all the facts and theories connected with electro-magnetism, and I shall always recollect with pleasure his instructive conversation on this subject. No one of his experience had clearer views of chemical science, was more expert in analysis, or more ingenious in drawing conclusions from facts. His untimely death will ever be lamented by the friends of virtue and science. In this little book, devoted to his favourite pursuit, no apology will be necessary, for this passing tribute to the memory of such a friend. One of the periodical journals in New York, speaks of his death in the following terms:

"We were sensibly shocked to-day, (15th of April, 1827,) in receiving the melancholy, and to us, most unexpected, notice of the death of Professor Dana. It is so few days since we were listening, among many others, to one of his admirable lectures on chemistry—he was then, apparently, so full of health, and life, and intelligence, that the fearful truth of his sudden decease seems scarcely credible to us. It is, however, one of those startling realities that laugh to scorn the calculations of human presumption, and almost make a mockery of the affections of the heart, when lavished upon beings so frail and transitory as we are all."

There is a mineral substance, called the loadstone, which possesses the property of attracting iron filings, and these adhere to different parts of it in greater or less quantities: they are particularly accumulated at two opposite points, and stand, as it were, on end. The mineral, an ore of iron, which possesses this property, is said to be magnetic, and its properties to depend on magnetism. The points around which the iron filings are accumulated, are called *magnetic poles.* We are entirely ignorant of the nature of magnetism. The phenomena presented by magnetized bodies have been explained on the supposed existence of a magnetic fluid or fluids.

The magnetic influence may be communicated by the loadstone to some metallic bodies, particularly to iron and steel, and it is exerted through water, glass, metals, flame, &c. &c. A steel bar, which has been rendered magnetic by the loadstone, or by other methods, is called a *magnet;* and if it be suspended by a filament of silk, so as to move easily in a horizontal plane, it does not turn indifferently to every part of space, but takes a direction nearly north and south. A small magnetized steel bar, delicately mounted on a central pivot, is called a *magnetic needle.* In some places, the north end of the needle deviates from the true meridian towards the east, and in other places towards the west, and sometimes to a very great degree; this deviation is called the *declination* of the *magnetic needle*, or *variation.*

The vertical plane in which the needle directs itself is called the *magnetic meridian.*

If the north extremity of one needle be presented to the north extremity of another, it repels it; but if to the south extremity, it attracts it; and the south extremity of one needle repels the south, but attracts the north extremity of another. Hence the two polar extremities of a magnet or needle are dissimilar; the one attracts what the other repels, and *vice versa*.

When a magnet or loadstone is brought near a magnetic needle, the two poles act at once on it; but the pole which is nearest acts most powerfully, and the needle turns towards the magnet that pole which is most strongly attracted, and averts the one which is repelled. After the needle has taken a position of equilibrium, if we turn it ever so little from its place, it returns to it again, by a series of oscillations, in the same manner as a pendulum, pushed from the perpendicular line, returns to it again by the attraction of gravitation. A similar motion takes place in a magnetic needle turned ever so little from its magnetic meridian, so that the earth acts on a magnetic needle like a true magnet or loadstone; and the magnetism residing in the southern hemisphere is called *austral magnetism*, and that in the northern hemisphere *boreal magnetism*. Hence, as dissimilar magnetisms attract each other, we must suppose the extremity of the needle which ... the north is charged with *austral* *magnetism*, and the opposite pole with *boreal magnetism*.

Take a steel bar, and suspend it delicately by an axis in the middle between the two ends, so that it may move easily, but in a vertical plane only; if the bar be now carefully magnetized, it will not in this latitude remain any longer in a horizontal position; but the end which possesses the *austral* magnetism will decline downwards, and after a few oscillations will rest at a determinate angle with the horizon: this angle is called *the dip of the needle*, and is very different in different places; the apparatus by which it is ascertained, is called the *dipping needle*, in which the needle probably points to the magnetic pole of the earth. Near the equator is a zone where there is no dip; to the north of this zone, the extremity of the needle charged with the *austral* magnetism declines from the horizontal; and to the south of this zone the opposite extremity declines. The poles of the earth and of a magnet can be considered only as *centres of action*.

A piece of soft iron held near a magnet, becomes itself a temporary magnet: this phenomenon is analogous to electrical excitement by induction; and that part of the iron which is nearest the magnet assumes

B—ON THE MANIPULATIONS OF THE GALVANIC BATTERY.

It was our intention to give in this place some directions for the use of the galvanic battery, not only in reference to electro-magnetism, but to chemical experiments generally; but on this subject we shall obtain the approbation and thanks of our readers, by substituting an article from Mr. Faraday's Chemical Manipulation, a work which we have just received from London. Mr. Faraday, it is well known, is the principal manipulator in the Royal Institution at the English capital, where, perhaps, the largest galvanic apparatus in the world is to be found; his opportunities, therefore, on this subject, are unparalleled, and the clear and simple manner in which he details the minutiæ of the operations, cannot be surpassed. Mr. Faraday has enriched chemical science with many brilliant discoveries; it will in particular be remembered, that we are indebted to him for the first instrument for exhibiting electro-magnetic rotation. As directions respecting the manipulation of the galvanic apparatus, appear to us to be much wanted in this country, even among gentlemen tolerably versed in the operations of the laboratory, we have not hesitated to republish a large part of the article on the subject, from Mr. Faraday's work.

Great variety in the forms of the voltaic pile, trough, or battery, have been introduced at different times, of which a knowledge may be obtained from elementary works on Chemistry or Electricity, and from particular memoirs on the subject. The information here to be conveyed does not concern these varieties of form, so much as the management, by which they are to be rendered serviceable and effectual, in the performance of experiments. This management, though to be spoken of generally, will be described with reference, principally, to the ordinary form of the apparatus, in which the plates being arranged in sets of ten each, and fixed to a bar of wood, are inserted into earthenware troughs, like those suggested by Dr. Babington.

Troughs are usually charged with a diluted mixture of acids, which, when the plates are immersed, confers power and activity upon the arrangement. A mixture of a proper strength is obtained by adding two parts in bulk of oil of vitriol, and one part of common nitric acid, to 100 parts of water, the whole being stirred together until well mixed. Its power should, in all cases, be ascertained before it is poured into the troughs, by dipping a piece of clean zinc into a little of it in a glass, and observing the degree of action exerted upon the metal. A stream of bubbles should be disengaged so small that their size can hardly be distinguished by the naked eye, and which, as they rise up through the fluid, should be carried freely in different directions by the currents in the fluid itself. If the action be so strong as to evolve bubbles of a considerable size, which rapidly rise to the surface, and are numerous, the acid must be diluted. If, on the contrary, little or no chemical action can be perceived, the charge must be strengthened by the addition of acid.

The cells are to be filled to within half an inch of their upper edges; when the plates are in their places the mixture should not flow from one cell into another. The fluid in the cells may be levelled and made equal in all by raising the trough on one side, so that the liquid may flow from one cell into another over the divisions; its passage from the trough, is prevented by the height of the edges of the latter all the way round, above the level of the divisions.

This superior height of the edges of the trough, is attended to in all constructions of voltaic apparatus with cells, whether formed of earthenware, or whether the cells are made by the plates themselves, set at equal distances, and cemented into a trough of wood.

When the plates of the battery are separate from the troughs, and are to be immersed after the latter are charged with fluid, great care is necessary that they be properly introduced; the zinc and copper plates of two contiguous pairs are to be placed in the same cell, but not the zinc and copper plates of the same pair. There is no fear of erring on this point with Wollaston's double coppers; but when the copper plates are single, considerable risk of this kind is incurred. It is also essential that the plates be arranged in the same relative position, i. e. all the zinc plates in one direction, and all the copper plates in the other. When by accident 10 pairs of plates are turned the wrong way in a battery of 100 or more, they do considerably greater harm, than merely results from the loss of their own power, and the neutralization of that of 10 other pairs. It is always adviseable so to arrange a battery, that whatever the number of troughs may be, the two extremes of the series should be within two or three feet of each other. The troughs may stand very well on dry boards; and no material loss of power will occur, if, in the convolution of the battery, the rows are two feet apart, unless indeed the series be very extensive. Damp ground or damp boards occasion considerable loss in the power of extensive batteries, especially if the intervals between the rows are small, and the wires of communication for the experiments thin and long.

When the battery is charged, and the plates immersed in the acid, the good order of the whole is to be ascertained by fastening two wires to the extreme plates, to serve as poles, twisting their ends round two pieces of well burned box-wood charcoal, and bringing these together. An immediate discharge of electricity will take place, producing an exceedingly brilliant spark of light, which will be larger or smaller in proportion to the size and power of the battery. If, therefore, it be wanting altogether, or by no means equal to what was anticipated from a trial with a single trough in the same manner, then the obstruction, or whatever it may be that interferes, is to be sought for by the following method.

A piece of copper wire about the $\frac{1}{20}$th of an inch in diameter, and four or five feet in length, is to have one end twisted round a piece of box-wood charcoal, and the other brightened; then beginning at one extremity of the battery, the bright end is to be pressed tightly against the last plate with one hand, whilst by means of the other, the corner of some plate, as far off as can conveniently be reached, is to be touched with the charcoal at the opposite extremity. If the spark be as brilliant as could be expected, it will prove the perfection of the arrangement in the portion tried. The bright end of the wire is then to be brought to the plate last touched, and a second portion of the battery tried in the same manner, until the whole has been tested. If, during the trial, the discharge of any portion seems imperfect, or is altogether wanting, then keeping the bright end of the wire against the plate with which it was in contact at the time of the failure, every fifth or sixth plate is to be tried backwards with the charcoal, which is to approximate, at each remove, that to which the bright end is applied, and it will be found that on a sudden the discharge is effected, though with less force, because of the smaller number of plates between the ends of the wire. Whenever this discharge occurs, it points out the place where, from some derangement or untoward circumstance, the obstacle to the action of the battery, exists.

The battery is to be examined at this point, and it will be found that a plate is in the wrong trough; or that acid is wanting; or that a wire lies across to some other part of the arrangement; or that the metallic communication is bad, the zinc plate being either broken or injured by corrosion; or some other cause for the obstruction will be found. This must be removed, or if it be of such a nature that it cannot immediately be corrected, either the trough where it occurs must be rejected, or a good metallic connexion by thick copper wire must be made between the plates on different sides of the obstruction, so as to allow an efficient and concurring action, of the rest of the battery. This trial of the battery need not necessarily be made on portions of four or five feet, but when from the convolution of its course an opportunity is offered of connecting the battery across, more extensive portions may be tried, as for instance one half at a time, and thus the half containing the obstruction may be at once discovered.

The charcoal used in these and similar

experiments, with the voltaic battery, is made from box-wood, which being cut into pieces, having a length of two inches, and a thickness of about a quarter of an inch, are to be charred in close vessels. The wood may be packed in an earthenware crucible, and being covered with dry sand, should be heated until it ceases to flame. Although the greater part of such charcoal will conduct electricity almost as well as metals, some pieces will probably fail. Before being set aside, therefore, for use, it should be examined by a single trough, a wire being brought from each end of the trough against the opposite ends of each piece of charcoal in succession. Such as easily conduct the electricity and yield a brilliant spark, are to be preserved in a stoppered bottle; those which afford a small spark, or do not act, should be rejected.

When two or more troughs are to be connected, and the instrument maker has not furnished the necessary means, or attached them to the sets of plates, the arrangement should first be examined to ascertain that the plates of both troughs are placed in the same relative position and order; when that is the case they may be connected, and considered but as one trough. The connexion should be made by a single, culiar situations, such a bend must be given to the wires that they may act as springs and press against each other. It is often advantageous to amalgamate the surface of these ends, for then, if they be moistened with a little mercury, the fluid metal causes a perfect contact over a comparatively large surface at the point where the wires meet, the moment they are connected together.

Clean copper wires are readily amalgamated on the surface, by washing them with a solution of nitrate of mercury, then washing them in water, and afterwards dipping them in mercury. When the experiments are of long continuance, it is convenient to put about a quarter of an ounce, in bulk, of mercury into a cup or glass, with half an ounce by measure of moderately strong solution of nitrate of mercury; on cleaning the curved end of the wire a little, dipping it into the nitrate, and moving it about in contact with the solution and the metal beneath, it will quickly amalgamate, after which it should be removed into another glass containing water, with a little mercury at the bottom, the adhering solution washed off, and the wire dried by a piece of bibulous paper. This method is very convenient for insuring the amalgamation and perfect contact of chain or link joints, by which the necessary mobility of part of the metallic communication in electro-magnetic experiments is attained. The ends of wires thus amalgamated, if not well washed, frequently oxidate, and become covered in a few days with a thick crust of badly conducting matter. If, from the duration of the experiments, this be inconvenient, the wires should be amalgamated, not by nitrate of mercury, but by the use of a little tallow and metallic mercury, putting the tallow, with a few globules of the metal, on a piece of chamois leather, and rubbing the wire with it until the adhesion is effected. Wires thus prepared do not tarnish or become foul, nearly so soon as those prepared in the former method.

Where flat surfaces are to be brought into contact, the intervention of a little mercury is very useful, but the surfaces should previously be well cleaned, and if amalgamated, the contact is more secure. A cup of mercury is also convenient for making metallic communications, which require to be broken frequently, for which purpose the ends of the two wires to be connected should be cleaned, amalgamated and dipped into the metal. The wires may be readily arranged, so that one may be displaced and restored, without the slightest shake or disturbance of the apparatus, and the perfection of the contact is insured every time the wire is replaced.

The importance of these four points, namely, accurate metallic contact; sufficiency of thickness in the conducting wires; their shortness; and also extent of surface where a good conductor and a bad one are in contact, should never be forgotten in practice; and though one or the other, or most of them, may now and then be of little consequence in particular experiments, yet attention to them is always useful, and often essential. This is especially the case in electro-magnetic experiments, where electricity in great quantity, but of low intensity, is frequently the subject of investigation. One person will not be able to perform electro-magnetic revolutions and motions with five or six troughs, which another, by attention to these circumstances, will effect with a single pair of small plates.

In all experiments with large batteries, it is adviseable to retain only one of the poles in the hand at a time, unless indeed they are previously in communication with each other by good conducting matter, or by large surfaces and masses of badly conducting substances. The pole-wires should be preserved distinct from each other in all parts of their course, so that no accidental discharge and consequent waste of power, may take place between them. For this reason both should not be allowed to come in contact with the same piece of metal or wire, or connected by good or even moderately conducting matter. All their energies should be preserved unimpaired until they are exerted upon the substance placed purposely for decomposition between their extremities.

In all cases the experiments should be prepared as far as possible *before* the battery is put into action, that none of its power may be unnecessarily wasted during such preparation.

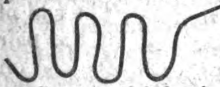
The plates of a voltaic battery should be removed from the action of the charge at every considerable intermission of the experiments. The acid rapidly dissolves and destroys the zinc plates during the time it is in contact with them, and though the degree of action may not be of such importance as to justify the raising of the plates during the cessation of experiments for a minute or two, or even for a longer time in particular circumstances, yet they should never unnecessarily be left to the action of the charge, when the electricity they evolve is not actively employed on other bodies. When five or ten minutes intervene between one experiment and another, it is worth while raising the plates of a battery of ten or twelve troughs, or less, from the cells; this affords the additional advantage of an increase of action upon their re-immersion, due in some way to draining or exposure to air. Instrument-makers sometimes hang the plates to a frame, which being suspended by a cord, and connected with a lever, allows the whole to be raised or depressed at pleasure; and Dr. Hare has constructed a trough, in which the cells being formed by the metallic plates, the charge is poured on and off at pleasure, by a quarter revolution of a handle.

Although it is highly advantageous to operate with a large battery, as for instance of 100 pair of plates four inches square, when such can be had, and when the object is to render the experiments and other results evident at a distance, yet such a power is by no means always necessary. Even the repetition of the most refined and admirable experiments may be made with a battery no way comparable to one of this size, if the object of the experimenter be only to satisfy himself or those close to him, and if he use the precautions as to contact, vicinity, &c. already given. A single trough, of ten pairs of plates four inches square, will suffice to repeat nearly all the experiments that have yet been made on the decomposition of bodies in solution, and all those relating to electro-magnetism. Nor is it essential that a greater power should be used in many new investigations. In the same manner a small trough with 40 or 50 pairs of plates, one inch square, will be found a very useful instrument in a laboratory not affording the opportunity of working with a larger arrangement; and the habit of experimenting with small apparatus, and on a minute scale, is highly valuable for the independence, which it gives to the philosopher, of larger, more expensive, and consequently scarcer instruments.

Where copper and zinc in sheets can be obtained, a voltaic arrangement may easily be constructed. They are to be cut into single plates of equal size, two inches square for instance, and are then to be arranged as a pile with equal sized pieces of flannel dipped in dilute acid in the order zinc, flannel, copper; zinc, flannel, copper; zinc, flannel, copper; until twelve or more pairs of metallic plates have thus been put together. Such an arrangement should be made in a plate, that any acid exuding from it may be caught and retained. The surfaces of the contiguous metallic plates should be clean, that the contact between them may be good. To insure this, it is convenient to solder the plates together at their edges into pairs, each comprising a zinc and a copper plate. On building these up with the intervening flannels, the order will be copper, zinc, flannel; copper, zinc, flannel; copper, zinc, &c. The wires, which, when attached to the top and bottom of this pile, serve as its poles, should be clean and in good contact with the end plates, and then a pile of twenty of these pairs will be found to have very considerable power, and will be competent to the performance of a great number of experiments.

The nature of the poles of an ordinary battery may be determined by inspection of any one of the pairs of metallic plates employed in its construction. The end of the battery on the zinc side of the pair examined is the positive pole; the end on the copper side of the same pair is the negative pole. This holds good wherever the pair may be in the battery, or however far the ends may be removed.

Electro-magnetic, and many other experiments relative to the transmission of electricity through good conductors, such as the metals, and the effects produced thereby, often require for their performance voltaic arrangements, consisting of a few large plates rather than many small ones. It is easy to arrange the ordinary troughs, consisting of ten pairs of plates four inches square, so as to produce intensity or quantity at pleasure. Thus if four of these troughs were to be used for chemical experiments, it would be best to place them end to end in their proper order, so as to form a battery of forty pairs of plates four inches square, connecting them, if necessary, in the manner described: but if large plates and few in number be more advantageous, then these four troughs may be arranged so as to form a battery equivalent to one of ten pair of plates eight inches square. For this purpose, they must be placed with their sides together, their similar ends being in the same direction; and they should be connected by two thick pieces of copper wire, bent



according to the figure, in such a manner, that the lower angles of one piece will enter the four terminal cells at one end of the

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... of plates is sufficient for ... ance of nearly all electro-mag- ... riments, and a combination of ... may be constructed with great ... by those who possess a piece of ... e and a piece of plate copper. ... require merely to be put near each ... in a jar or vessel of dilute acid, and ... ected by a wire. The plates may be ... veniently tied together with a couple ... ieces of glass rod, or tobacco-pipe, be- ween them, to prevent metallic contact. ... hick wire, a few inches in length, should ... attached to each plate, to act virtually ... he poles, (though they are not really ... s according to the usual acceptation of ... word in voltaic electricity,) and these ... s or poles should be connected by the ... mental wire, which, though thinner ... e former, should not be unnecessa- ... This arrangement has been de- ... s formed of flat pieces of zinc and ... e, but any shape may be given ... that their relative position is the same: they may be coiled; or even a copper vessel may be used instead of a copper plate, and then the jar for containing the acid may be dispensed with altogether.

The double copper arrangement described by Dr. Wollaston, is excellent for ordinary experiments, and may easily be constructed. It consists of a plate of zinc surrounded on both sides by a plate of copper, so that a surface of the latter is brought into opposition with both surfaces of the zinc. This arrangement when immersed in acid is very powerful; a zinc plate of less than an inch square being able to effect the ignition of fine platina wire, the deflection of the magnetic needle, and most of the electro-magnetic experiments.

It is necessary the student should be informed that instruments consisting of a single pair of plates, have no chemical action.

A very usual problem which the chemist has to solve, is, whether a substance be a conductor of electricity or not, or what is the degree of conducting power which it possesses with regard to electricity. Whether it conducts like a metal or not may be ascertained in the following manner. If a piece of zinc and a piece of silver be placed one above and the other below the tongue, and the edges be then brought into contact, a peculiar taste will be perceived at the moment, which will be repeated every time the contact is broken and resumed. If instead of bringing the zinc and silver in direct contact, a piece of metal, as a wire, intervene, the taste will still be perceived; but if the interposed substance be a body not metallic, or one of those numerous substances which, though they conduct electricity, are less efficient than the metals, a piece of wet paper for instance, a piece of starch, or even a piece of galena, then no taste will be occasioned. The experiment should, therefore, be made first with the zinc and silver, and having succeeded, the substance to be tried should be placed between the two metals, and the attempt repeated; the production or non-production of taste will immediately indicate whether it conducts electricity or not. All the pure metallic bodies, and all combinations of them with each other, conduct electricity so well as to occasion the taste; but as yet no other substance has been ascertained to do so, nor even any of the definite compounds of metals with other substances, as sulphur or oxygen. Dr. Wollaston's method of preventing accidental contact of the zinc and silver on one side of the substance to be tried is very useful: it is to cut a hole in a piece of card, and lay the doubtful body in this hole between the other metals; its contact and retention in its place is secured, and the accidental contact of the known metals, perfectly prevented.

Evidences of the conducting power of solutions and transparent fluids are of the following kind. If on placing a small portion between the voltaic poles, gas be evolved, or metals or other substances separated, or any change effected which would not have taken place by mere contact of the liquid and the metal of the pole distinct from the battery, such action is a proof that a current of electricity is passing, and consequently that the fluid is a conductor: and the energy of the action is to a certain degree an indication of the degree of conducting power. A small voltaic battery is sufficient for this purpose.

It is, however, possible, though not usual, that no apparent change may take place, notwithstanding the body is a conductor, equally good with those fluids which suffer decomposition; this is the case with fluid chlorine. In such instances, besides the portion of fluid to be tested, there should be in another vessel a portion of a solution of salt; one of these should be connected with one pole of the battery, the other with the other pole, and a piece of platina wire should be bent so as to dip into both portions of fluid, and its ends should be brought near to the ends of the poles *immersed*. There are thus two portions of matter ready to be decomposed by the electric current: if the decomposition is seen by the liberation of gas to proceed in the solution of salt, it is a proof that the other fluid is a conductor of electricity sufficient for this purpose: if no decomposition take place in the solution, then the other fluid will not permit voltaic electricity of this intensity to pass, and is in that respect a non-conductor.

The same kind of trial serves for such solid bodies as are not comparable to metals with regard to this property, they being then substituted for the liquid in this experiment, and the solution of salt acting the part of a test as before. It will in this way be found that several of the native and artificial compounds of the metals and other bodies conduct electricity, though by no means with a readiness sufficient to answer the test of taste first proposed.

Again, there are very many substances

which, though so inferior in conducting power as to appear perfect insulators by these modes of trial, will yet show many degrees of it by more powerful tests, that is, by electricity of higher intensities. These are generally classed amongst very bad conductors, and are most readily examined perhaps by the gold leaf electrometer. If the electrometer be diverged, and its cap then touched by any substance held in the fingers, or at the end of a wire, it will be discharged, and the leaves collapsed with more or less rapidity, according to the conducting power of the substance. If the leaves retain their first divergence, it is a proof of the entire absence of conducting power as far as our tests usefully extend. For the application of this method to a liquid, the latter should be placed in a convenient vessel, a capsule or tube for instance, connected by a wire, or the hand with the earth, and then a piece of bent wire, well insulated by a stick of sealing wax or gum-lac, is to be made to touch the cap of the electrometer by one end, and the surface of the fluid by the other. If the leaves collapse entirely, it is a proof that the fluid conducts electricity.

M. Rousseau has devised a very ingenious variation of this test. He brings one

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Although the great use of the voltaic pile is to effect chemical change by means of the peculiar power of its poles, it is often otherwise applicable. When the discharge of a powerful battery is made through air between two pieces of charcoal, the heat ... intense, and is extended over a ... than when the discharge takes ... pieces of metal. To ... may be subjected ... made, and the ... d. Carbu- ... re thus decomposed. Other gases examined in the same manner would probably present peculiar phenomena.

By transmitting the voltaic current through thin wires, they are heated, ignited, and fused. This effect supplies a means of conveying, or rather of producing and applying, heat in situations in which it could not otherwise be excited, and thus facilitates certain refined experiments. Substances, having wires passed through them, may be placed within globes under water, or in remote situations, and then be heated, ignited, and exploded: eudiometers have been constructed, in which a fine wire passing across the cavity, has been ignited by a voltaic battery, and thus used to inflame the included mixture of gases.

The *insulation* of substances is frequently required in electro-chemical investigation, and numerous methods must be resorted to, according to the circumstances of experiments. When an insulating plane is required, a plate of mica is the best substance for the purpose, then a plate [illegible] resin or wax, or, in their absence, a plate [illegible] glass. In all similar insulations, [illegible] to be supported should be [illegible] from the edges of the insu- [illegible] to be independent in its

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further in the north or south; so that these unusual agitations of the needle may be considered as a proof of the existence of the meteor, and may, perhaps, be regarded as a consequent of it. By comparing observations on the above phenomena, made at the same time, but at places very distant from each other, it has been found that the variations of the needle are seen in the instant. It appears also, that their violence and rapidity depends on the brightness and intensity of the aurora; a low and faint glimmering towards the northern horizon usually produces only a very slight, and almost insensible, disturbance of the magnetic needle. When the meteor is very high and the principal focus is in the plane of the needle's direction, commonly called the plane of the magnetic meridian, then the motion is also very inconsiderable. When the corruscations of the aurora, or the phosphoric jets, as they have been called, are numerous, the atmosphere being calm, or only agitated by a steady breeze, the meteor is almost always disposed in one or several concentric arcs, resembling those of the rainbow, sometimes white, and sometimes tinged with the brightest colours. The common centres of these arcs, and their summits, are usually in the magtain physiological effects on the nerves and muscles, and lastly, actions on other electric currents, and on magnetic bodies.

D—AURORA BOREALIS.

The supposed relation subsisting between the auroras at the poles of the earth, and electro-magnetism, will render it proper to say a few words on this subject. Numerous observations have demonstrated, that the magnetic needle is often subject to sudden and irregular variations during the appearance of the aurora borealis. These variations are sometimes but of short continuance; so that after the needle has been thrown into rapid agitation, during the continuance of the meteor, it resumes its ordinary position and recovers its wonted motions. It, however, sometimes happens, that the variation, or deflection, is permanent. It has also been remarked, that there are instances in which the needle is apparently under the influence of the aurora, when no meteor is to be seen at the place where the variations occur. But in such cases we always find, that the meteor has presented itself with more or less distinctness, either at the same moment, or a few hours before or after, in some places farther to the north or south; so that these usual agitations of the needle may be considered as a proof of the existence of the meteor, and may, perhaps, be regarded as the precursor of it. By comparing observations on the above phenomena, made at the same time, but at places very distant from each other, it has been found, that the variations of the needle have been the same. It appears also, that their violence or rapidity depends on the brightness and extent of the aurora; a low and faint glimmering towards the northern horizon usually produces only a very slight, and almost insensible, disturbance of the magnetic needle. When the meteor is very high and the principal focus is in the plane of the needle's direction, commonly called the plane of the magnetic meridian, then the motion is also very inconsiderable. When the corruscations of the aurora, or the phosphoric jets, as they have been called, are numerous, the atmosphere being calm, or only agitated by a steady breeze, the meteor is almost always disposed in one or several concentric arcs, resembling those of the rainbow, sometimes white, and sometimes tinged with the brightest colours. The common centres of these arcs, and their summits, are usually in the mag-meridian of the place where they are seen. This coincidence with the meridian has been remarked, ever since any accurate observations have been made, although during this time, there has been a considerable variation in the direction of the magnetic meridian. It sometimes happens that the corruscations, or phosphoric fires, breaking forth from all parts of the horizon,—from the east, the west, and the north,—ascend, or seem to ascend, vertically over the head of the observer, even to the zenith; and having passed this point, they form by their union a brilliant crown, the centre of which is some degrees lower, near the south. Now if we determine the apparent position of this crown, either by astronomical instruments, or by observing what stars are comprehended within it at the time of the formation, we shall find that its centre, in every place where it has been observed, is always exactly in the direction of that point in the heavens, to which the magnetic needle is directed, when suspended by its centre of gravity, in such a manner as to admit of perfect freedom of motion.

These appear to be the principal facts which have been accurately observed. They have been derived from Biot's admirable Précis Elémentaire de Physique. Biot had an opportunity of verifying most of the particulars here mentioned, during his visit to the Shetland Islands, in 1817. In a work which I published a short time since, entitled Astronomical Recreations, I have given an account of a splendid aurora, seen by me some years since when at Albany, New York. On a late visit, I had also an opportunity of examining an aurora, similar to the one seen by Mr. Biot at the Shetland Islands; I shall here add the account of it, which was written on the spot.

On the evening of the 28th of August, 1827, about twenty minutes before ten o'clock, a remarkable and splendid meteor made its appearance.—When first noticed, it had the form of a broad brilliant arch or zone, of white or rose coloured light, traversing the heavens from east to west. The eastern end of the arch approached the horizon near the Pleiades, and the western end between Arcturus and Ursa Major; the middle of the arch was a few degrees from the zenith. The light in those portions of the zone nearest the horizon, was at first much the most dense, and well defined; but in a short period, the light gradually accumulating in the east and floating towards the west and south, *the whole zone* became distinct, regular, and splendid. About half after ten, this beautiful aurora appeared the most perfect; at this time the zone, which was four degrees in its broadest part, had expanded, *so as* to divide the heavens nearly *into two* equal portions, and a tremulous, undulatory motion from east to west could be observed. The eastern end of the arch, which from the time of its first appearance, was much narrower and denser than the western, now began to diminish, fade, and rise above the horizon, and shortly after the whole meteor slowly but visibly moved towards the west and south, enlarging in breadth, and diminishing in lucidity as it progressed. About eleven o'clock the zone, which before was a continuous surface of light, now separated into small narrow bars, a clear blueish sky appearing between each bar, having somewhat the appearance of the palings of a garden fence. At twelve o'clock the meteor had entirely vanished. The heavens during the continuance of the meteor were clear, and stars of the second magnitude could often be seen through its edges. A fine aurora borealis, with beautiful corruscations, was visible immediately after the meteor, and a faint one during the whole time of its continuance.

A luminous appearance something like the one we have just described, is mentioned in the memoirs of the Connecticut Academy, vol. 1, p. 137.

I regret very much, not to have noticed the commencement of this meteor, but I learn from those who witnessed it, that its first appearance, was similar to that examined by Biot, at the Shetland Islands, *exactly* ten years before. First, the north-eastern parts of the horizon were illuminated with slender jets of light, which soon becoming stronger, more brilliant, and more extended, shot into a broad column of white clear light; after a little, a broader though not so luminous a column, appeared in the western region of the sky, which meeting the first, formed the bow as it appeared when I first saw it. In company with my early friend, Dr. T. R. Beck, the learned author of the work on Medical Jurisprudence, I examined the influence of this meteor on the magnetic needle; but notwithstanding the vividness of the meteor, and the size of the needle, which was about seven inches, no perceptible deflection could be perceived.

Polar lights and auroras somewhat si-

Provide a flat brass plate, with an opening in the centre; into the circumference are screwed, or soldered, several rods of the same length and diameter, but if different metals, the ends of the rods are flattened to receive each a small piece of phosphorus. This plate is then to be placed over a spirit lamp, after the phosphorus has been applied to the ends of the different metallic bars. By this arrangement it will be seen that the plate will be equally heated, and the relative conducting power of the different rods will be shown by the inflammation of the phosphorus at their extremities. If six rods be used, viz. a silver, a copper, a tin, a zinc, an iron, and a brass rod; the phosphorus on the end of the silver rod will take fire first, because it is the best conductor of caloric; then that on the copper and the tin, which are nearly equal; and, last of all, that upon the leaden rod.

That the passage of caloric through a metallic rod is gradual, or that it is successively propagated from the particles which are nearer the heated body than to those which are more remote, may be shown by screwing a long rod into the circumference of the plate, and placing upon it two pieces of phosphorus, one piece on the extremity farthest removed from the plate, and the other piece on the middle of the rod; this last piece of phosphorus will take fire much sooner than the other.

While on this subject, I will mention that my friend, Dr. De Butts, of Baltimore, has a very neat way of exhibiting to his class, the increase of temperature, produced by mixing cold sulphuric acid and water together. A watch crystal, containing a small piece of dry phosphorus, is floated on the surface of water in a convenient glass vessel; sulphuric acid is then to be added, and upon stirring them together, the phosphorus inflames by the heat thus produced. This is a much more striking manner of exhibiting the fact, than the boiling of ether in a glass tube, which is sometimes resorted to.

F—MATTER AND MIND.

The following passage from Dr. Gregory's letter to a friend, on the Evidences, Doctrines, and Duties of the Christian Religion, should have been referred to in our note at page 128.

No person can look into the world with the eye of a philosopher, and not soon ascertain, that the grand theatre of phenomena which lies before him, is naturally subdivided into two great classes of scenery: the one exhibiting constrained, the other voluntary motion; the former characteristic of matter, the latter as clearly indicating something perfectly distinct from matter, and possessing totally opposite qualities. "Pulverize matter, (says Saurin,) give it all the different forms of which it is susceptible, elevate it to its highest degree of attainment, make it vast and immense, moderate or small, luminous or obscure, opaque or transparent, there will never result any thing but *figures;* and never will you be able, by all these combinations, or divisions, to produce one single sentiment, one single thought." The reason is obvious: a substance compounded of innumerable parts, which every one acknowledges matter to be, cannot be the subject of an individual consciousness, the seat of which *must* be a simple and undivided substance: as the great Dr. Clark has long ago irrefragably shown. Intellect and volition, are quite of a different nature from corporeal figure, or motion, and must reside in, or emanate from, a different kind of being, a kind which, to distinguish it from matter, is called spirit, or mind. Of these, the one is necessarily inert, the other essentially active. The one is characterized by want of animation, life, and even motion, except as it is urged by something *ab extra;* the other is living, energetic, self-moving, and possessed of power to move other things. We often fancy, it is true, that matter moves matter; but this, strictly speaking, is not correct. When one wheel, or lever, in a system of machinery, communicates motion to matter, it can, at most, only communicate what it has received; and if you trace the connexion of the mechanism, you will at length arrive at a first mover, which first mover is, in fact, *spiritual.* If, for example, it be an animal, it is evidently the spiritual part of that animal from whence the motion originally springs. If otherwise, if it be the descent of a weight, or the fall of water, or the force of a current of air, or the expansive power of steam, the action must be ultimately referred to what are styled powers of nature, that is, to gravitation or elasticity; and these, it is now well known, cannot be explained by any allusion to material principles, but to the indesinent operation of the Great Spirit, in whom we live, and move, and have our being—the finger of God touching and urging the various subordinate springs, which, in their ture, move the several parts of the universe. Thus God acts in all places, in all times, and upon all persons. The whole material world, were it not for his Spirit, would be inanimate and inactive; all motion is derived either from his energy, or from a spirit which he animates; and it is next to *certain*, that the only primary action is that of spirit, and the most direct and immediate that of spirit upon spirit.

INDEX.

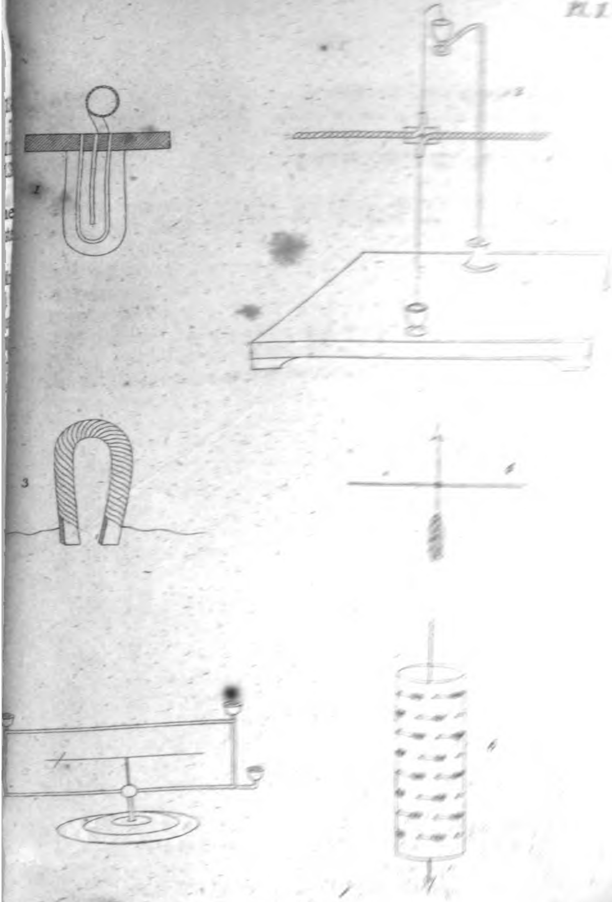
DESCRIPTION OF THE PLATES,

WITH REFERENCES.

For the drawings of the apparatus from which the engravings were made, I am indebted to the taste and skill of my friend, William Stewart, Esq.

Most of the above instruments were made by Mr. Benjamin Pike, of New York, who has devoted a good deal of attention to this subject, and of whom they may be obtained at a moderate expense. Mr. J. Saxton of this city, an artist of great ingenuity, can also furnish most of those which are described.

Pl. I.



Pl. 3.

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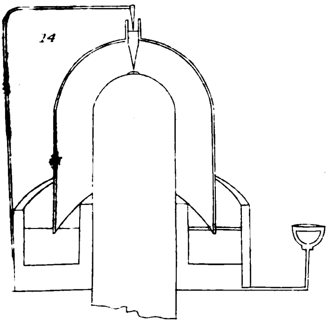

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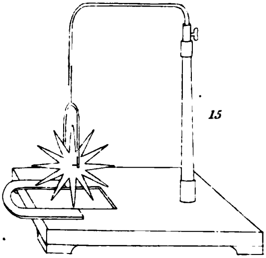

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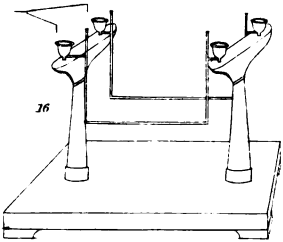

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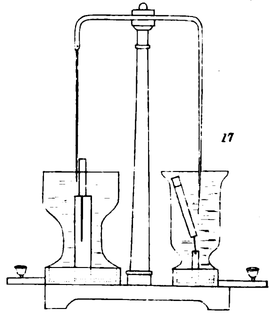

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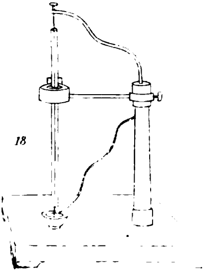

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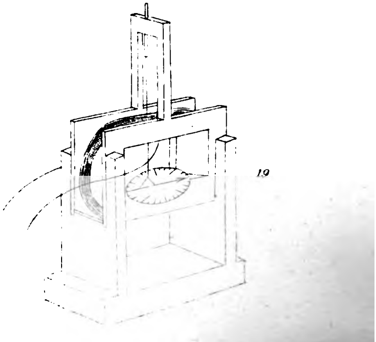

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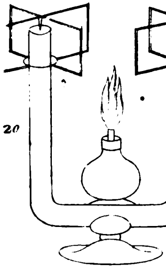

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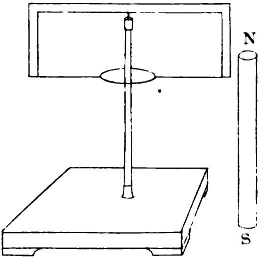

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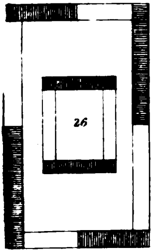

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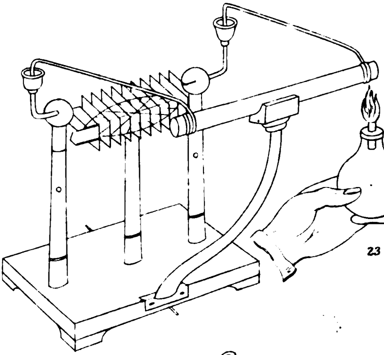

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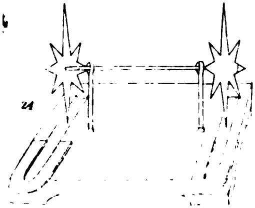

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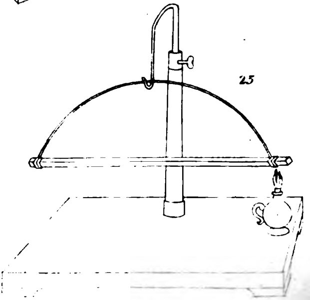

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