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# PRACTICAL ELECTRICITY

AND

# GALVANISM.

# PRACTICAL ELECTRICITY,

AND

# GALVANISM,

CONTAINING

## A SERIES OF EXPERIMENTS

CALCULATED FOR THE USE OF THOSE WHO ARE DESIROUS OF BECOMING ACQUAINTED WITH THAT BRANCH OF SCIENCE.

ILLUSTRATED WITH NINE COPPER PLATES,

*By JOHN CUTHBERTSON,*

PHILOSOPHICAL INSTRUMENT MAKER,

AND

*Fellow of the Philosophical Societies of Holland and Utrecht.*

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# PREFACE.

THE contents of the following pages are in part Experiments translated and selected from three small volumes published by me in Amsterdam, at three different periods during my residence there; the first in 1769, the second volume in 1782; these two volumes being well received were soon translated into the German language, and published at Leipzic, where they underwent several editions, as also in Russia—the last volume appeared but just before my return to London in 1793.

The motives which induced me to publish my first volume were to diffuse more generally the science of electricity in Holland, the knowledge of which was at so low an ebb, that the most simple experiments were known but to a few individuals; as well also as to introduce the plate electrical machines, which were at that time made in London, but with a defect in the rubbers, which rendered them even less powerful than the cylindrical ones, which defect, however, I was fortunate enough to discover, and correct in such a manner as to render them the most powerful that have ever been constructed. And farther, I was induced to publish my second volume, as the plate machines, from my improvement, being found far superior to any other, the sale increased so rapidly that their use became so extensive all over that part of the Continent, and the taste of electricity so general, that a more extensive range of experiments became absolutely necessary. With objects somewhat similar to those I have here stated, I venture on the present publication.

The remaining part of the Work contains experiments since invented by myself and others, together with an Appendix on Galvanism, containing some of the most familiar and interesting experiments on that subject. My original intention was to have translated the whole of the three volumes alluded to, but my professional occupation caused such interruptions that I conceived it most advisable to adopt the present method. *viz.* that of leaving out what I thought could be best spared.

With regard to the plate electrical machine I shall here say but little, its superiority being universally allowed by every person conversant in the science, who has witnessed its effects. Some of the experiments in this work will shew that they are such as have never been attempted with cylindrical machines, or with those of any other construction. See PART VI and VII. And for a farther account *see Carpue's Introduction to Electricity and Galvanism, published* 1803, *by A. Phillips, Great Russel Street, Covent Garden.*

With regard to the theory, which I have advanced in Part I, it will be found to coincide with that of Franklin; but whether or no it is the true theory I do not pretend to determine. I can only say that all the experiments with which I am acquainted can be more easily explained by it than by any other.

I have endeavoured to arrange and methodize the experiments so as to render them easy and pleasing to the young practitioner, in hopes that it will lead fresh admirers into a walk where such wide scenes of interest and amusement are continually unfolding themselves. I shall conclude with observing, that in publishing the present Treatise in my native country I feel considerable diffidence, arising from the consciousness that my language, in many parts, from having been so long accustomed to speak a foreign tongue, may offend the ear of my reader. However I will venture to throw myself on his liberality: and in soliciting his indulgence, I farther plead my occupation as an artist, and the various interruptions I must have experienced from that source, in defence of any other errors which may be perceived.

JOHN CUTHBERTSON,

54, Poland Street, Soho.

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# PART THE FIRST.

## OF THE NATURE, GENERAL LAWS AND PROPERTIES OF ELECTRICITY.

### SECT. I.

THE term electricity is derived from *electron*, a Greek name for amber, which, when rubbed, will attract light bodies; but this term has since been extended to signify this attractive power which can be communicated, or which also resides in other bodies. We are not yet acquainted with any body in which, as is supposed, it does not reside, in a greater or in a lesser degree; but it is imperceptible in all, till properly excited: in some by friction, in others by heating, oxidation, &c. And there are several bodies in which it cannot be made to appear but by other excited bodies. Electricity passes freely through the pores of some substances, and not at all through others: the first of these are called non-electrics, or conductors; the latter electrics, or non-conductors. Non-electrics, or conductors, are all sorts of metals, vegetable and animal matters, &c. Electrics are air, amber, glass, sealing wax, sulphur, pitch, silk, dried wood, tourmalins, &c. These bodies are easily excited so as to make electricity visible to our senses, by rubbing; but if any of them be wet, either by the dampness of the weather, or by other means, they lose that property till the wetness is removed: so that when they are to be used as non-conductors, they must be well rubbed with a dry cloth, to clear them from all moisture.

II. That quantity of electricity which seems to lie dormant in all bodies, is called their natural quantity; and this, though, doubtless, always in motion, would remain imperceptible, if not disturbed. It is roused in all electrics, and in some conductors likewise, by rubbing; in both by excited electrics approaching them; by which they gain a power of attracting and repelling light bodies. By being more strongly excited, there will appear in the dark a light upon their surface; and this light, if glass is made use of, will fly to the hand, or to any conductor held near it. This luminous fluid is electricity, drawn from the ground through the person who rubs the glass; by this means, it gains more than its natural quantity, and repels it to any conductor that may be near it, to restore an equilibrium. Since all bodies have their natural quantity of electricity, we can not add to that quantity, unless we take it from another: so that, by exciting electrics, we rob one, and give it to another: that which we rob gains an attractive power for electricity, and that to which we add acquires a repulsive one. In these opposite states, they act with mutual force to restore an equilibrium; and this can not be prevented, but by making the excited electric throw its superabundant electricity into a conductor surrounded by electrics; and then being by some means enclosed, it is possible to detain it for a time, by making the electric give it to a conductor, standing upon electrics, which is called insulating; and here the drier the air, the longer it will remain; but the air is always mixed with conducting particles, which assist its escape.

III. When a body has received more electricity than is natural to it, it is said to be electrified positively; and when it has less than its natural quantity, it is negatively electrified.

IV. Two bodies, being equally electrified positively, they will repel each other; but if one be more strongly electrified than the other, they will attract one another; if one body be electrified, and theother not, they will also attract; if one be electrified positively, and the other negatively, they will also attract; if the bodies be negatively electrified, equally or unequally, they will act upon each other as when positively electrified.

V. Different sorts of electrics have, when excited, different properties of electrifying. By exciting glass, it gains an additional quantity of electricity, and becomes positively electrified: if any conductor be made to approach it, it will receive part of that electricity, and consequently will be positively electrified, if insulated; but if sulphur or sealing wax be excited, they gain no additional electricity, but lose their natural quantity, and become negatively electrified. If any insulated conductor be brought near them, they attract part of its natural electricity, and, if insulated, it becomes negatively electrified.

VI. We are accustomed, but rather improperly, to say negative and positive electricity, which embarrasses most learners, as it certainly implies two different sorts; but what is to be understood are the two different directions which the electrical fluid takes, *viz.* from or to the body electrified. When any body is electrified, and it is asked, what sort of electricity it was electrified with, then certain experiments, which I shall mention in their proper place, must be tried, to prove whether there is a redundancy or a deficiency of electricity in that body. If there be found a redundancy, then the body was electrified with positive electricity; if there be a deficiency, with negative electricity.

VII. Glass is absolutely impenetrable to electricity, though some former writers have very strenuously asserted the contrary, and thought that they had proved it by experiment; but it will be here found that they have deceived themselves, by making experiments without that caution which is absolutely necessary in establishing a general rule.

VIII. Electricity enters in, or flies from, any thing pointed, more readily than into or from round or flat surfaces. This may be occasioned by the air, as it is an electric, and may be probably more condensed upon flat or round surfaces than at points. An insulated conductor, having a point at each end, and an excited electric being held near to one of the points, little or no alteration can be perceived, because it will run off from one point, as fast as it is received by the other; so that conductors, which are intended to retain electricity must be round, and as free from points as possible. Insulated conductors, being electrified, become nearly the same as excited electrics; they will then attract and repel light bodies, give or take sparks agreeably to that sort of electricity which is communicated to them: the only difference is, that, at the approach of conductors not insulated, they will part with all their electricity at once; whereas, excited electrics only do so partially, *viz.* at the place touched by the conductor: thus the sparks from excited electrics are not so dense, nor the explosion so loud, as from insulated electrified conductors.

IX. Electrics being brought in contact with excited electrics, will not destroy their electricity; hence they are called non-conductors, that is, because they will not conduct the electric fluid.

X. If electricity be strongly communicated to insulated animal bodies, it is said to quicken the pulse and increase perspiration.

XI. The growth of vegetables is also said to be quickened by electricity.

XII. By covering glass with any sort of metal, on both sides, that is, coating it, and then electricity being strongly communicated to one side, it is called charging, while any conductor is in communication with the other, and a communication being afterwards made between those two sides, it is called discharging, and then a flash of electric light will appear, attended with a report in proportion to the communicated electricity. If it is discharged through animal bodies it gives a very painful sensation, which is denominated the electrical shock. If the coated glass be large enough, it may be charged so as to set fire to gunpowder, melt metals, kill animals, &c.

XIII. The terms charging and discharging are here made use of in compliance with custom, and for want of others more suitable. I shall here explain what is meant by them.

XIV. By charging coated glass, we mean the adding of electricity to one side, and letting its natural quantity discharge itself from the other; and when there is so much added to one side that it can not take any more, and as much of its natural quantity gone from the other side, it is then said to be charged. By discharging, is meant, the letting that additional quantity of electricity depart from the side to which it was added, and letting that quantity which had left the other side, return. This is done by connecting the two sides with conductors, which causes an explosion, and it is then said to be discharged. When any coated glass is charged, for instance a bottle, there is, with respect to the bottle itself, no additional quantity of electricity given to it, nor any taken away: there is just as much electricity, and no more, within the bottle after it is charged, as there was, within and without before it was charged. All that is done, is that the natural quantity of electricity which the bottle contained, in and about itself, before it was charged is when charged, contained on one side only. To understand this better, suppose a coated bottle in its natural state, on the outside to contain a hundred particles of electricity, and withinside also a hundred; then charge this bottle in the inside positively, and it will have two hundred, and the outside none: that which it had being transferred. To restore the equilibrium to a charged jar, a communication must be formed from without the bottle, between the outside and inside, by a conductor touching the outside first, and while it is held in contact, or nearly so, with the outside, make it approach the inside, and it will be restored with an inexpressible velocity and violence; or if each side be touched alternately, the equilibrium will be restored by degrees.

XV. No more electricity can be forced into the inside of a bottle than can leave the outside; nor can any be forced into the inside, when none can be obtained from the outside. Again, no electricity can be drawn from the inside, unless an equal quantity can, at the same time, come to the outside; and none can come to the outside, unless an equal quantity is taken from the inside, so that a charged jar contains at the same time a plenum of electricity and a vacuum of the same fluid.

XVI. The shock to the nerves, or more properly, convulsions, is occasioned by the sudden passing of electricity through the body, from the inside to the outside of the bottle.

XVII. It has not been found that the electric shock occupies the smallest sensible space of time in being transmitted to the greatest distances.

XVIII. The electric shock, as also the common spark, displaces the air through which it passes, and if its passage from conductor to conductor be interrupted by non-conductors of a moderate thickness, it will rend and tear them to pieces in its passage.

XIX. Electricity and lightening are in all respects the same thing. Every effect of lightening may be produced by electricity, and every experiment in electricity, may be made with lightening, by conducting it down to any convenient place, by means of insulated pointed rods; but rods are not so proper for this purpose as kites, because they cannot be erected so high as kites may be made to fly, and I have always found, the higher they fly, the more electricity is produced. There is no necessity to wait for a thunder-storm, or any other appearances of lightening in the air, when there is wind enough to raise a kite: I never failed to collect sufficient electricity, to make an experiment, either from the earth, in its way to the higher parts of the atmosphere, or from the higher parts of the atmosphere to the earth. When we have it in its passage from the earth to the higher parts of the atmosphere, it is then called negative electricity, because it leaves all bodies then electrified by it in a negative state. In its passage from the higher parts of the atmosphere to the earth, it is called positive electricity, because it renders all bodies, then electrified by it, in a positive state.

# PART THE SECOND.

## DESCRIPTION OF THE PLATE ELECTRICAL MACHINE *.

Pl. 1. fig. 1. A C D represents the machine with its prime conductor in a position for simple electrification; C D is a square piece of mahogany, which forms the basis of the machine, about two feet long, one broad, and an inch and a half thick; g h is a straight wooden stile glued fast to c: at k l is another stile, not glued as the former, but fixed by three screws, one at the front to draw it close to C D, the base of the machine, and two under the bottom, to draw the stile downwards npon the bottom, in order that it may be secure against any motion; m n is a cross-piece, which forms the top of the frame, screwed fast to the two stiles by two brass screws, which pass through the cross piece into h k, by which means it can be drawn so tight, as to secure it from any motion; o, is the spring frame,

* For a short and concise account of the progress made in electrical machines, see Carpue's Introduction to Electricity.

which contains the upper pair of rubbers, and is screwed to A by a screw P; q is also a spring-frame, which contains the under pair of rubbers: r r is prepared silk, sewed to each rubber, seen separate at fig. 2; a t w is the prime conductor; w x is a solid stick of glass, which serves to support, and also to insulate the conductor, the end w is mounted with brass, which screws into the centre of the large ball of the conductor; Y y is a round glass plate, fixed upon an axis, one end of which turns in a hole in the stile g h, and the other runs through a hole in the middle of the stile k l, and is turned by means of a winch z, which causes the plate to revolve and pass between the rubbers fixed at the top and bottom of the frame of the machine.

## *Construction of the Rubbers.*

Fig. 3 represents the spring-frame of the upper cushions on one side, and the silk, for the sake of distinction, is taken off; o, is the screw seen at fig. 1, which passes through a, and screws into the opposite spring, by which it is held fast in its proper position. Fig. 2 represents a single rubber with the silk flap; this is covered with red leather, and stuffed with slips of woollen cloth; then a piece of silk properly prepared and cut to the shape, as may be understood by the figure, is sewed fast to the middle of the rubber. By turning o, one way it will draw the rubbers close, and by turning it the other, it will loosen them. As it is difficult to get at the head of this screw, and turn it with the fingers, there are holes made at the side of the head of the screw, in which the end of a wire may be put; it may then be easily turned. To fix this to the frame of the machine, as is represented in fig. 1. open the rubbers to about the width of half an inch, then slip them upon the plate so that the top comes close under fig. 1; then put the long screw P, through a hole in the cap of the machine, and screw it into the top of the frame of the rubbers, very tight, taking particular care that the plane of the rubbers applies to the plane of the plate; this will hold the rubbers in their proper place; m is a wire, from which proceeds two or three silk cords fastened to the edge of the silk flaps, which serve to prevent them adhering to the edge of the plate while turning.

The rubbers q are constructed exactly the same as those already described, but are different in their application to the frame of the machine. The piece a b, fig. 4, which forms the bottom of the frame for the under rubber, is cut open from one side quite to the centre of the piece, and at the bottom of the frame of the machine is a piece of brass placed upright with a male screw, to which is fitted a nut with a female screw, having holes at the edge for the convenience of screwing it tight, by means of a wire; the two sides with the rubbers being placed upon the bottom of the machine, so that the upright brass pin goes into the groove, and is there screwed tight by the female nut.

### *Construction of the prime Conductor.*

a t w is the prime conductor; w is a large brass ball with a shank about an inch long, fitted into the cylindric part, so that it may be turned for the purpose of placing the hole, which is seen at one side of the ball, in any position that the experiment may require. This hole will be faund useful for various purposes. The conductor is supported and insulated by the solid glass cylinder w x. If required, at any time to be taken to pieces, the cylinder part of the conductor must be unscrewed from the large ball, where there is a square nut, which being unscrewed, w x may be taken out, one end of the two receiving arms or tubes t a is screwed into the large ball by w, one having a left-handed screw, so that the arm may be supported by the shoulder to prevent it falling by its weight. The two cross pieces fronting the plate with two or three points to receive the excited fluid, are each screwed on to their respective arms, one with a right-handed screw, the other with a left-handed one, for the same purpose as the screws at the other end of the arms. The end x of the glass cylinder is mounted with a joint, which fits into the frame of the machine opposite the hole in which the axis moves.

### *Construction of the discharging Electrometer.*

E F, fig. 1, represents the electrometer screwed to the machine as when in use. It is a solid stick of glass, mounted at each end with brass; the mounting of the lower end has a hole near the middle, through which a screw passes, and connects it fast to the end of the bottom of the machine, as is represented. This electrometer is very serviceable, particularly in medical cases, to govern the degree of strength of either shocks or sparks; and also in philosophical experiments for the same purpose, by altering its distance from the knob a of the conductor; at the lower end is a finger-screw, to keep it tight when it is placed at its required distance. The farther the ball E, of the electrometer, is placed from the knob a of the conductor, the stronger will be the shock or spark, provided it is not beyond the striking distance.

*Description of the Plate, Electrical Machine, constructed for positive and negative Experiments.*

Pl. 2, Fig. 1, A C D represents the machine for positive electrification, described page 11, with the difference only, that it has a glass winch, z, instead of a metal one. For negative electricity, it is placed upon a stool, with three glass leggs, made to the shape of the basis of the machine, and so contrived, that it can be removed at pleasure from the stool, and be used upon a table, when the negative part is not required. O D is the negative conductor. If a coated jar, q s, be placed with its inside connection in contact with o, by the help of a sliding table, as A B, fig. 3, and another at fig. 2, when the machine is in motion, they will both charge at the same time: the first will charge negatively, and the other positively; and when charged high enough, if their outsides have a metallic connection, the positive charged jar will discharge itself into that which is negative, flying from a, to p, and both the jars will be discharged. The negative conductor is fixed to the basis of the machine, in the same manner as the discharging electrometer, both of which can be removed at pleasure.

### *The Method of making Amalgam.*

Take one part of tin and zinc, melt them in a crucible, and pour them on two parts of mercury, which is put into a wooden box made for the purpose; shake the box till the metals are cold. The amalgam is then to be pulverized in a metal mortar to a very fine powder, and afterwards mixed with a sufficient quantity of hog's lard, to make it into a paste.

### *How to clean or amalgamize the Rubbers, and to put the Machine in good acting Order.*

Unscrew P, fig. 1. pl. 2, and take it out, then turn the winch a little towards y, and the rubbers will come out from under m n, when they may be drawn off from the plate; take out the under rubbers, by means of a wire turn the round nut at the bottom till the rubbers are loose; when the winch is turned, they will come out of their places; unhook the two silk strings, and the rubbers may be released from the plate, as the others. To separate the rubbers, take out the screw o, fig. 3, pl. 1; then the side springs with each rubber may be separated so far that they will admit of sufficient separation to be cleaned and amalgamized. If the rubber and the silk be not very dirty, slight rubbing with a dry linen cloth will be sufficient, and then a little amalgam may be spread very thin on the flat part of the rubbers, just covering the seam, but not rising above the silk. It must be spread on with a knife, or any other kind of instrument that is flat and smooth. If the old amalgam should be very thick and unequally laid on, it is necessary to scrape it off and put on fresh: great exactness should be observed in laying it on of a proper thickness. It ought to be so laid on, that the surface of the amalgam is equal with the surface of the silk, and no openings or separations between the amalgam and the silk. This being done to all the rubbers, put them again into the dove tails, and the screw o, into its place; the glass plate must be cleaned with a little whitening or a linen rag, or what is better, powder blue; then put one pair of rubbers into their places as they were, and give them their proper pressures by screwing o tighter; then turn the plate briskly round, and hold your finger or side of your hand close to the plate at the end of the silk flaps, the conductor being turned up, or taken away, and sparks will fly very abundantly to it; if not, turn the screw o, till you find that it does, and that it does not increase by screwing tighter; then put in the other pair of rubbers, and follow the same rule, wipe the greasiness off the plate, which is occasioned by the amalgam; let down the conductor into its place, and it will be found to act very powerfully. When its greatest acting power is required, it is necessary that each pair of rubbers should excite the plate equally; to prove this, take fig. 4, pl. 2, which is a leyden phial, with its inside connection wire bent, as may be understood by inspecting the figure; take hold of the coated part in the hand, and hold it so that the part a, of the wire nearly touches the glass plate just at that part where the silk flap ends; then turn the winch, and the phial will charge and discharge itself from the end of a, to the outside coating, in one turn of the winch. Note the number of discharges from a certain number of revolutions, if it is a single plate machine of two feet diameter, it will cause two discharges in one revolution; then hold it to try the action of the other rubbers; if they cause the same number of discharges in one revolution, or in a certain number of revolutions, as the other rubbers, their acting power is equal; but if this should not happen, the pressure of the rubbers must be increased or decreased, or the face of the amalgam altered, till they are equal. A two feet plate machine never requires more friction than that which requires a weight of eight pounds hung upon the winch when in a horizontal position, to move it; if it requires more, it is not properly amalgamized.

# PART THE THIRD,

## ELECTRICAL EXPERIMENTS.

### *Electrical Attraction.*

#### Exp. 1.

Having put the machine in good acting order, according to directions given in page 17, turn the winch, hold fig. 1 near the conductor, the feather will be attracted, and stick close to it as long as the turning is continued.

*Rationale.*—The electric fluid is drawn upon the glass plate by the action of the rubbers at the point of action only, from all conducting bodies in connection with it; and by the action of the glass, where the friction ends, it is repelled off into the prime conductor, which attracts the feather and makes its way along the thread to the person who holds it to the ground, and restores the equilibrium. Page 2, § 11.

*Electrical Repulsion.*

Exp. 2.

Put the end of fig. 2 into any of the holes in the knobbed ends of the prime conductor, turn the winch, the pith ball b c will be repelled and remain at a distance from each other as long as the machine is in motion.

*Rationale.*—The pith balls being in connection with the prime conductor by means of the thread, they become equally electrified with it, consequently repel each other. Page 4, § iv.

*Electrical Repulsion and Attraction.*

Exp. 3.

Put the end of fig. 3 into the side hole of the large knob at the end of the prime conductor, when turned so that the wire can stand upright, the hairs will then hang downwards by the sides of the wire; but as soon as the machine is put in motion, they will rise upwards and be repelled by the conductor and by each other, if a hand or any conducting body be held near them, they will be attracted by it.

*Rationale.*—The electricity being by the action of the plate condensed on the prime conductor and wire, the hairs are repelled from the sides of the wire and the conductor; being all positively electrified, they repel each other. If any conductor be made to approach the hair, it will be attracted by it, and stick close to it, to deposit the overplus of electricity forced into it by the prime conductor. Page 4, § IV.

### *Miscellaneous Experiments.*

Electricity passes freely along non-electrics or conductors.

#### Exp. 4.

Take a piece of metal, or any vegetable in its natural state, or any living animal, set it in contact with the prime conductor; if the machine be turned, no sparks can be drawn from the prime conductor; take them away, and sparks may be drawn as usual, which plainly shews that the electricity had left the prime conductor, and made its escape along the body, which was placed in contact with it. Page 1, § I.

Electricity does not pass along electrics or non-conductors.

## Exp. 5.

Take any of those bodies called electrics or non-conductors, render them free from all moisture, set them in contact with the prime conductor, turn the machine, and the sparks will be as long and as strong, as if there was nothing in contact with it, which could not be the case if they admitted the electric fluid to pass along them, as in the last experiment. Page 1, § 1.

## Exp. 6.

Take the wire n, fig. 6, set it in the side hole of the prime conductor with its point upwards, upon which place the wire o, so that its bent ends lay horizontal; turn the machine, and the wire will turn round in a contrary direction to the way its points are bent; with a very quick motion; if the experiment be done in the dark, there will appear a brush of electric light at each point, but by its quick motion it will appear as a circle.

*Rationale.*—The motion of the wire o, is occasioned by the action of the electric fluid against the electrified air near the point.

## *The electrical Planetarium.*

### Exp. 7.

Annex to the prime conductor fig. 7, commonly called the electrical planetarium, by means of a metal chain, or conducting silk cord, as represented in the plate: which must at least be two feet and a half long, because the action of the machine will otherwise influence its motion, when standing near the conductor. The cord must likewise hang with a bend downwards, otherwise the earth and moon will be attracted, and interrupted in their motion. Set the planetarium so that B, stands nearest the prime conductor, with the moon between the earth and sun in a right line. Turn the machine, and the planetarium will begin to move—the sun upon its axis, the earth round the sun, and the moon round the earth and sun.

## *The inclined Plane.*

### Exp. 8

Fig. 4. Connect either of the wires of the instrument with the prime conductor, and lay the

cross needle as is represented in the figure; turn the machine, and the needle will move upon its axis with a velocity sufficient to occasion it to ascend to the top of the inclined plane, by the same cause as gave motion to the two foregoing instruments.

### Exp. 9.

Take a little bit of cotton, or a very light downy feather, lay it upon the palm of your hand, and hold it about four or five inches from the prime conductor; turn the machine, and the cotton or feather will fly to the prime conductor, and from the prime conductor to the hand, with a very quick motion, and continue as long as the machine is turned.

*Rationale.*—The prime conductor being strongly electrified, attracts the unelectrified cotton or feather, and electrifies it, then repels it to the nearest conductor, *viz.* the hand; there the cotton, or feather, deposits its electricity, and is again attracted by the prime conductor.

## *Bells rung by Electricity.*

### Exp. 10.

Take fig. 8, hang it to the prime conductor, by putting the brass pin into the hole at the end of the prime conductor, so that the bells hang horizontally, and that the chain which goes from the bottom of the bell may touch the table—turn the machine, and the bells will begin to ring—hang the chain that goes from the middle bell by its hook, upon the top of the frame, and the bells will cease ringing, though you continue to turn the machine—take the hook from the frame, hold it in your hand, and the bells will begin to ring again—fasten a silk thread to the hook, hold it in the hand, so that the chain does not touch the table, and they will again cease to ring.

*Rationale.*—The bells e g hanging in metal chains, are electrified from the prime conductor; but the middle bell and the two clappers are not electrified, because they are hung in silk, but are attracted by the electrified bells e g; becoming then electrified, they are repelled to the middle bell, depositing their electricity, which passes off by the chain to the table, they are again attracted, and repelled, and the ringing continued—when the chain is hooked upon the frame, the middle bell becomes electrified, as well as e g, so that the clappers being equally attracted by the three bells, must remain still—

take the hook from the frame, and hold it in the hand, they will then begin to ring as before—for the same reason, the electric fluid, which is thrown upon the middle bell by the clappers, immediately runs off, through the person that holds the chain, to the ground; but by taking the silk thread in the hand, they will again stop, because the middle bell has no means of parting with that quantity of electricity, which it has received from the clapper, being stopped by the silk.

## Exp. 11.

Fig. 10, pl. 11, represents a set of bells, which will also ring, when electrified—place them so that one of the four brass balls is in contact with the prime conductor—turn the machine, and they will begin to ring, because all the bells and clappers are hung in silk; all the bells except the middle one are connected by conductors to the table; the electricity being stopped in the centre bell, it attracts the clappers, and they are repelled to the outside bells, where they deposit their electricity, and it is again attracted; but if the chain, which hangs from the outside bells, be hung or held up by a silk thread, they will ring or not at pleasure, as in the last experiment.

### Exp. 12.

Take k, fig. 11, hang it upon the conductor, and set the brass sliding stand m, directly under it, upon which place a large metal plate l, and lay a little bran, or sand, upon it. The stand is made to slide, and the best height will be found by experiment; turn the machine, and the bran will be attracted and repelled, so quick, that the motion is almost imperceptible, and appears like a white cloud between the two plates. If in the place of bran, you put little images cut out of paper, they will appear to be animated, dance, and exhibit very singular motions.

*Rationale.*—The electricity being communicated to k, it attracts the nearest and lightest particles of the bran, which also become electrified, and would be repelled back to l, but in their passage they meet with other particles unelectrified, and the repelled particles deposit their electricity in the attracted ones, and are repelled back, before they arrive at k. This appearance depends upon the same principles as the ringing of the bells, but the irregular and quick motion is occasioned by the multiplicity and minuteness of the particles—the dancing of the images arises from the same cause, but they seldom reach the upper plate k, because the sharpness of the edges of the paper makes them capable of receiving electricity enough to be repelled back, before they reach the electrified plate k.

### Exp. 13.

Take n, fig. 6, and put it into the hole of the prime conductor with its point upwards, upon which set the head fig. 13—turn the machine, and the hair of the head will be repelled, so as to stand upright, and will have the appearance of a person in a great fright—hold a point to it, and the hair will drop; the point being taken away, it will rise as before.

The reason of the hair rising, see exp. 3.

### Exp. 14.

Fig. 14 being made fast to the prime conductor by means of the end d, which must be put into the side hole of the conductor, place under it the brass foot and plate used in experiment 12—the plate must stand exactly parallel to the ring, fig. 14, and at about half an inch distance; then take a light glass ball, and lay it upon the large plate in the inside of the ring—turn the machine, and put the glass ball in motion; it will run round in the inside of the ring, and continue as long as the machine is turned. If the glass balls are well made, they will run on the outside as well as the inside of the ring.

*Rationale.*—The balls turn round, because that side of the ball, which is in contact with the ring, is electrified and repelled, the other side being unelectrified, is attracted, electrified, and repelled, so that it is kept in continual motion, and in contact with the electrified ring.

### Exp. 15.

Take fig. 15, being a small pail with a spout near the bottom, which has a hole just sufficient to let the water out by drops; fill it with water, and make it fast to the prime conductor, by putting it into one of the holes. Turn the machine, and the water which before descended from the spout only by drops, will fly from it in several streams.

*Rationale.*—The electricity being condensed in the conductor, pail, and water, and finding its easiest escape from the small end of the syphon, is then driven out with great force—the water being a conductor, is taken with it to the nearest conductor, and by the repulsive power of the electricity it is divided into several streams. If this experiment be done in the dark, the streams of water will appear like streams of fire. Lay your hand upon the prime conductor, while you continue turning the machine, the streams will be converted into drops as at first, the electricity finding a more easy passage to make its escape into the hand, and through the body, to the ground.

### *To draw the electrical Spark from the human Body.*

### Exp. 16.

Take the insulated stool, wipe the legs very dry with a clean cloth, and the stool itself free from dust; set it in a convenient place upon the floor, where there is no conductor near it; make a metal chain or wire, fast to the prime conductor; let any person stand upon the stool, and take the chain in his hand; hold it so as not to touch any thing but the prime conductor; the person standing upon the stool must have no communication with any thing but the prime conductor, even his clothes must not touch any thing—turn the machine, and the person will be strongly electrified, without feeling any alteration in himself; and if any other person or substance be made to touch the electrified person, a spark of fire will fly from him.

*Rationale*—The electrified person makes a part of the prime conductor, being connected with it by means of a chain, and insulated by means of the stool, he receives, and retains in his body the electricity which comes from the machine, to the prime conductor; and parts with it on being touched by any conducting substance.

## *The electrical Kiss.*

### Exp. 17.

The electrified person in the former experiment being a lady, may challenge any gentleman, not acquainted with the experiment, that he will not be able to kiss her in that situation, although she may incline to meet him. If he accepts the challenge, and the machine turn while they are inclining their heads to kiss each other, provided their clothes do not touch before their lips meet, a spark of fire will fly from the lady to the gentleman, which will be sure to make him draw back, without accomplishing his design.

### *Spirit of Wine fired by the electrical Spark.*

EXP. 18.

Let the insulated person, in the two former experiments, take in his hand a spoon, or fig. 13 filled with rectified spirit of wine warmed; let another person barely touch the spirit with his finger, as quickly as possible; a spark will fly out of the spirit, and set it on fire. The chain being taken away from the conductor, put the shank of fig. 13 in the hole of the prime conductor; if any person present their finger wetted with spirit, it will also take fire.

### *The electrical Star.*

EXP. 19.

Introduce the blunt end of the wire n, fig. 6, into the hole of the prime conductor, upon which, set fig. 19; turn the machine, and flames of electricity will fly from each point, resembling a star. If it is turned round upon its center, the flames will appear as one continued circle of fire.

### Exp. 20.

Let a person standing upon the insulated stool, take a piece of money between his teeth, and if a person standing upon the ground, touch it, the spark will be so painful to the person who holds the money, that he seldom fails to let it drop, provided his lips do not touch it at the same time.

### Exp. 21.

Fig. 16 being half full of water and air condensed upon it, afterwards insulated and connected with the prime conductor; on turning the cock, the water will fly out of it in several diverging streams, but if touched by the hand, the streams will unite; the hand being taken away the water will diverge as before.

## *Charging and discharging coated glass.*

### Exp. 22.

Take fig. 17, screw out the brass wire q s; wipe the uncoated part of the jar with a clean dry cloth; screw the brass wire in again; set the bottle so near the conductor, that the ball r may stand at about a quarter of an inch from the ball of the prime conductor; turn the machine, and the electric fire will be seen to fly from the end of the prime conductor to the brass ball, and from thence it will pass along the wire into the inside of the bottle. When no more sparks are seen to pass, the bottle will be charged; take the bent wire or discharging rod, fig. 5, in your hand, and hold one end close to the coating, keeping it there till you cause the other end to touch the ball r, and the bottle will be discharged with a loud report and flash like lightening.

*The electrical Shock.*

EXP. 23.

The bottle remaining as in the last experiment, turn the machine, till the bottle has received about twenty sparks; take the charged bottle in one hand by the coating, and with the other touch the ball r, and a shock will be felt, occasioned by the electric fire passing through the body, from the inside to the outside of the bottle, which, in the former experiment followed the wire fig. 6.

*The electrical Shock given to any number of Persons.*

EXP. 24.

The bottle being charged as in the former experiment, let any number of persons join hands, —the first with one hand touching the outside of the bottle, and the last, with one hand touching the ball r, and all will receive the shock at the same time.

*To give the Shock to any Number of Persons, by Means of the Electrometer, E F, fig. 1, pl. 1.*

EXP. 25.

Let any number of persons join hands, the first with one hand taking hold of the conducting silk cord fastened to the electrometer at F, and the last person with one hand taking hold of the same kind of silk cord, which is connected with the outside of the bottle; turn the machine, and when the bottle is loaded high enough to discharge from the prime conductor to the electrometer, they will all feel the shock at the same time, the electrometer being previously fixed so that the ball

F stands at about a quarter of an inch distant from the knob of the conductor at a.

## *To confine the Shock to any particular Part of the Body.*

### Exp. 26.

Suppose it is required to give a shock from the ancle to the knee, in the direction from the ancle to the knee—bind a brass chain or conducting cord round the ancle, and fasten the other end of it to the electrometer at F, and the other chain or cord, which is annexed to the outside of the bottle, fasten round the knee; turn the machine—and when the bottle is loaded high enough to fly from the prime conductor to the electrometer, the shock will be given in the direction required. If it is proposed to give it in any other direction, proceed in this manner, *viz.* the part where the fire is to enter in, must be connected with the electrometer, and the part where it is to go out, with the outside of the bottle.

*To give the Shock with a square Pane of Glass coated in the Middle.*

EXP. 27.

Take fig. 18, rub it all round the edges where it is not coated, with a dry cloth or with leather; if it is damp weather, it will be necessary to warm it; then lay it flat upon the table. Fix the electrometer at one or two inches from the conductor; let a chain, which is fastened to the prime conductor at one end, remain upon the coating; turn the machine four or five times; slide one hand under it so far as to touch the coating; with the other hand touch the coating on the other side, and a shock will be felt.

*To give a Shock by the magic Print.*

EXP. 28.

Take fig. 20, and wipe it well about the edges, or rather warm it; then hold the frame by one side, with the face of the picture against the prime conductor, turn the machine four or five times, and it will be loaded; then give it to the person whom you mean to receive the shock; let him take hold of one side of the frame with one hand, and touch the picture with the other, and he will receive a shock. Hold the picture by the top of the frame, otherwise the person at receiving the shock, may let it fall.

*By adding electricity to one side of coated glass, or electrifying one side positively, the other side loses its electricity, or is negatively electrified.*

### Exp. 29.

Take A, fig. 18, from the stand, and set it so that its ball may nearly touch the prime conductor; let the machine make two or three revolutions; discharge the jar with the discharging rod, as in the 22nd experiment, and take notice of the loudness of the explosion.

### Exp. 30.

Screw A, used in the last experiment, upon its insulated stand, and set its ball in contact with the conductor. Nothing being near the outside of the bottle, tnrn the machine exactly as before; try it with the discharging rod, and it will be found, either not charged at all, or much weaker than in the former experiment.

## Exp. 31.

Let the jar remain upon its insulating stand, as in the last experiment; set it so that its ball may stand about a quarter of an inch from the prime conductor, and while the machine is turned, present your knuckle, or any conductor about a quarter of an inch from the outside of the coating of the bottle; and when a spark flies from the prime conductor to the ball of the bottle, a spark will also fly from the coating to your knuckle; and when no more sparks go from the conductor to the ball, nor from the coating to your knuckle, try it with the discharging rod, and you will find that it was charged very high.

### *To examine whether just as much Electricity goes from the outside, as is driven into the inside of a coated Jar.*

## Exp. 32.

Let the jar remain upon its insulating stand, and place it so that its ball may touch the conductor—take another coated bottle of the same size, and hold, or place it so that the ball, which projects from the inside, may touch the outside coating of A; then turn the machine till the jars are charged—take them from the conductor, and set them apart; discharge them both, successively, and you will find by the report, which they will give, that they were both equally charged, the one by being in contact with the prime conductor, and the other, by being in contact with the outside coating of that which was in contact with the prime conductor. But as this method of trying whether they were both equally charged or not may be thought not exact, the following is more accurate.

### Exp. 33.

Charge the two jars as directed in the last experiment—take the insulated one from its stand, and set them both upon the table at about a foot distance from each other—take an electrometer fig. 18; hold it as is represented in the figure, first to one and then the other—if the cork ball rise to the same height to each, in that case, they must be both equally highly charged, and contain an equal quantity of electric fluid. This makes it evident, that the insulated bottle has lost as much from the outside, as it gained in the inside, and is electrified positively in the inside, and negatively on the outside, that is, an additional quantity is given to the inside, and just as much of its natural quantity is gone away from its outside, so that with respect to the charge, the bottle has neither more nor less electricity after it is charged, than it had before it was charged; but it has more on one side, and less on the other. Page 7, § XIV.

*One Side of coated Glass, when charged, being always negative, and the other positive, depends upon the following Principle.*

EXP. 34.

Take the insulated brass ball, fig. 19, being about the size of the ball at the end of the prime conductor; set it as near to A as possible, without taking a spark when the machine is turned: turn the machine, and hold your finger upon B. When you have turned it two or three times round, take your finger from the ball B, while the machine is in motion, and it will be negatively electrified.

*Rationale*—The prime conductor being positively electrified, has repelled the natural quantity of electricity from the ball, into the fingers in contact with it, along the body to the ground: while in that state, the finger being taken away, the electricity is prevented by the insulated stand, from entering it again. Coated glass is acted upon in the same manner, one side being positively electrified by the prime conductor, repels the natural quantity from the other side.

*To know whether the Ball, in the last Experiment, was electrified positively, or negatively.*

### Exp. 35.

After B has been held a sufficient time before the conductor, as in the last experiment, charge E at the prime conductor; then place it upon the table, so that the cork balls, a b, may hang free over the edge, being the best position for B to approach them; then after B has been electrified, as in the former experiment, move it quickly near to one of thee cork balls a b; if the ball is attracted by B, then it must have been negatively electrified, but if it should repell a b, it must have been positively electrified.

### Exp. 36.

Take the jar D, and hold it against the conductor by E, while the machine is in motion, and it will charge the outside coating positively, but the inside will be charged negatively, from what has already been said—set the jar upon an insulating stool; then take it by the outside, and place it upon the table, as before; proceed with the brass ball, as in the last experiment. If it be negatively electrified, it will repel the cork balls, they being negative, but if positively, it will attract them, they being negative. Page 4, § IV.

*Rationale.*—Why the jar, when charged, as in the last experiment, must be placed upon an insulating stool before the outside is taken hold of, is this: the jar having received an additional quantity of electricity upon its outside coating, if that side be placed upon conductors, while the hand is holding it by E, being in contact with the inside, the additional electricity will go off from the outside, and the deficiency will be supplied by the hand to the inside; but if it is insulated, it can receive but very little of the electricity from the outside of the jar, so that it may be taken by the hand any where, without any sensible diminution of its charge, although the electricity added to the outside makes its efforts to go away, there is nothing to supply its inside.

*To charge a jar negatively and positively by fig. 1, plate 2, see page 16.*

EXP. 37.

Place a jar upon a sliding table A B, fig. 3, plate 2, so that any part of the wire q r, proceeding from the inside of the jar, may be in contact with the conductor o, being the negative conductor of the machine fig. 1; screw upon r, the electrometer, fig. 18, plate 3—hang a metal chain or wire from the prime conductor to the ground—turn the machine, and the jar, to all outward appearance, will charge as at the prime conductor of fig. 1, pla. 1, the cork ball rising and denoting the power of the charge. When the cork ball ceases to rise higher, the jar will be of sufficient power—remove it from the conductor—take away the chain from the prime conductor, and hang it upon o; this being done, set the jar in contact with the positive conductor, represented in fig. 2—turn the machine, and the ball of the electrometer will begin to fall till it is in contact with r; then it will begin to rise again, if the turning be continued.

*Rationale.*—When the jar stood at the negative conductor o, its natural quantity of electricity was drawn out of it, by the action of the rubbers, which was shewn by the rising of the ball of the electrometer, and made its escape to the ground, by the chain which hung to the positive conductor, and the jar became in the same state, as that in the last experiment, but differed in the manner of charging. In the former experiment, the natural quantity of electricity was repelled from the inside of the jar, by an overplus being forced upon the outside, it was charged positively on the outside, and negatively in the inside. The jar being afterwards placed to the positive conductor, the natural quantity of electricity was given to it by degrees, as was seen by the falling of the cork ball, and when it had received its natural quantity of electricity, the cork ball hung perpendicularly, when more, it began again to rise; and when it had risen as high as it could, then the jar was charged positively within, and negatively without, just the reverse of that at the conductor o.

## *The Direction of the electric Fluid shewn by the Heat of a lighted Candle.*

### Exp. 38.

Insulate two wires, furnished at each end with a metal ball of about three quarters of an inch in diameter, or fig. 67; connect one with the positive conductor, and the other with the negative conductor; set them so that their balls may be at about four inches distance; place between them a common sized lighted candle, with the center of its flame nearly upon a level with the center of the balls, and at an equal distance from each. Put the machine in motion, the flame will waver very much, and seem to incline rather more to the negative conductor, than to the positive, but is very equivocal. Continue turning, and if the machine be a plate of two feet diameter, about fifty revolutions, will occasion the negative ball to grow warm, but the positive will remain cold. If the revolutions be continued to two hundred, the negative ball will be too hot to be touched, and the positive will remain as cold as at first. If the two balls, b c, be so contrived as to contain in each a thermometer, the experiment will be more evident.

## *Experiments upon the Permeability and Impermeability of Glass to Electricity.*

### Exp. 39.

Charge a coated jar, or a coated square glass plate, as in experiment 27, and afterwards insulate it; then present your knuckle to the negative side, and a spark will appear. The advocates for the permeability of glass say, that this spark is the electric fluid, which comes through the glass from the opposite side, where it was forced by the machine, and these sparks continuing till the coated glass is discharged, they think sufficient proof is afforded of the permeability of glass. That this spark, which is seen, goes in a contrary direction, that is, from the knuckle to the glass, will evidently appear from the following experiments.

### Exp. 40.

Fig. 23. Charge the small coated bottle, E, positively in the inside; insulate it, by hanging it by its hook as is represented in the plate; F being taken away, hold your knuckle to its outside coating, and a spark will be seen.

## *To shew the Direction of the before-mentioned Spark.*

### Exp. 41.

The bottle E remaining, charge equally the other two bottles, F and G—place F under E, so that its hook may touch the outside coating. Having stood so long that no more sparks can be seen between the hook of F, and the coating of E, take F away, and set it near G; discharge the two, and F will be found much weaker than G, which sufficiently proves, that the sparks which were seen went from F, to the coating of E, otherwise F must have been stronger than G.

It may be said, that the electric matter was forced out of F upon G, by its being previously charged; but the following experiment will sufficiently prove the contrary.

### Exp. 42.

E being charged and hung up, place F, so that its hook may touch the outside coating of E, as before, but not charged; after it has stood so long, that no more sparks can be seen—take F away, and by applying the discharging rod to it, you will find it charged to a certain degree.

This, at first sight, appears to shew the permeability of glass, but when we consider that a coated bottle can be charged negatively in the inside, as well as positively, it will again contradict it, as will be seen by the following experiment, which shews that F was charged negatively in the inside, or part of its natural electricity was drawn out of it.

### Exp. 43.

After F has stood at E a sufficient time, as in the former experiment, take E away, and hang F by its hook—discharge E, then charge it positively within, but very weakly, *viz.* about as strong as F was charged in the last experiment; then place E, with its hook to touch F, and after it has stood there a sufficient time, as in the last experiment, discharge E, and it will be found something stronger than G, which is contrary to the third experiment, and makes it evidently appear, that the bottle which was last hung up, must have been charged in a different direction to that in the last experiment, that is, negatively in the inside. This sufficiently proves what was intended, *viz.* that a certain quantity of the natural electricity was drawn out of F, in the last experiment, upon the outside of E, which could not be the case if glass were penetrable to electricity.

*The Reason of a Spark appearing on the Outside Coating of an insulated charged Jar.*

EXP. 44.

Fig. 44. Charge A B positively in the inside, by the long wire, which projects from the tube C; and afterwards screw it upon its insulating stand, as is seen in the plate; then by holding a knuckle to the outside coating, sparks will appear. Draw the long wire out of the bottle—hold your knuckle as before, and you will see but one spark. Put the wire in again, and you will see sparks as before.

*Rationale.*—By this experiment we learn, that if there is no provision made, by which the fire can escape from the inside of A B, no sparks can be seen, which, if glass were permeable to electricity, the more perfect the stoppage is to prevent its flying off from the inside, the more plentiful will the sparks appear on the outside.

*The Abbé Nollet's Experiment, shewing the Permeability of Glass to Electricity, described in the first Volume of his Letters on Electricity.*

**Exp. 45.**

Annex fig. 25, by the brass chain, hanging from the wire C, to the prime conductor; place the receiver so prepared, as is seen in the figure, upon the plate of an air-pump; exhaust it; then turn the machine, and the electricity, which is forced upon the inside of the glass globe by the machine, will repel the natural electricity from its outside to the plate of the air pump, and make a very beautiful appearance, filling the whole receiver with streams of light, which will continue till the globe is charged, and then cease. To discharge it, one end of a chain must be made fast to the plate of the pump, and with the other end touch the prime conductor, as soon as the light disappears. The Abbé Nollet tells us, that it will continue as long as you continue to turn the machine, but it is so plain to the contrary, that he could only have imagined this experiment, without trying it.

### *The self-moving Wheel*

### Exp. 46.

Fig. 24 represents an instrument invented by Dr. Franklin, and by him called the self-moving wheel. If the weather be damp, it will be necessary to warm the plate, by setting a little fire under it, and keeping it continually turning round: the five pillars should likewise be warmed or rubbed very dry, and all the insulating parts about it;—place the pillars so that the balls on their tops, may be as near as possible to the balls upon the plate when it is turned round. Charge either the upper or under side of the plate positively; if the upper side, make a chain fast, proceeding from the prime conductor to that piece of brass in which the uppermost center of the wheel moves, and make a communication from the under side to the ground. When it is well charged, it will begin to move, and then the communication must be taken away.

*Rationale.*—The balls upon the plate, which are nearest to one of the pillars, move towards it, and electrify it; the succeeding balls communicating with the under side of the glass plate, are then attracted by the pillars, which were electrified by the other balls, and thus its motion will increase, till it is in this manner discharged, the balls on the upper side giving away the overplus of electricity to the pillars, and the balls on the under side taking it from them to supply their deficiency.

### *The electrifying Cane.*

### Exp. 47.

Fig. 26 is so constructed as to give any person the electrical shock unexpectedly. To charge it, hold it in a perpendicular position, the head touching either of the conductors of an electrical machine, so that the sliding wire may lie against the head; when it is charged, it may be used as a cane (only remember it is glass), without being intirely discharged, for the space of a whole day; and if you meet a friend, whom you would wish to surprize, offer your hand, as if you only intended to shake hands with him, hold your cane so that the sliding wire may fall to the head, and touch his leg with it, your friend will be surprized by an electrical shock. If the cane should not contain the charge long enough, take the head off, let the sliding wire fall out, and clean the inside of the small tube with a piece of cotton or leather tied to one end of the wire.

*The electrical Tower.*

Exp. 48.

Fig. 27. Annex the electrometer to the prime conductor, by means of a wire or chain, and let the screw head loose by pulling out a brass pin, which confines it; a chain will then fall to the bottom of the enclosed jar. Charge it as high as you can, which you will know by the rising of the electrometer; then turn the screw head, a, four or five times round, till it stops; then make it fast by the brass pin, and the tower is in a proper situation for keeping its charge twelve or thirteen weeks, if there is no defect in the jar. But the intent of this is to fire two or more cannons, at the word of command, after it has been charged some time, without any person in company perceiving from what cause. The cannons being charged with gunpowder, fill their touch-holes, which are of ivory, with gunpowder also, stopped very closely; afterwards, stick a brass pin into each of the

touch-holes, nearly to the bottom, but this differs according to the number of cannons you intend to fire, and likewise, according to the time the tower has been kept charged, which experience will soon teach. The brass pin, which goes into the touch-hole of the first cannon, must communicate with the electrometer; the pin of the second must touch the outside of the first cannon, and the body of the last cannon must be annexed to C, by means of a wire or chain. Every thing being thus prepared, bring the tower to the place where you choose to exhibit the experiment—loosen the screw-head, *a*, and give the word of command—the cannons will at the same instant be discharged.

### Exp. 49.

Fig. 27, being charged by electricity, in some degree shews the impermeability of glass to electricity, by containing its charge eight or ten weeks, and likewise, that there is nothing farther necessary to make any glass contain a given quantity of electricity in it, but to be well closed by electrics.

*The magic Bell-Ringer*

EXP. 50.

Fig. 29. Place this instrument on the right side of the electrical machine, so that the ball c, may be in contact with the conductor and that side facing the operator, on which is a brass screw in the middle of the wooden cylinder; then hang the balls as is seen by the figure—set H upright with its heaviest end upwards—turn the machine, and the bells next to the prime conductor will begin to ring—continue turning till sparks fly from one bell to the other—take the lightest end of H in your hand; hold it in a horizontal position pointing towards I—command the bells on that side to stop ringing, and those on the other to begin, and they will both instantly obey. It is not necessary, in commanding, that H should remain near I: as soon as the bells have answered the command, H may be taken away. By again moving H to the other side they will stop, and the others will begin to ring: thus they may be commanded till the insulated bottle is discharged, which, in good weather, will last nearly an hour. Place H upright in front of

the wooden cylinder, and command the bells on both sides to ring at once.

### Exp. 51.

Take the bells from that arm, which is in contact with the prime conductor—hang upon the other arm (the bells remaining) the small plate E. F is a large brass plate placed directly under E upon a stand, which can be set higher or lower at pleasure—charge the instrument as in the former experiment, then take a small image cut out of thin paper, about a quarter of an inch shorter than the distance between the two plates, holding it between them with the thumb and finger of one hand, and with the other set H towards I—the bells will begin to ring, and the figures to dance, as if it were to the ringing of the bells, which will continue a considerable time, depending on the state of the atmosphere.

Fig 30 shews the construction of fig. 29, with which the same experiment may be repeated.

*The condensed Tube and Jar.*

### Exp. 52.

Fig. 31 being filled with water about an inch or two higher than the coating, condense air upon it, and afterwards charge it with electricity—it may be held in the hand, and made to play in several diverging streams; but the chief intent of this instrument is, to shew that the motion of the particles of water is no obstacle to the contrary motion of the particles of electricity. It may be charged by causing the stream to play into an electrified jar, as if charged in the common manner.

### Exp. 53.

The glass tube being filled with water as in the last experiment, and air being condensed upon it, charge very strongly, a jar with a wide mouth, containing about twice the quantity of coated surface as the tube; then make the tube to play into the inside of the jar, they will both be charged equally. If there is a metallic communication made from the outside of the tube to the outside of the jar, the tube will receive half the charge from the jar the moment the stream reaches the inside of the jar.

*To make a Jar give one or several Discharges.*

EXP. 54.

To make the jar, fig. 32, give one discharge, annex the several outside coatings by means of a chain or wire—charge it at the ball A; then discharge it in the common manner, and it will only afford one discharge.

*To make the Jar give ten or fifteen different Discharges.*

EXP. 55.

The connexions with the several coatings, as in the last experiment, continuing, charge the jar as before; then take away the connecting chain or wire—place one end of a discharging rod to the uppermost coating, and with the other end approach the ball A, but not to touch it: it will cause one discharge. Draw the charger back quickly; then wait two or three seconds—apply your discharger as before, and it will cause another discharge. Proceed in like manner, and it will give ten or fifteen different discharges, without fresh charging.

*To make the Jar give four Discharges.*

EXP. 56.

The jar being charged as above described, and the connexions taken away, place one end of the discharging rod to the uppermost coating, and with the other end approaching A, it will give one discharge—set one end of the discharger to the second coating, and approach A with the other: it will give a second discharge. Proceed to the third and fourth coatings, and after the fourth discharge, it will be totally discharged.

*The double Leyden Jar.*

EXP. 57.

Place fig. 33 so that any part of the outside coating of the jar A may be in contact with the prime conductor of an electrical machine—turn the machine, and the large jar will become charged; then set one end of a discharger to the coating of B, and the other end to C, and it will cause a discharge; next set one end of the discharger to C, and the other to the coating of A: it will cause a second discharge—place one end of the discharger to B, and the other end to A, it will give a third discharge—set one end of the discharger to A, and the other to C, it will cause a fourth and total discharge.

*Rationale.*—The outside coating of A, being by conductors connected with the inside coating of B, it is evident, that if electricity be forced against A, it will run down into the inside of B None will remain upon A, because there are no conductors connected with the inside to let its natural electricity go away; but as soon as there is a communication with the outside of B, and extended to the inside of A, the natural electricity, contained in the inside of A, will be repelled out of it, and go along the conductor to the outside of B; and part of the electricity, which was forced into the inside of B, will spread itself upon the outside coating of A, and the two jars will then stand partly charged, the uppermost jar negatively within, and the undermost positively within. The second discharge is caused by fixing a conductor to the inside of A at C, and extending it to the outside, part of the positive fire is repelled from the outside, and goes into the inside: the uppermost bottle is for that moment discharged, but does not remain so, because the undermost jar standing upon conductors, is capable of receiving electricity upon its outside, by which means, the positive electricity contained in its inside is admitted to spread itself upon the outside coating of A, because the hand, holding the communicating conductor to its inside, not being yet taken away, admits a proportionate quantity of that which is coming upon its outside, to go away from the inside, along the hand to the ground: thus the two jars remain still partly eharged. By fixing a conductor to B, and extending it to A, the undermost jar will be intirely discharged; and also the uppermost, when communication is made between its inside and outside.

*To light a Candle by an electrical Explosion.*

EXP. 58.

Fig. 67. Place a lighted candle upon the top of h, and screw off the two balls b c; then slide the wires till they stand at about one inch distance from the flame of the candle; the top of the wick of the candle must be at the same

height, or about one line lower than the points of the wires—charge a common sized jar—annex a chain to its outside coating—blow out the candle—and immediately after, make the ball of the jar to touch the ball of that wire, which goes through the top of B; the jar will then discharge itself through the smoke of the candle, and make it flame again.

### *To extinguish a Candle by an electrical Explosion.*

#### Exp. 59.

Fig. 67. Slide up the piece h, till the middle of the flame of the candle is exactly on a level with the two points of the wires; set the point of that wire, which goes through the top of B, at the distance of an inch and a half from the flame; then charge the same jar as was used in the former experiment—annex k to its outside, snuff the wick of the candle very low, and make the ball of the jar touch the ball of that wire which goes through B—the jar will discharge itself slowly, and put out the candle.

## *To illuminate a Piece of Sugar by an electrical Explosion.*

### Exp. 60.

Fig. 67. Lay a piece of sugar upon the top of h—screw on the two balls b c—slide the wires till they nearly touch the ends of the sugar: the surface of the sugar must be nearly the same height as the center of the balls—set the instrument thus prepared, so that the end ball of that wire, which goes through B, may stand at about half an inch distance from the conductor of an electrical machine—set the jar used in the two former experiments, so that its ball may be in contact with the prime conductor; and make the end of the chain touch the outside coating of the jar. Darken the room—then turn the machine, and when the jar is charged high enough, it will discharge itself over the surface of the sugar, and the light will be seen upon its surface continuing some time after the explosion. If chalk be used, it will also retain the light after the explosion, which will be of a different colour.

*To pierce one or any number of Cards by an electrical Explosion.*

EXP. 61.

Charge fig. 17, as in experiment 22, but instead of placing it at half an inch from the conductor, set it in contact with the conductor: it will then take a higher charge—turn the machine till the jar has sufficient power—set two or three cards upright against the side of the jar—place one end of the discharger against the middle of the cards, propping them close to the jar—cause the other end to touch the knob of the jar, which will discharge, and a hole will be found through all the cards, large or small, depending upon the size of the jar, and strength of the charge—a disagreeable and sulphurous smell will be left between the cards. If the cards be examined, there will be seen a burr round the holes on each of the cards, particularly if only one card be used. If this burr were raised only in one side, it would enable us to judge which way the electric fluid had passed; whether from the inside of the jar to the outside, or from the outside to the inside; but the burr being raised on both sides, it does not furnish us with the expected information. The burr being often very irregular, supposed to be occasioned by the discharger pressing unequally against them, the following experiment will obviate that objection.

*To shoot a Hole through a Card.*

EXP. 62.

Place fig, 34 so that any part of a d may touch the prime conductor; a card being properly fixed before the mouth of the cannon so that it is intirely free from either the cannon or brass plate e, then when the jar is charged, it will discharge itself, and pass through the card to e, and so to the outside of the jar. It will be easily understood that in this case there can be no burr but that which is caused by the action of the electric fluid.

This may be done with a square glass plate coated on both sides, as represented by fig. 35.

EXP. 63.

Take a piece of brass, and bend it to a right angle; to which fix a piece of baked wood to contain a card. Lay the plate upon the table—place the cannon upon it—and annex it to the conductor; slide one end of the brass angle under the plate till it touches the outside coating.

Turn the electrical machine—the plate will charge till the cannon discharges its contents through the card, as in the last experiment—by moving the card in the wood, as many holes may be struck through, as are thought proper.

### *To fire cold Spirit of Wine by an electrical Spark.*

#### Exp. 64.

Place fig. 36 so that the ball, *a*, can receive sparks from the prime conductor of an electrical machine—pour into the cup, e, spirits of wine, till the rising part of the bottom is just covered—place the cup under the point of the piece, d—turn the electrical machine, and the sparks that are received by *a*, from the conductor, will fly from the point through the spirits to the rising part in the middle of the cup. If the spirits do not fire at first, slide the points nearer or farther from the rising part of the cup, till you find the distance at which it takes fire. In very cold weather a prime conductor will hardly contain electricity sufficient to set cold spirits on fire; in this circumstance, a coated jar must be annexed to the conductor, and when the jar is charged, connect the ball of the jar to the ball a, by means of an insulating director, and the jar will discharge itself with a large brush of light, which will set the spirits on fire. The outside of the jar must not be connected with the brass dish, because then the jar would discharge itself by exploding from the points, which for the most part only disperses the spirits, and does not set them on fire.

*How to set fire to warmed Spirits by the electric Spark after it has passed through a Piece of Ice, or a Snow-Ball.*

EXP. 65.

Dispose the apparatus, fig. 37, as is seen in plate IV, with the knob of the jar against the prime conductor—charge the jar—lay the snow-ball, or what you would wish the electricity to pass through, upon the bearer E, and then discharge the bottle, by directing the spark through the snow ball, with an insulated discharger, by setting one leg upon the snow-ball, and extending the other to the knob of the bottle—the brass cup being previously filled with warmed spirits, it will be set on fire, by the spark which had passed through the snow ball.

The most convenient method of warming the spirits is, to set fire to them in the cup by a candle, and let them burn for the space of half a minute; the electric spark will then easily light them.

### *How to fire Rosin by the electric Spark.*

#### Exp. 66.

Take a piece of rough wood, two or three inches square—pulverize some rosin very fine; and rub it upon the piece of wood—lay upon the brass cup fig. 36—slide up the point till it is about half an inch from the wood—place the apparatus so that *a* stand at about half an inch from the prime conductor of an electrical machine—place also a Leyden jar at the prime conductor in a proper manner for charging—annex the outside with the brass cup—turn the machine—and when the jar is charged high enough, it will discharge itself to *a*, and fly from the point to the surface of the wood to the cup, where the rosin will be set on fire.

*How to fire Tinder by an electrical Spark.*

EXP. 67.

Put some fresh tinder into the cup used in the last experiment; suppose about half full, pressed hard down. Place the cup under the point, and proceed in every respect as if it was intended to fire spirits.

Tinder may likewise be fired by holding it between the fingers near an insulated conductor of an electrical machine; but in this case, the conductor ought to contain at least forty superficial square feet; then it will fire it sometimes at a foot distance from the conductor, without sparks or any other visible cause.

*How to fire Gunpowder by a very large Conductor without any coated Glass.*

EXP. 68.

Roll up a piece of red East Indian paper, as if it were intended for a very small cartridge— tye one end with a string, but not very tightly; fill it with gunpowder—and stick it upon a sharp iron point, which must be held in the hand—take care that the gunpowder be not attracted out of the cartridge; hold it to the conductor, so that the side of the cartridge touch the conductor: if it is not inflamed at first, slide it backwards and forwards, and it will then do so, without a spark being perceived.

*How to inflame warm Spirit without being connected with the electrical Machine.*

EXP. 69.

Place fig. 38 so that the ball, d, shall take sparks from the prime conductor of an electrical machine, and so that it stand in a right line with the body of the prime conductor—stand upon an insulating stool at some distance from the point, which must be regulated according to the acting power of the machine; that being commonly about five or six inches—approach your finger very quickly to warmed spirit, and it will be set on fire—sparks may be drawn from any part of the person thus standing, the same as in experiment 16, but weaker. Care must be taken that nothing stands between d c and the insulated person, otherwise the electricity will be intercepted in its passage.

*To illuminate an Egg, Apple, Onion, Lemon, and Orange, as well ae some calcarious Substances and Sugar by Electricity.*

### Exp. 70.

Take fig. 67—unscrew the balls, b c, from the wires—lay an egg upon the top of h, then push the two wires forward till one end touch one end of the egg, and the other, the other end—place the instrument at about half an inch distance from the prime conductor of the electrical machine—place in contact with the conductor a coated jar—hang a chain from that wire of the instrument, which is farthest from the conductor, and annex it to the outside of the coated jar; turn the machine, and when the jar is charged, it will discharge itself through the egg, which will appear as one body of light, and be so transparent, that the yolk may be plainly seen. Proceed in like manner with an apple, onion, lemon, or orange, which ought first to be well rubbed with a dry woollen cloth, and the points of the wires must be stuck into each of them. The proper depth will be found by experience as it is not always alike, differing according to the size of the article made use of.

*How to illuminate the Bolognian Stone, either artificial or natural.*

EXP. 71.

Lay it upon h, fig. 67—and instead of directing the shock to touch the surface of it, as for chalk or sugar; adjust h so that the stone, or rather powder may lie about one inch lower than the points of the wires—make the discharge as before, and it will receive the light and appear as if it was burning for a considerable time, very much resembling common phosphorus. If this powder be kept in a bottle, from its being first made in the dark, it will give no light; but if it be exposed to the light of the sun, and then placed in the dark, it will appear luminous for a considerable time. Geometrical figures or names, by means of this phosphorus, may be very beautifully illuminated, by bending small glass tubes into the shape or figure desired. Fill them with it, and illuminate them by the electrical shock, as above described.

Unless the electrical machine, made use of for the above experiment, charge pretty quickly, it will be difficult to make the discharge in the manner described: in such case, it will proper to make the discharge by means of the electrometer, E F, plate 2—a chain or wire must proceed from F to g, and k must touch the outside of the jar; then the whole instrument may be set at a distance from the conductor.

*How to break Glass by the electric Shock.*

EXP. 72.

The surprising effect that electricity has upon glass, when close confined, is very remarkable.

Place upon h, fig. 67, a piece of glass about an inch square or more, according to the acting power of the electrical machine; then slide the wires, p g, so that their points touch the edges of the glass, pointing under it; place a cylindrical piece of wood upright upon the glass, and on the top of that, lay any metal weight, suppose one or two pounds, according to the thickness of the glass; if the glass is not more than a quarter of an inch thick, one pound weight will be sufficient—place a common sized Leyden jar to the conductor of the electrical machine—connect k to the outside of the jar by means of a chain or wire, and g to the electrometer, E F, its ball at the top, standing about half an inch distance from a; the jar when charged, will discharge itself to E, and from E between the glass and the ivory in its way to the outside of the jar—the glass will be broken in several pieces according to the strength of the charge. If it should not be broke, increase the distance, and repeat the experiment.

The same instrument is made use of for breaking glass tubes, tearing wood in pieces, and striking gold leaf into glass, in the following manner.

### *How to break Glass Tubes.*

EXP. 73.

Take a glass tube, intended for breaking, of any thickness—fill it with water, and stop both ends very closely with cork; then push the end of each wire through the corks till they are about three quarters of an inch distance from each other in the inside of the tube—transmit the shock through it in the same manner as in the last experiment, and the tube will be broken in several pieces.

## *How to tear Wood in Pieces.*

### Exp. 74.

Take pieces of hard wood of any sort, square or round, as is thought proper, but they should not be above a quarter of an inch thick, unless a very great force is to be made use of to break them. If they are not above a quarter of an inch thick, and about an inch long, a jar containing two square feet of coated glass will answer the purpose very well; then drill holes in each end, leaving a small space in the middle not drilled: the two wires, d and g must be taken out or filed small at their ends, so as to fit the holes in the wood; then push the ends of the wires into the wood, till they stop against the part which is not drilled—discharge a coated bottle through it as in the last experiment, and the wood will be split in pieces.

The tube of a tobacco pipe may also be broken in the same manner.

## *To strike Gold Leaf into Glass.*

### Exp. 75.

Take a piece of card paper the size of the glass, and lay it upon h—spread a leaf of gold upon it, and cover it with the glass which is intended to be gilt—lay a weight thereon, and give the discharge through it, in the same manner as in experiment 72, and the gold will be melted into the pores of the glass, so that it cannot be rubbed off.

The greater the quantity of coated glass made use of, the more gold will be melted.

## *The Use of the Thunder House.*

### Exp. 76.

Fig. 39, called the thunder house, invented chiefly to show the utility of conductors to houses, in a thunder storm. Being put together, as is represented in the plate, with a metal chain hanging from the shank of A to the ground, and a coated jar being annexed to the prime conductor, place the thunder house so near to the conductor, that the ball, A, may stand at about three quarters of an inch from the ball of the prime conductor. If A should be too low, stick the brass wire, n, into the hole of the prime conductor, and bend it till the ball at the end of it may be of an equal height with A—connect the outside coating of the jar with a brass hook under the door by means of a chain or wire; when the jar is charged, the electricity will fly from the ball of the bent wire to A, representing a flash of lightening—put the square piece a b c d, into its place, so that the wire, which goes quite across it, may stand upright; it will then connect the other two parts of the conductor—cause the lightening as before to fall upon A, nothing will happen to the house, because the conductor is continued from A to the bottom of the house—turn the square piece so that that wire, which does not go quite across, may stand upright; then if a flash of lightening be made to fall upon A, the square piece will be driven out of its place to a considerable distance; the lightening, falling upon A, runs down to the bottom of the wire, which is continued to the square piece, and not finding there any further metal conductor, it is obliged to fly from the end of the wire to that in the middle of the square piece, and force it out of its place. It may represent a part of a damaged wall, a door, or window, driven out of its place by lightening. We find upon the tops of several houses in this country, weather cocks; if the lightening should happen to fall upon them, it must unavoidably be the ruin of the house. The lightening falling upon the weathercock, runs down to the bottom of the spindle, and finding there no further metal conductor, flies from thenc to the ground, rending and tearing the wall to pieces in its way. If the conductors to houses are not made of a proper thickness, the same misfortune will befall them, as if they had none.

### Exp. 77.

The two brass wires, c d, being drawn out of their places, and that part made fast with a fine iron wire fastened to the hook in the inside, and from thence to a hook corresponding with the shank of the ball at the other end of the house, and a flash of lightening being made to fall upon the ball at the other end of the house, it will run along the fine wire, which not being thick enough, will melt it in its passage, and that end of the house will fall to the ground.

For the amusement of those who are less speculative, I have invented several parts in the inside, which is seen at fig. 39, and which ought to be previously prepared in the following manner.

Fig. 39.—The brass tube, c, must be nearly filled with loose gunpowder as likewise the ivory piece—the brass pin must be stuck into it through the powder to within a quarter of an inch of the bottom; and the chain, which is fast to the pin, must be hooked upon h, free from the flooring or the brass dish, in which must be poured a little spirit of wine—the brass pipe, k, must be filled with gunpowder made a little wet, and being pushed through the hole of the brass dish to the end of the hollow arm—L must be filled with gunpowder hard stopped. The house being shut down, as is seen in fig. 40, the experiment may be made.

## Exp. 78.

It will be proper in this experiment to set the house on the ground.—Make one end of a chain fast to the electrometer, E F, plate I, and the other end fast to the hook at the bottom of the house, and from thence to the outside of the jar, standing under the prime conductor; and the lightening will fly out of a to E, and run along the shank of A and h, and so to the ivory piece: the gunpowder will then be set on fire, which will blow open the roof of the house, and setting the spirit of wine on fire, that part of the house will be in flames; which after it has burnt some time, will fire the gunpowder in the pipe, k, and when that has burnt to the bottom it will set that on fire in the arm L; which will give a very loud report—the flooring of the house will be blown up, and the whole house will fall to pieces and appear in a ruinous state, like unto a house destroyed by lightening.

*N. B.* If an iron wire be used, as in the last experiment, and some gunpowder laid under it, there will be no occasion to use the ivory piece, and the experiment will answer equally well.

*The dreadful effects of Thunder and Lightening upon Ships without Conductors, shewn by experiment, with Directions to make Conductors to secure Ships from such Misfortunes.*

EXP. 79.

Fill the trough, represented in fig. 41, with water, till the ship, c, swims in it, and so that when it sails exactly under the ball L the top of the mast may nearly touch it—place c at the end of the trough at c, and make it remain there by hanging a chain to the end of the trough upon the stern of the ship—fasten a small thread to the head of the ship, and to pass it through a loop between the jars; annex the ball, L, to the prime conductor of the electrical machine, by means of the wire—turn the machine till the jars are fully charged; then, by means of the thread, draw the ship quickly under L, and it will be struck as with thunder, flying out of L to the mast, which will fall into the water in pieces. When the mast is repaired and set up again, unscrew the round piece of brass from the top of the spindle, and hang the chain, q r, upon it; then bind it to the back stays of the mast, or let it hang loose in the water, which is the same thing; then screw upon the top of the spindle the star, A.

## Exp. 80.

Fasten the ship as before—charge the jar, and draw the ship, as in the last experiment—it will be struck by the ball, but no damage be done to the mast; the fire will be seen to pass along the chain, without touching the mast.

### Exp. 81.

Place the ship at the end of the trough, as before—charge the jars—then draw the ship slowly to imitate as much as possible, the motion of a ship under sail, till it comes under the ball, and the mast will receive no damage, nor will any discharge be heard, because the point of the star has drawn the fire out of the clouds.

### *How to kill Frogs by the electric Explosion.*

### Exp. 82.

Fig. 42.—A represents the end of a prime conductor of an electrical machine—B is a coated jar to be charged—e is a chain, one end of which is annexed to the outside of the jar, and the other hooked to the skin of the frog between its legs—d is likewise a chain, one end of which is hooked to the upper lip of the frog, and the other end fastened to an insulated director; turn the machine, and when the jar is charged, approach the knob of the jar by the director, to which the frog is fastened, hanging in the position seen in the figure, that is, free from all con-

ductors, the bottle will be discharged, and the frog will instantly die.

It is very remarkable, that a frog cannot be killed by an electric discharge, when sitting upon a table; and yet may be easily killed, when swimming in the water.

*How to kill Frogs in Water, as also Fishes, &c.*

EXP. 83.

The apparatus, used in the last experiment, is proper for this, only, instead of a frog hanging between the chains, e d, in the air, it is now in a bason with water, fig. 43. When the jar is charged, discharge it by approaching its knob to an insulated director; the discharge will pass through the water, and the frog will immediately die; or if any small fishes, &c. be used, the same will happen.

Another phenomenon attending a frog, not easily to be accounted for, is; that all attempts to kill it, when upon a table by electricty, will be fruitless; but when in water it is so easily effected. There have always been two reasons given why a frog could not be killed, while standing on the table, or any conducting substance. One is, the dampness of its body conducts the shock, and prevents it from entering its body: the other reason is, that the moisture of the body wets the wood it was placed upon, and the wood thereby becomes a better conductor than the body of the frog; but both these reasons are of no avail, on seeing it can be so easily killed, when in water, which is a better conductor than moist wood, or that moisture which is peculiar to frogs.

### *The animated Pith-Balls.*

#### Exp. 84.

Fig. 44.—Make some small pith-balls, cut nicely round out of the pith of elder—take a tumbler or small receiver—charge its inside by holding it in such a direction, that a wire proceeding from any convenient part of the prime conductor, suppose from a, fig. 1, plate II, can touch nearly every part of its inside; then, if the machine be put in motion, and the glass moved, so that the wire touches nearly all its inside surface, it will be charged—invert A over the balls, and they will begin to dance, and continue so for a considerable time.

*Rationale*.—The dancing is caused by the tumbler being charged with electricity, and afterwards set over the balls; they are attracted by the electricity, which was in the inside surface of the glass, and again repelled to the table, by that means, the glass is discharging, the balls taking away that quantity of electricity, which was added to its inside, and the conducting particles in the surrounding air, gives to the outside that quantiry which was repelled off by the action of the electricity in the inside.

### *How to charge Glass not coated.*

#### Exp. 85.

Take any kind of glass or bottle; which can be easily held in the hand, so that the end of a wire proceeding from the conductor, can touch its inside surface, by holding it in the hand, as in the last experiment, covering as much as possible of the outside of the glass towards the bottom—put the electrical machine in motion, and move the glass so that the end of the wire in the conductor nearly touches all parts of the inside, excepting about two inches of the top—set it upon the glass table, being previously well rubbed or dried; then pour some small hail shot into the inside of the glass, till it is nearly full—take the glass in one hand, and with the finger of the other touch the hail shot; a shock will be felt, which proves that the coating of glass is of no further use than to connect the pores of the glass, so that the electricity can be more readily communicated.

### *The insulated metallic Rod.*

#### Exp. 86.

A B, fig. 45, represents the metallic rod upon an insulating stand—c d, two cork balls hanging from the end—excite a glass tube, and hold it within three or four inches from the end A, of a metallic rod, and the cork balls at the other end of the rod will diverge—remove the tube, and the balls will collapse: no electricity will remain in them, or in the rod—hold the excited tube near to the rod again, and the balls will diverge as before, for the same reason. Continue to hold the tube at the same distance with one hand, and with the other touch that end of the rod, from which the balls hang, and they will collapse; because the hand, touching that end of the rod, takes away that electricity, which was repelled into it by the action of the tube—take the hand away, and they will diverge again—excite the tube, and bring it near to A, as before, and the balls will collapse—remove the tube, and they will diverge, contrary to the first part of the experiment.

*Rationale.*—The cause of the balls diverging at first, is, that the repulsive power of the electricity upon the glass tube, repels the natural electricity from the end, A, of the rod to the end, B, and that end becomes positively electrified, and the balls diverge with positive electricity—the tube being removed, the electricity which was repelled into the end, B, by the action of the tube, returns again to its former state, and leaving the rod unelectrified, the balls must of course collapse. In this experiment, care must be taken not to approach too near to the rod, nor to touch it with any thing—as soon as the balls begin to diverge, stop at that distance, because by bringing the excited tube too near to the rod, it will impart some of its electricity to the rod, and the balls will remain diverged after the tube is taken away—the rod having received more than is natural to it, will remain positively electrified. A small coated bottle weakly charged will do equally as well as a glass tube for the above experiment.

### *The two metallic Rods.*

### Exp. 87.

Take fig. 46, two insulated metallic rods, and place them at about an eighth of an inch from each other, with the cork balls hanging from them; then take the glass tube or coated phial used in the last experiment—hold it at about two or three inches distance from the first wire, and the balls from both rods will begin to diverge—hold it there three or four seconds—then remove it, and the balls of both rods will remain diverged. That, which was nearest the glass tube or coated phial, will diverge, because it is negatively electrified, and the balls c d, will be positively electrified; or, in other words, the first mentioned diverges because it is deprived of its natural electricity, and the last because it has received more than is natural to it.

*Rationale.*—When the excited tube is held near to one rod, the action of its electric fluid repels the natural electric fluid out of that rod, and it enters the other, so that the last has too much electric fluid, and the other too little.

*Why the Balls at one Wire are negative, and the other positive.*

EXP. 88.

Separate the two wires while their balls are diverging—set them at some distance from each other; then excite the glass tube, and approach gradually towards the balls at the first wire, and they will be attracted. The balls will strive, as it were, to meet the tube, because they, having lost their natural quantity of electric fluid, do their endeavour to attract some of the superfluous quantity from the tube—approach the balls of the other tube in the same manner, and the balls will be repelled, or strive to recede from the tube, because, being excited, it has too much electricity, and the balls too much also, which they had received from the other wire, so they must of consequence repel each other both being in the same state. § IV. Page 4.

In the three last experiments there is no particular necessity for a glass tube, a small coated bottle weakly charged positively will do as well, and the result will be exactly the same. A stick of sealing wax, or a small coated bottle weakly charged negatively will also have the same effect, but will be exactly the reverse, as for example: where the electric fluid was repelled out of one into the other, will, by the action of the electric fluid, either from the bottle or stick of wax, in the last mentioned case, be attracted out of one into the other; and when separated the first will be found to be positive, and the second negative: because by exciting sealing wax in the usual manner, by rubbing it with any convenient rubber, except metals, it will be negative, that is, its electric fluid will be drawn out of it by the rubber, consequently, if it is brought near to any non-electrics, it will endeavour to attract the natural electric fluid out of it; but the sealing wax, being kept at a proper distance, that is, not too near, upon which the success of the above experiment depends, does not attract the fluid out of it; it is only attracted into the balls from the other end of the wire, being there stopped by the air being an electric and condensed; the other end of it must of course be left as strongly negative as the balls are positive, and part of the fluid being attracted out of the second wire, the sealing wax or negative bottle, being set away out of the sphere of action, the balls at the first wire will diverge, because they are negative, or because they have less electricity than their natural quantity, which is exactly the reverse of the case when the glass tube was used.

### *The exhausted Flask.*

#### Exp. 89.

Fig. 47 represents a glass about the shape of a Florence flask, with a brass cap and ball fixed to its neck, and nearly exhausted of air;—hold it by the brass ball, and rub the flask in the common manner used to excite electrics; it will appear luminous within, and give flashes of light; —but, to make it appear more luminous, hold it to the prime conductor of an electrical machine; the whole cavity of the glass will appear full, with a flashing light, and will remain so for a considerable time after it has been removed from the prime conductor.

After it has been laid away for some time, and it had ceased to give light of itself, grasp it in the hand, and strong flashes of light will immediately appear in the inside of the glass, if the weather be favourable.

If it is held in the hand by the ball, and the opposite end touched by the prime conductor of an electrical machine when in motion, the electric fluid will be condensed on the outside of that end, and its natural electric fluid in the inside, belonging to that space only where it is condensed on the outside, will be repelled away in streams through the whole space of the glass to the hand;—the glass then becomes partly charged, being condensed or positive on the outside, and rarefied or negative in the inside:—the reverse will happen, if the end (a) be held in the hand, and the brass ball to the prime conductor—the electric fluid will be driven in streams throgh the space of the glass, towards the end, and there be condensed in the inside, and rarefied or negative on the outside—in whatever manner it is presented to the prime conductor, it becomes always in some degree charged. Suppose it then to be charged in the manner first mentioned, negative in the inside, and positive on the outside—after it is taken from the conductor, it continues to give flashes of light, because one side having too much electric fluid, or more than its natural quality, is continually giving way, and the other receiving; the passage of the electric fluid to and from causes that flashing light till it is nearly discharged; then it will cease to give flashes of itself;—but, when taken in the hand, or touched on the outside by any conducting substance, the flashing will again appear, because it then goes away to the touching conductor, and, by that means, gives the inside an opportunity to receive what it had been deprived of.

*The exhausted Glass Globe.*

EXP. 90.

Fig. 48 being set near to the prime conductor of an electrical machine, so that c can receive sparks from it, turn the machine, and every spark that passes from the prime conductor will fill the whole glass globe, making a very beautiful appearance in a dark room; if the electrical machine acts strongly, it will give light enough to read by. This experimnnt shews the surprising expansive property of electricity; as one spark, not so large as a pin's head, in the common density of the atmosphere, can fill so large space.

EXP. 91.

If, instead of making sparks fly from the prime conductor to C, you cause them to fly to the wooden pillar D, the appearance will be different, but the light will be much the same.

### Exp. 92.

The globe will always be charged, by being strongly electrified, in either of the former experiments;—to discharge it after the first experiment, make one end of a chain fast to the top of the wooden pillar, and cause the other end of the chain very quickly to touch the bent wire c,—a large body of fire will be seen to fly from under the brass plate, in a direct line to the bottom, in its passage to the outside. After the last experiment, one end of a chain must be made fast to the bent wire c, and the other end, while the globe is charging, must be made to touch the bent wire projecting out of the top of the wooden pillar.

### Exp. 93.

*The exhausted Cylinder.*

Let AB, fig. 49, represent a long glass cylinder standing upon the plate of an air pump—make a metallic communication between the regulating electrometer EF, fig. 1, plate 1, set the ball F at about half an inch distance from a—begin to exhaust the cylinder, while an assistant turns the machine—if the cylinder were made very clean and dry, no sparks, or, at least, very faint ones, will fly from a to F, till the cylinder is about half exhausted; then sparks will pass freely, and be seen at the points at the top of the cylinder, and afterwards at the bottom also, passing from the top to the bottom of the cylinder in variegated flames of light—the exhausting and passing of sparks still continuing, the cylinder will be filled with a steady light, the exhausting may be carried so far, that the light will begin to get much fainter.—But this can only be obtained by an air pump of an extraordinary rarefying power, such as Cuthbertson's improved air pump. By varying the distance of th. ball of the electrometer from the ball of the prime conductor, much variation in the light may be obtained.

### Exp. 94.

Take the pieces first used away, and in their place fix two balls, exhaust the cylinder as before, and slide the wire E so low, that the ball at the end of it may stand about seven inches distant from the other—electrify, as in the last experiment, and the cylinder will be filled with light in the form of a tree; the root between the two balls, and the branches spreading from the side of the wire to the side of the cylinder, it will sometimes appear in the form of a screw, winding about the wire E in continual motion.

*The exhausted Glass Tube.*

EXP. 95.

Fig. 50, plate V. Take one end in the hand, and lay the other end upon the prime conductor of an electrical machine when in motion, and the tube will be filled with light; which will continue for a considerable time after it has been taken away, and begin to flash by intervals, which will continue for an hour or longer, depending upon the state of the atmosphere.

*Visible electric Atmosphere.*

EXP. 96.

Fig. 51 represents a glass with two necks, both mounted with brass; from the inside of each projects a brass wire, with a ball of two inches diameter finely polished, and of an exactly true figure, standing at about four inches distance from each other. This glass is nearly exhausted by an air pump. Annex the ball at the top, by means of a wire or chain, to the electrometer E, fig. 1, pl. 1, turn the machine, acting very weakly, and the ball of the electrometer nearly to touch the ball a, otherwise the electircity will pass in a stream from one ball to the other, and the experiment will not have the desired effect; a little practice, however, will soon render the operation easy and familiar;—a lucid atmosphere will appear at that end of the glass which is connected with the electrometer, at the same time that the ball at the other end, has not the least appearance of light; this atmosphere does not exist all round the ball; but reaches from about the middle of it to a small distance beyond that side which is towards the opposite ball. If the same end be held to a negative conductor, and electrified negatively, the lucid atmospere will appear about the other ball, at the same time that the negative electrified ball does not shew the least appearance of light; which makes it appear that the electric fluid consists of one uniform homogeneous fluid, and not two, as some have supposed; for, if it were two distinct fluids, attracting each other, then there would, in this experiment, appear two atmospheres, that is, one about the ball at the end A, and a second about the other ball; which, we see, is not the case. If the appearance of the lucid atmosphere be always about that ball which is overcharged with electricity, when A is electrified positively, the superfluous fluid is visible on that part which is nearest to the other ball, because being in a contrary state of electricity, it endeavours to attract it; but when electrified negatively, it will attract the electric fluid from B; which fluid, on that account, is visible on its surface, just in the act of leaping to the other ball.

*To prove that the electric Fluid does not expel the Air out of a coated Jar while charging.*

Fig. 52 represents a jar coated in the common manner, mounted at the top perfectly air-tight, excepting *a*, which is put through the mounting, and has a small drop of red liquid put into it at the time of the experiment; c is a brass wire, with a brass ball at one end, the other being in contact with the inside coating of the jar.

### Exp. 97

Set c in contact with the prime conductor of an electrical machine, and begin to charge the jar. It is plain, from the construction of the jar, that if any air be expelled by the electric fluid, it must pass through the small glass pipe *a*, and thereby displace the drop of liquor which is in the pipe:—there will not be the least motion perceived in the liquor; which shews that the electric fluid, transmitted in the bottle, does not exclude any of the air contained in its inside;—when it is discharged, if the wire be not in close contact with the inside coating, of the jar, it will be a little displaced, owing to the spark which passes from its inside coating to the wire, so that this ought to be particularly guarded against.

*The Course of the electric Fluid, in a Discharge, rendered conspicuous by a pith Ball.*

### Exp. 98.

Lay upon h, fig. 6 7, a piece of baked wood, with a long curve in the middle; nearly of the same radious as the pith ball; then slide the two wires till they are within about one-half or three-fourths of an inch from the pith ball; annex one of the wires, suppose g, by means of a metal chain, to the outside of a charged bottle, and, with an insulated discharger, direct the discharge to pass between the balls of the wires, and over the surface of the baked wood—the pith ball, lying in the middle, is always driven in the direction of the electric fluid, that is, towards the negative side of the bottle. It must be observed that, in this experiment, the charge of the bottle must be only just sufficient to pass through the interval in the circuit, the baked wood must be very dry and clean, and, in short, the disposition of the apparatus, and the performance of this experiment, requires a degree of nicety that can only be obtained by practice, which when the operator has once got to succeed, and afterwards follows exactly the same method of operation, he may be sure that the event of the experiment will constantly be as above described.

*The Direction of the electric Fluid in a Discharge, shewn by causing it to pass over the Surface of a Card.*

EXP. 99.

The apparatus used in the last experiment is most proper for this. Lay a card upon h, and unscrew the balls off from the wires, then slide one of the wires under the card, and the end of the other wire above the card; at about an inch distance, annex g to the outside of a charged bottle, by means of a metal chain; discharge the bottle, as in the last experiment, with this difference, that it is necessary to be pretty strongly charged; and it will be observed, that the electric fluid will run over that surface of the card on which the end of the wire lies which is connected with the positive side of the bottle, and it will pierce a hole through the card, just over the extremity of the wire which is connected with the negative side of the bottle. This makes it appear, that the electric fluid must have passed from the positive side of the bottle to the negative, by its piercing a hole just above the end of the wire: if it had passed the contrary way, the hole must have been made under the end of the wire to have got to the positive side.

### *The Direction of the electric Fluid ascertained, or the two Kinds distinguished, by the Production of Heat.*

#### Exp. 100.

Place upon h a common sized candle, burning, with its flame nearly upon a level with two wires, and their balls at about four inches distant from each other, with the candle in the middle; connect one of the wires with the prime conductor of an electrical machine, and connect the other with some good continued conductor, or with the negative conductor of the machine, or, if it it has no negative conductor, a wire connected with it may be held in the hand, which will answer equally well;—turn the machine; the flame will waver very much, and seem rather to incline more to the negative ball, than to the positive one; but it is very equivocal;—continue turning, if the machine be a plate of two feet diameter, about fifty revolutions; then the negative ball, or that one which is connected with the hand, will begin to grow warm, and the positive one remain cold. If the revolutions be carried on to two hundred, the negative will be too hot to be touched, and the positive remain as cold as at the beginning.

If the two balls at the end of the wires next to the candle be made hollow, so that a ball of a thermometer can be placed in each, the experiment will be more evident, and the apparatus more complete for further researches; the subject being certainly worthy of investigation.

### *To swell Clay by an electrical Explosion.*

### Exp. 101.

Roll a piece of soft pipe clay in a small cylindrical form, as c d, fig. 53; put two wires into it, so that the ends within the clay may be about one-fifth of an inch from each other; then lay it upon h, fig. 67; adjust the wires f, g, so that they touch the knobs a, b, and then discharge a bottle through it as directed in Exp. 82—it will be inflated by the spark which passes between the two wires; and, after the explosion, it will appear as represented in fig. 54.

The clay for this experiment must be very moist and pliable, otherwise it will break by the explosion, and its fragments be scattered in every direction.

*To break a Wine Glass by an Electrical Explosion.*

Exp. 102.

Fig. 55 represents a common glass, nearly full of water; C, D, are two wires with knobs at their ends, hanging in the water half an inch asunder.

Annex C, by means of a metal chain, to the outside of a coated bottle; charge it, and, by means of the insulated discharger, direct the discharge to D—the discharge will have passed through the water from one knob to the other, and the glass will be broken with very great violence.

*To prove that the electric Spark displaces and rarefies the Air through which it passes.*

EXP. 103.

Make a brass chain fast to the brass foot b, fig. 56, and annex it to the outside coating of a charged bottle; with the insulated discharger, direct the charge to the brass ball a—and, on the explosion it will be seen, that the water in the small tube rose to a very great height, and immediately fell again, but not quite so low as before the explosion.

*How to charge a Plate of Air.*

Let two circular boards, about four feet in diameter, be planed very smooth, and coated with tin foil, carefully, so as to be free from points; insulate one, by a glass foot, and the other by means of a silk string; which goes over a pulley fixed to the cieling of a room, for the convenience of raising and lowering it as is found necessary.

EXP. 104.

Let the boards hang at about an inch distance from each other; then the plate of air, which is between the two boards, will act as a plate of glass, and the boards as the two coatings upon it;—if the uppermost be annexed to the prime conductor of an electrical machine, it will be found that no charge can be communicated to the air, because the undermost plate is insulated;—hang a metal chain from it to the ground, the other being still annexed to the prime conductor, put the electrical machine in action, and a voluntary explosion will happen between the two plates, which is a proof that the air between them was charged. By not turning long enough to make them explode of themselves, they may be discharged in the common way (that is) by first touching the undermost board with one end of the discharger, and extending the other end to the uppermost board—a discharge, as from a plate of glass, will happen; but, when they are discharged in this manner, it is necessary to continue turning the electrical machine, because the air, not being free from conducting particles, discharges itself imperceptibly, as soon as the action of the electrical machine is stopped; neither will the discharge be found so strong as an equal quantity of coated glass, for the reason already mentioned. Notwithstanding that a plate of air cannot receive a very high charge, yet we have some advantages from this experiment; that is, we can see what happens between the two coatings in charging or discharging; and, likewise, we can introduce several things into the substance, if it may be so called, of the coated electrics, which will produce several remarkable appearances. By this experiment, the state of the atmosphere, when covered by clouds, may be represented exceeding well, and several effects of natural electricity may be imitated.

The distance between the two boards must be regulated according to the acting power of the electrical machine: the stronger the machine acts, the farther the boards may be separated.

*To discharge a coated Jar without causing an Explosion.*

EXP. 105.

When a large jar is charged, so as to give a strong shock, put your hand in contact with the outside coating, and with the other hand hold a sharp-pointed needle, directing the point towards the knob of the jar; proceed gradually towards it, till the point of the needle touches the knob of the jar;—by this operation, the jar will be entirely dicharged without giving any shock; the point of the needle has, therefore, silently and gradually conducted all the superabundant electric fluid from the inside surface of the electrified jar, which has passed through your body to its outside.

*An electric Discharge prefers a short Passage through the Air, to a long one through good Conductors.*

EXP. 106.

Bend a wire, about five feet long, in the form represented by fig. 57, that the parts a, b, may stand about a quarter of an inch from each other; then connect the end d to the outside of a battery, or coated surface, sufficient to melt wire, when it is charged; set one leg of the insulated discharger upon c; and make the other end to touch one of the knobs of the battery—it will be discharged;—at the time of the explosion, a spark will be seen between a and b, which shews that the electric fluid prefers a short passage through the air, to a long one through the wire:—this spark, at first, was supposed to contain the whole discharge; but the contrary is proved by the following experiment.

### Exp. 107.

Lay a small wire from a to b, of such a thickness as the battery is capable of melting; when charged to the same height as before, discharge it—and the small wire will not be melted; cut the large wire in two at e, so as to discontinue the circuit, make the discharge as before—and the small wire will be melted, by the same explosion which before scarcely made it red-hot. In this manner, says Dr. Priestly, who is the inventor of this experiment, the conducting power of different metals may be tried, using metallic circuits of the same length and thickness, and observing the passage through the air in each.

## *To make coloured Rings upon Metals.*

### Exp. 108.

Set up edgeways upon the table h, fig. 67, a piece of polished metal, supported by the ball of the wire f; unscrew the ball of the other wire, under which is a fine point; slide it towards the piece of metal; then, by means of an insulated discharger, send several explosions of the battery through the piece of metal, or from the metal to the point—they will gradually mark the surface of the piece of metal, opposite the point, with circular prismatic colours, which are evidently occasioned by the lamina of the metal raised by the explosion. These colours appear sooner, and the rings are closer to each other, when the point is near to the surface of the metal; the number of rings is more or less, according as the point is more sharp or blunt: it makes no difference what sort of metal is used; a watch case answers very well.

*Glass becomes a Conductor when made very hot.*

Fig. 58. a b is a small glass tube, about a foot long, close at one end; c is a brass wire, pushed through a cork into the inside of the tube; d is another wire, bound upon its outside.

EXP. 109.

Make the wire d fast to the outside of a coated bottle, and, by means of the insulated discharger, try to send a shock through the tube from the end of the wire c to d, which will be impossible, without breaking the tube; take a candle, and, with a blow-pipe, make the tube red-hot at the end; then try to direct the discharge as before, and it will be easily transmitted from one wire to the other through the substance of the glass.

*Resinous Substances, and Oils, become Conductors when made hot.*

Fig. 59 is a glass tube bent to the form of a semicircle, nearly filled with resinous substances or oil; a b are two wires inserted in the inside of the tube.

EXP. 110.

Suppose the glass to be filled with pitch, by being poured into it when it is in a perfectly fluid state—try to direct the explosion of a coated bottle through it in the manner described in the last experiment, and you will find the bottle to discharge very well through it, from one wire to the other—let it stand till it is cold and you will not be able to send a discharge through it. Oils, or any other fluid electric, will answer in the same manner.

## *Hot Air is a Conductor.*

### Exp. 111.

Electrify the balls of fig. 45, so that they diverge; then hold a red-hot iron under them, and they will close—take notice of the distance the iron was from the balls when they lost their electricity; make the iron cold, and bring it to the same distance from the balls as before, and you will find that they will not in the least be disturbed.

From the above experiments we may learn, that a great many substances which are ranked among conductors, will become electrics when brought into a different temperature, and that all electrics become conductors when heated to a certain degree.

## *The Force of an electrical Explosion is greatly diminished, by causing it to make long Circuits.*

A, fig. 60, is a Leyden jar; B C, a brass wire, about three feet long, wound up in the form of a spiral spring, made fast upon an insulated stand.

## Exp. 112.

Suppose A to be standing at the conductor of an electrical machine—take iron wire, of such a size and length as is known that the jar can make red-hot when charged to a certain degree, governed by the regulating electrometer E F, fig. 1, pl. 2; hook one end of the small wire to a, and fasten the other end to a thicker wire, which proceeds from the electrometer; let also a wire proceed from the hook to the outside of the jar, by hooking it to a; set the electrometer E F at a proper distance from a, pl. 2, fig. 1. Charge the jar till it discharges itself from a to E; from thence through the small wire—which, if E stood at a proper distance, will be either red-hot or melted; the experiment will be more decisive if it is only red-hot. Hook one end to a small wire, of exactly the same length and thickness as the other was, to d—hook the other end to a, which is connected with the outside of the jar; charge the jar as before, (E remaining at the same distance from a) till it discharges itself—it will pass from a to E through the small wire, to d, and from thence along the spiral to a, and from thence to the outside of the jar—the small wire will neither be red-hot nor melted;—if it was only made red-hot in the last discharge, it will, in this, not be changed;—but if melted before, then it will perhaps be blued in this

### Exp. 113.

Take the small wire away, and make two other pieces of the same size and length, the one fast from g to a, and the other from d to E, charge the bottle till it discharges as before—and the wire between d E will be blue as before—but that between g and a, not in the least altered;—To melt the wires, as in the first experiment, they must be of a smaller size, and that between g a, smaller than between d E.

From these experiments we learn, that the force of the electrical discharge is greatly diminished by making it pass through long circuits; and that the force is diminished at the beginning as well as at the end of the circuit, though not to the same degree; and, from this, it also follows, that when we have scarcely sufficient quantity of electric fluid to perform the required experiments, the circuit must be shortened as much as possible.

## *How to give an electric Shock without coated Electrics.*

### Exp. 114.

This may be done by increasing the size of the prime conductor, or connecting it to another conductor of larger dimensions; but at the same time, a proper passage, for the electric fluid to get to a proper conducting part of the earth, must be attended to;—if the size of the conductor be only increased, the spark will also be increased, but not give the sensation of a shock, because a wooden floor, not being a good conductor, can only let a certain quantity of electric fluid pass away through it at once; so that, by increasing the size of the conductor, and not making a proportionate passage for it to get at a good conducting ground, the point in view can not be obtained; to do this, a wire must be contrived so, that one end of it is carried out of the window of a room, and connected with some good conducting part of the ground, while the other end remains in the room, so that it can conveniently be taken in one hand, while sparks are drawn by the other; and each spark will be a perfect shock. By increasing the size of the conductor, and providing a proper passage for the electricity to pass away, wire may be melted, and all the effects of a battery may be performed without any coated glass.

### *On the lateral Explosion.*

When a Leyden jar is placed so that its knob touches the conductor of an electrical machine; and a chain is stretched out upon the table, with one end nearly touching the outside coating of the jar; let it be charged so high as voluntarily to discharge itself;—then, at the same time that the discharge happens, a spark will be seen between the end of the chain and the outside coating of the jar; which spark is called the lateral explosion: upon which Dr. Priestly, Mr. Cavallo, and others, have taken some pains to explain, but without success. I invented the following apparatus.

### *To shew the lateral Explosion.*

#### Exp. 115.

Place fig. 61 so that the knob a, touch the prime conductor of an electrical machine, the knob b, at about a quarter of an inch distance from c, and the knob d, at about two inches from a; hang to e, a long metal chain, one end touching the ground;—turn the machine, and when the jar is charged, it will discharge itself, and fly from a to d, and, at the same instant, a spark will be seen between c and b, which is the lateral explosion.

*To make the lateral Explosion visible, when a large Ball, C D, is set upon the Jar, instead of the little Ball or Knob a.*

EXP. 116.

Screw the little ball a, from off the jar, and in its place set the large ball C D, so that the wire of the jar may pass, through the large hole, into the ball, and let the ball rest upon the neck of the jar; slide the wire, with the knob d, backwards, so far that the jar can discharge itself to it; when it is charged as high as possible, which is best found by experiment, and when the jar discharges itself, a spark will be seen between c and b, as before.

*How to examine the Direction of the lateral Explosion, or Spark, that was between c and b, in the last Experiment.*

EXP. 117.

Take the chain away from e, and hang it upon g: set the small bottle h, upon i, and so that its knob is about an eighth of an inch from c and b;—charge the jar till it discharges itself, and the spark will now be seen between the knob of the bottle and c, which must have either gone from c, to the knob of the bottle, or from the knob of the bottle to c; examine whether the bottle is charged positively or negatively within;—if it is found to be positive, then the spark must have passed from c, to the knob of the bottle—and if negative, it must have gone from the bottle to c;—the bottle will be found to be positive, so that the spark must have passed from c, to the bottle.

*How the Bottle becomes positively charged in the last Experiment.*

EXP. 118.

Charge the jar as before; only, instead of charging it at the positive conductor, charge it at the negative conductor o, so high that it voluntarily discharges itself: having previously discharged the small bottle h, and set it upon i, as in the last experiment;—after which, the small bottle will be found to be charged negatively in the inside. This will be constantly found to be the same as the jar was before the discharge;—if the large jar was charged positively in the inside after the discharge, the small bottle will be found to be the same, and *vice versa*.

From the two last experiments we learn, first, that the lateral explosion is a certain quantity of electric fluid, which, at the time of the discharge of a positively charged jar, departs from its outside; and, secondly, that it is a certain quantity of electric fluid, which, at the time of the discharge of the negatively charged jar, comes to its outside.

### *The Cause of the lateral Explosion.*

#### Exp. 119.

Take the little bottle h, away, and set the knob b, at about half an inch from c, slide d backwards, so that it may stand about half an inch farther from the knob of the bottle than it did in the last experiment, charge the jar positively as high as possible, without causing a voluntary discharge, and take notice of the number of revolutions necessary—move the apparatus from the conductor—take an insulating discharger, hold it so that one of its balls may be between the knob of the jar and d: it will then cause a discharge, but no lateral explosion will be seen, because the distance is too long. Repeat the experiment several times; after each discharge, slide b, a little forwards towards c, till you obtain the exact distance at which the explosion happens; when found, take the large ball in the last experiment, charge the jar as before, and when charged by the same number of revolutions, proceed as before with the discharger: the jar will be discharged, but no lateral explosion seen. Repeat the experiment, and slide b towards c, after each discharge—and it will be found, that b and c, must be much nearer to each other to make the lateral explosion visible when the small knob is used, than is necessary when the large ball is used.

It is evident, from the above experiments, that the lateral explosion is caused, first, from the height of the charge, and, secondly, by the magnitude of the conducting substances connected with the charged side of the jar.

The lateral explosion, when a jar is charged positively in the inside, is that quantity of electric fluid which is contained in any conducting body annexed to the inside coating of the charged jar, repelled into it by the action of the machine being more than that which was repelled from the outside.

The lateral explosion when a jar is charged negatively in the inside, is that quantity of electric fluid which is drawn out of the conducting body annexed to the inside coating of the charged jar by the action of the machine, and being less in quantity than that which is come up to the outside.

*The amazing velocity with which condensed quantities of electricity, or sparks, pass from one conducting substance to another, affords many curious experiments.*

### *The spiral Tube.*

### Exp. 120.

Fig. 62. Hold one end in the hand, and apply the other to the prime conductor of an electrical machine—and sparks will pass from the conductor to the hand in the form of a spiral, and form very beautiful and brilliant appearances, witha powerful machine;—many fanciful

devices may be made upon glass planes, by fixing small pieces of tin foil at small distances from each other.

### *The curved Line.*

#### Exp. 121.

Fig. 63 being fixed upon a stand, and a brass ball at each end—when one is set near the conductor, so as to receive sparks, they will fly from one end to the other; the ball at the other end must be touched by the hand, or annexed to the ground;—if one side of the glass be painted with different colours, the sparks will appear of different colours when seen on one side.

### *Illuminated Word.*

#### Exp. 122.

Fig. 64 is two glass planes; upon one of which is pasted tin foil in parallel lines, and cut through, or separated, at different places, to cause sparks;—and the separations being from one parallel to another, in the form of letters, any word may be made and illuminated, which has a very striking effect;—the other glass plane is only to prevent the tin foil from being damaged.

*To prepare a resinous Plate for electrical Figures.*

Prepare a board, nineteen inches square, and three quarters of an inch thick, with edges three quarters of an inch high above the surface of the board; the board to be a single piece of good solid mahogany, to prevent warping by heat. Take six pounds of rosin, nine ounces and a half of bee's wax, and two ounces and a quarter of lamp black; the rosin to be free from impurities, and the lamp black to be passed through a fine hair sieve; melt these ingredients together in any convenient vessel with a gentle heat, until the mixture be very thin, stirring it about constantly with a wooden spatula, and removing any impurities that may be floating on the surface. Warm the board, and place it level; then pour the composition quickly on its middle, and it will spread equally over it with an even glossy surface; when it is cold, warm the surface several times at the fire, to take out the blisters and pits; this resinous plate will be about half an inch thick. Procure an instrument, like unto a square open-bottomed candlestick, of three inches a side, and furnish it with a glass handle; and another instrument, like a metallic waiter, of twelve inches diameter, with scolloped edges and glass handle. Both may be made of tin, shaped something like fig. 65; the circular rim a, must come in contact with the resinous plate, as well as the scolloped edge b, as is seen in the section; the upper part of the scolloped edge is soldered to the middle of the circular rim, quite round its outside, and then declines from it, until it is on a level with the lowest part of the circular rim, as at b, in the section.

### Exp. 123.

Put both positive and negative conductors of the plate machine in their proper places, as in plate 11; hang a chain from the positive conductor to the floor; place the resinous plate on a table, and near the negative conductor; set the square-bottomed candlestick on the middle of the resinous plate, and connect it with the negative conductors by means of thick wire; near the resinous plate set a jar, containing about a square foot of coating, and make a metallic communication between its inside and the negative conductor; pass a pretty full charge through the candlestick, by applying a discharging rod from it to the outside of the jar; remove the wire from the candlestick with a glass stick, beyond the area of the plate, and take away the candlestick by its glass handle; likewise remove the chain from the positive conductor; make a metallic connexion betwixt the positive conductor and waiter placed in the middle of the resinous plate, and likewise betwixt the said conductor and inside of the jar, pass a full charge of the jar through the waiter, by extending a discharging rod from it to the external coating of the jar; remove the wire and waiter from the plate, by means of glass; set the resinous plate upright; then blow upon it, from a pair of bellows, at the distance of three or four feet, a large tea spoonful of a powder, composed of equal measures of red lead and flour of sulphur, intimately mixed; the powder is to be poured down the pipe of the bellows.

This experiment, with the flour of sulphur and red lead, is a very striking one, and is much admired. To observe two powders, previously mixed in the most intimate manner, separated in the air by an invisible power, and projected upon a plain surface in a disunited state, so as to produce two figures of different but most beautiful colours—the red lead falls on the negative figure, and the sulphur on the positive.

*The same Experiment can be done, without the Aid of a negative Conductor, in the following manner.*

### Exp. 124.

Take a glass jar, fig. 66, containing about half a square foot of coated surface, whose central wire is fixed firmly to its inside. And, to prevent the unpleasant circumstance of the jar's discharging when it is held in the hand, a quadrant electrometer may be placed upon the prime conductor. Set the resinous plate upon a table, and at any distance from the machine; on the centre of the plate put down a square-bottomed glass handle; near the resinous plate lay a piece of thick glass, about six or eight inches square, or an insulating stool; upon which place the jar, and connect the central wire with the square bottom standing upon the board, as is represented in the figure; take up the jar by its knob and apply its outside coating to the prime conductor, during the turning of the machine; as soon as the jar is charged, set it upon the middle of the square piece of glass, or stool, and the ball of the wire in contact with the metallic bottom, the jar being still held by its knob during this process; discharge the jar immediately, by making a communication by means of a discharging-rod, as in the figure. Remove the jar by its coating, and the metal bottom by its insulating handle; place the instrument, used for the above experiment, on the middle of the resinous plate; set the jar upon the table, and, near the resinous plate, charge the inside of the jar positively, and set it upon the table, with the ball of the wire in contact with the waiter; extend the discharger from the waiter to the outside coating of the jar; remove the jar by its coating, and the waiter by its glass handle; place the resinous plate in a vertical position, and proceed as above.

## *To decompose Water by the electrical Machine.*

The apparatus necessary for this experiment is represented fig. 67, pl. V; a, is a common wine glass with two holes drilled opposite each other, in which are cemented two capillary glass tubes, having gold or platina wire passing through them; the wires at their outward ends are bent in the form of a hook or eye, to form the necessary annexions; the inside ends are hermetecally sealed, so as to cover the end of the wire, (which was previously filed to as fine a point as possible) but not so thick, but that a weak spark, from the prime conductor of an electrical machine, can pierce it; the inside ends of the tubes are bent upwards, so that a small receiver can be set upon each, to receive the respective gases formed by the decomposition.

The decomposition of water by electricity, was first done in Amsterdam, by Mr. Van Troostwyk and myself, in 1789 (see Nicholson's 4to Journal, 1 vol. page 241) which was done only by electrical discharges. Dr. Wullaston has improved upon this; and invented an apparatus, whereby it can be decomposed merely by a current of electricity. The apparatus which I have described is only an improvement upon his, to make the experiment more easy both in its use and construction.

### Exp. 125.

Fill the glass a, with pure water, as also the two receivers; invert the receivers, and set them upon the upstanding ends of the tubes; place it so, that a wire, proceeding from the electrometer E F, fig. 1, can be hooked to one of the wires proceeding from one of the outward ends of the capillary tubes (the wire with the director 5 must be removed); to the outward end of the other capillary tube must be also hooked to a wire, which must be annexed to the negative conductor of the machine; but if the machine has no negative conductor, the experiment will succeed equally well if it be held in the hand, or connected with any good continued conductor; when the machine is put in motion, the electricity will pass from the knob of the conductor to E, which must set at about one-eighth distant from thence, along the wire, to the end of the capillary tube, under one receiver, —where small bubbles of air will be formed, and ascend, through the water, to the top of the receiver; from thence, it enters the point of the other capillary tube, and forms other bubbles of air, which will ascend to the top of the other receiver;—the first will be oxygen gas, and the second, hydrogen; it passes then through the wire to the hand, or the continued conductor to the ground, or, if it was connected with the negative conductor, it passes from it to the rubbers.

*Description of the improved electrical Condenser.*

Fig. 68 represents a vertical section of the large condenser standing edgeways to the eye; a b are two flat round brass plates, of about six inches diameter; c is a glass cylinder, fixed at one end into a wooden foot d; e is a brass ball, and mounting at the other end, to which the plate b is screwed fast; f is a brass wire, with a joint at its lower end, and at the other end a ball to which the plate a, is screwed, standing parallel to b; by means of the joint, the plate may be moved back in the situation of the dotted outline g. The joint has a shoulder, which stops the plate a, and keeps it at its proper distance from b.

*Description of the condensing Electrometer.*

Fig. 69 is the common gold-leaf electrometer, with an addition of two vertical brass plates, of about an inch and a half diameter: one is screwed fast to the brass mounting at the top of the electrometer; and the other, to a wire which has a joint fixed to the foot of the electrometer, by which it is moveable, and is set parallel, and at a proper distance from the other plate, the joint being furnished with a stop for that purpose, or may be moved backwards in the direction of g, fig. 68; l is a brass cup, with a shank at the bottom which fits into a hole in the top of e, serving to examine the state of electricity excited by dropping of metals; m is a wire, filed to a point at one end, and the other a joint, with a shank which fits into the hole at e, to examine the electricity of the atmosphere, or into the top of the gold-leaf electrometer, fig. 69. These two instruments, fig. 68 and 69, are used separately or combined, as the nature of the experiment may require. When the experiment requires the aid of both condensers, they are combined, as is represented fig. 70; the two fixed plates standing towards the eye. The fixed plate of the large condenser has a small brass pin at one side, which, when the instruments are used together, must touch the fixed condensing plate of the gold-leaf electrometer.

*The Method of using the double electrical Condenser.*

*To shew the electric Fluid excited by Effervescence, &c.*

### Exp. 126.

Screw l into the top of the ball e of the large condenser, and set therein a China or glass cup, with proper ingredients for that purpose; then join the two instruments, as in fig. 70. While the effervescence is going on, turn back the moveable plate of the large condenser into the position of the dotted line, fig. 68, taking care not to touch the fixed plate; then, if the excited electricity be very strong, the gold leaf will diverge; but if not, just move the electrometer, so that it is quite free from the pin—turn back its moveable plate, and if a sufficient quantity of electric fluid be excited, the gold leaf will diverge.

*To shew if there be any sensible Quantity of electric Fluid in the Atmosphere.*

EXP. 127.

Screw m, into e, of the large condenser; a convenient place being chosen, not much surrounded by buildings or trees—set the instruments combined as in the last experiment, and proceed in the same manner.

To try if there is electricity in rain, snow, &c. let the apparatus stand in a room, near a window; hold an insulated rod, covered with tin foil, out of the window, and at the same time to touch the insulated plate of the condenser for half a minute or thereabouts; remove the stick, and operate with the condensers as before. As it is sometimes difficult to hold the stick out of the window, and at the same time in contact with the plate of the condenser, if the electricity is very strong, it will answer by drawing the stick into the room and touching the condensers afterwards: but when the electricity is very weak, the above method of operating with the stick will not succeed; it is then necessary, while holding the stick insulated out of the window, (or any convenient place where it is sufficiently exposed) by one hand, with the other touch it beyond the insulation for a moment, and afterwards take it insulated to touch the condensing plate. The last-mentioned method is always the most secure; but it must be observed, that the electricity in the stick will be contrary to that in the atmosphere.

*Method of applying the combined Condensers, to shew the Principle of Metallic Galvinism.*

Screw the short end of m into e of the large condensing plate (the instruments being combined as above); bend the end of m downwards (the whole length of it, or, if it is more convenient, it may be reduced to one-third, as it screws in three pieces) at such a distance from the table, or whatever it may stand upon, that two pieces of metal zinc and copper can be put under it, and at the same time perfectly in contact, and also that it can be drawn away without letting m touch the table. Take two pieces of metal zinc and copper, either separate or soldered together, with their flat sides in contact, and push them under the end of m; after remaining a short space of time, draw them away from m; take notice that m does not touch the table, or any conducting substance; turn back the moveable plate of the large condenser, move the electrometer, so that it is quite free of the pin of the large plate, and turn its moveable plate back, the gold leaf will remain undisturbed; turn up the condensing plates and set the instruments in their first position, taking particular care that the fixed plate of the electrometer condenser touches the pin proceeding from the large plate; lay upon the pieces of metal before used, a piece of woollen cloth, well soaked in a solution of muriate of ammonia, or any other menstruum commonly used for the excitation of galvanism, either upon the zinc or copper, and push them under m, as before; press the end of m down upon them that it may be perfectly in contact. After they have remained the same time as before, draw the metals away—separate, or turn back, the large condensing plate; and also the small one; after having moved it free from the pin of the large one, and immediately the gold leaf will diverge. If the zinc was uppermost, the gold leaf will diverge with positive electricity; but, if it was undermost, negative. It makes no difference in the general effect, upon which metal the wet cloth was laid, or whether two pieces of cloth were used; one under the metals, and the other above; or only one, either above the metals or below; but if the cloth be only laid upon the copper, the electricity excited will be so weak, that the combined instruments can hardly shew it.

If the two metals used in the last experiment be not soldered together, and provided so that they can be separated by insulated handles, while lying under m, not touching them, but about two or three inches above, lift the uppermost up by the insulated handle so as to strike the end of m, electricity will be excited. Sometimes once touching it will not be evident, owing to the state of the atmosphere, and state of the metals, not being being perfectly clean and dry, hence the experiment must be repeated ten times, or more. If the plate lifted be zinc, (the operation above being observed) the electrometer will diverge with positive electricity, and if copper the contrary.

If zinc be reduced to filings, and sifted through a piece of copper with holes, into the brass cup, l, electricity will be excited; and so strong as to cause the gold leaf to diverge without the use of the condenser: l, must, in this case, be set upon the top of fig. 69, and the condensing plate turned back previously to the sifting;—if the sieve be zinc, and the filings copper, the contrary electricity will be evident.

# PART THE FOURTH.

## DESCRIPTION OF AN ELECTROPHORUS.

This instrument is composed of one electric plate of the resinous kind, and two non-electric plates of any desired form; they are commonly made round; this being the most proper shape, and the easiest to be made free from edges or points. This electric plate is laid between the two other plates, and is somewhat larger in diameter. These two are commonly made of wood turned flat on one side, and on the other turned with round up-standing rims: the whole being covered with tin-foil perfectly smooth. One of these must be provided with three silk strings fastened to the hollow side; and so that, when it is laid upon the electric plate it can be lifted up by them in an horizontal position; or a stick of glass fixed in the centre will answer the same purpose; the other must be made to screw upon an insulated stand occasionally. These two plates are called the conductors, the first mentioned is the upper conductor, and the latter the under conductor; the electric plate being in the middle, between these two. See A B, fig. 70.

This instrument, after being excited, has the property of remaining in that state for a considerable time; and also that of increasing its electric action, and recruiting the electricity upon its surface by its own power, when nearly exhausted by being too long exposed to the action of the atmosphere—hence the name electrophorus.

*To excite an Electrophorus negatively.*

EXP. 128.

Separate the electric plate from the other, and lay it upon a flat table, rub it with a cat or hare skin in a longitudinal direction; and after being rubbed, it will shew signs of being negatively electrified—by approaching it with pith balls positively electrified, they will be attracted, and with negative electrified balls they will be repelled. See Experiment 35.

*To draw, and to give Sparks.*

EXP. 129.

Lay the electric plate upon its under conductor, and rub it as before; take the upper conductor by the silk strings, holding it in a horizontal position—lay it upon the electric plate, fig. 70, and afterwards touching it with your finger, a small spark will then appear. Lift it up quickly by the silk strings with one hand, about six inches or more above the plate, while you approach its rim with a finger of the other, a spark will appear. Repeat the operation, and it will repeatedly take and give sparks without any sensible diminution of its power.

The spark that appears by touching the upper conductor, when laid upon the electric plate, is an electric spark passing from the touching body to the conductor; and that which appears after the conductor is lifted up, is an electric spark passing from the conductor to the touching body.

The strength, or quantity of electricity contained in the sparks caused by an electrophorus, depends upon the degree of excitation that the composition of the electric plate is capable of receiving—that which I have found to answer best is composed of equal parts of schellak, rosin, pitch, and turpentine.

Such compositions do not attract moisture or damp to such a degree as glass; yet they attract so much as to render it sometimes difficult to produce excitation. The power of excitation does not only depend upon the composition of the electric plate, but likewise upon the rubber; that which seems to answer best is a cat's skin. To excite an electrophorus, and to put it in proper order for experiments after it has been neglected, or long exposed to the action of the atmosphere, it will be sometimes necessary to hold it before a fire, as likewise the two conductors and cat's skin—this last attracts the damp out of the atmosphere very powerfully, which entirely destroys its exciting property, and is very seldom in a proper state without warming.

### *How to prepare the Electrophorus for such Experiments as are necessary for the Illustration of its Properties, &c.*

#### Exp. 130.

Insulate the under conductor, and hang under it the two pith balls electrometer, as at fig. 71;

lay the electric plate upon its under conductor and excite it, the balls will diverge and shew signs of being negatively electrified. Lay the upper conductor upon the rubbed surface as before, having previously supplied it with pith balls, as is represented fig. 72, they will also diverge and shew signs of being negatively electrified: we may conclude from this, that the plate has been brought into a negative state by the action of the rubber; and that it is constantly endeavouring to procure the electricity it had lost by attracting it out of all bodies placed within its sphere of action. But it must be observed at the time, that the upper conductor being laid on to the plate, that the balls of the under conductor will first colapse and afterwards diverge, and shew positive signs. The two conductors are always differently electrified—when the one is negative the other will be positive; and that conductor which covers the strongest excited side will always be negative, and change the other to positive, though the balls were diverging with negative electricity before.

Lift the upper conductor up by the silk strings, the balls of the under conductor will change and diverge with negative electricity, and the upper one will change to positive. By continuing to lift the upper conductor up from the plate, and laying it on by intervals, the state of the plate with respect to electricity will constantly change by laying it on negative, and by lifting it up positive, the balls of the under plate will also change in the same manner.

### Exp. 131.

Lay the electric plate upon the insulated conductor, as in the last experiment—take away the pith balls from each conductor—place under B, a small coated phial, so that its inside wire or ball touches the coating of B—take an insulated rubber, annex it to the inside wire of a similar coated phial, either with a chain or wire, allowing a free action to the rubber; excite the plate with the insulated rubber, and both phials will charge; that annexed to the rubber will be found to be positive, and the other negative. This proves that the rubber draws electricity out of the plate, while rubbing, to itself, and becomes positively electrified, as also the phial which was annexed to it; and that the plate while being rubbed parts with its own electricity, and that of the inside of the phial to the rubber, which also proves that when a resinous electric plate is rubbed though only on side—both sides are brought into a negative state, and the rubbing body positive.

### Exp. 132.

Place the electrophorus as in experiment 130, where the pith balls are diverging with negative electricity—touch both conductors and they will both close—lift up the upper conductor by the silk and its balls will diverge, and be positive, contrary to its former state. This shows, that by laying that conductor upon the plate, after rubbing, part of its natural electricity was drawn out of it by the action of the plate. The electricity, though attracted into the conductor by the plate, could not be absorbed by it on account of the surface of the plate, and the conductors not being in perfect contact with each other. As the pith balls are not easily manageable, the following will perhaps be preferable.

### Exp. 133.

Excite the electric plate, and lay it upon B, take C by the silk strings and lay it upon the electric plate, then touch it with the projecting wire of a Leyden phial, and it will be found to be weakly charged negatively—discharge the phial, and after touching C, lift it up by the silk strings, and touch it with the inside wire as before, it will receive a spark, and be weakly positively charged, contrary to the first and agreeable to the last experiment with the pith ball electrometers.

### Exp. 134.

Lay C upon the electric as before, by the silk strings, and touch it by the inside wire of the phial used in the last experiment, and it will charge negatively—lift C up by the silk strings, and touch it again by the inside wire of the phial, and it will be discharged.

The last experiment proves that the electric plate does not absorb the electricity that it had caused to be drawn into its upper conductor, because the same quantity is thrown of as soon as it is out of the sphere of attraction, neither does it receive any electricity from the conductor; because if it had, the phial would still shew some remains of a negative charge.

The above experiments will no doubt be thought quite sufficient to explain the electric properties of the electrophorus; and also, that it can supply the want of an electrical machine in many experiments. The following will shew that a coated bottle can be charged by it; sufficiently powerful to fire gunpowder.

*To discharge a Cannon with an Electrophorus.*

### Exp. 135.

Screw the insulating legs from B, and lay it flat upon the table with the electric plate upon it, excited as strong as possible—lay C D upon it, and place the bottle m, so that when C is lifted up perpendicularly, it may touch o—charge the cannon, and place it so, that when o is elevated, p may touch the brass ball upon the top of the pin proceeding from the ivory touch-hole of the cannon; then, after touching C, lift it up by the silk strings, so high that it gives a spark to o—lay it on, touch it, and lift it, so as to give a spark to o as before; repeat this till no more sparks appear at o, then, for the last repetition, srike o so strong with C, that p touches the abovementioned brass ball, and the cannon will discharge.

The success of this experiment depends much upon the manner of charging the ivory touch-hole. See fig. 75, a, b, c, d, representing a section of the ivory piece, e e is a small hole about one-tenth of an inch diameter, and b c, one of a larger diameter; the small hole must be filled with gunpowder pounded or bruised very fine, and near the large hole perfectly close; the large hole must be filled about half full, stopped very close—set it upon the brass touch-hole, and push the pin h, in to the small hole till it is about one-tenth of an inch from the large one: these directions being closely followed, and the electrophorus properly excited, the cannon may be discharged with ten sparks from C, if it is about eighteen inches diameter.

# PART THE FIFTH.

## MEDICAL ELECTRICTY.

*The following are the different Methods used in applying Electricity to the Cure of Diseases.*

Method I. To connect the patient, while standing on the ground, with the prime conductor of an electrical machine, when in action, by means of a conducting silk cord, or wire. By this method, electricity runs through the patient to the ground, beginning at the point of connexion, and continues as long as the machine is in motion.

II. To connect the patient with the negative conductor of a machine, while in action in the above manner. By this method electricity runs through the patient, beginning at the point of contact with the ground, and ending at the point of annexion with the conductor.

III. To insulate the patient, and connect him with the prime conductor as above. By this method the patient receives, and partly retains electricity received from the machine.

IV. To connect the patient when insulated with the negative conductor. By this method, the electricity in the patient is rarified in a degree depending on the power of the machine.

V. To pass the aura to a patient when standing on the ground. By this method, the electricity is forced into the patient in several rarified streams, attended by a breeze of electrified air; to do this, see plate 1, 5 being an insulated director with a point, and connected with the prime conductor by means of a wire, and the point directed towards the part where it is intended to enter; when the aura is to be very faint, or as little irritating as possible, a wooden point is screwed on to cover the brass one.

VI. To draw the electric aura from a patient. The difference from the last is, that the insulated director must be connected with the negative conductor o, fig. 1. plate 11. By this method the electrical aura is drawn from the patient, but the breeze which is felt, is electrified air passing to the patient, as in the last-mentioned method.

VII. To pass sparks to a patient while standing upon the ground. By this method, the electricity is caused to enter in, and pass out of the patient, by intervals to the ground. In this case, the insulated director is used with the brass ball d, screwed over the point; and the end of the conducting cord e, must be hooked to the electrometer E. fig. 5, plate 1, its ball being set at about half an inch distant from a, where the method of passing sparks to the hand is represented; when very strong sparks are required, a large conductor must be used, hanging in silk strings from the cieling of the room, above the prime conductor, and connected with it by means of a wooden stick, covered with tin-foil. Such conductors are generally made of tin, about five feet long and twelve or fourteen inches diameter.

When sparks are required in the ear, a glass tube, with a small wire passing through it as represented 2, is generally used; one end of the conducting cord is tied to the wire, and the other end to E; the tube is held in the hand, and directed within the ear, the director 5 must be taken from E.

In some particular cases for the eye, a glass instrument is used with a metal wire passing through it, represented 3; this is connected to E, in the same manner as the last mentioned.

VIII. To draw sparks from a patient while standing on the ground. By this method, the electricity is drawn out of the patient, and supplied from the ground by intervals. In this case, the conducting cord of the director must be annexed to the negative conductor o, fig. 1, plate 11.

IX. To pass, and draw sparks at the same time, through any particular part of a patient. To do this, the cord of the insulated director must be annexed to E, fig. 1, plate 11, and if the sparks were intended to pass in at the hand, and drawn out at the shoulder, hold the director as represented with one hand, and apply the other to the shoulder, under the patient's clothes, pressing quite close, then every spark that passes into the hand, will come out at the shoulder to the operator; this method of passing and drawing sparks at the same time, succeeds very well with plate machines, on account of their high acting power; but if this should be found difficult, on account of having only a machine of a weak acting power; then the patient must be insulated, and proceed as before described. If the operator should find drawing of sparks with his hand to be disagreeable, he may take a second insulated director, and connect its cord to any convenient conducting substance. A brass ball, of two or three inches diameter, with a wooden handle, are sometimes used to weaken the power of the sparks; when the patient finds them too painful, see fig. 4, plate VIII. A brass wire of about six inches long, see fig. 6, with a ball at each end, are much used for drawing sparks.

X. To pass shocks through any part of a patient. To make a beginning with shocks, a small coated glass tube is commonly used, represented fig. 7. in plate VIII, connected with the conductor by passing the end of the brass wire which proceeds from its inside, into the hole at the end of the prime conductor; then take two insulated directors, with conducting cord; the cord of one must be hooked about the outside coating of the tube, and the other to the electrometer E, plate I, set so that its ball stands at about one-fourth or one half-inch distant from a, the distance may be shorter, or longer, accordingly as the shock is required; the greater the distance, the stronger will the shock be, (provided that it is not beyond the striking distance)—if the shock be intended to pass through one side of a patient, and to enter in at the shoulder; that director which is hooked to the regulating electrometer E, must be held against the shoulder, and the other to the foot; the application of the whole is represented, fig. 76. When the machine is in motion, shocks will successively pass through that part of the patient; but if it should not have the desired effect, recourse must be had to coated phials, or jars of larger dimensions, which must be set upon the table, so that their knobs, or inside wire, touch the prime conductor. The end of the conducting cord of one director must be either laid round, or only to touch their outsides; the conducting cord of the other director must remain as before, between F E, but E must be set nearer to a, at about one-fourth of an inch distant, to make a beginning, and the distance must be increased according as the patient can bear it.

The application of shocks with jars, are represented in fig. 77, where they are directed through a patient's leg, entering in at the heel and going out behind the knee.

It is necessary to observe, that shocks always enter the part intended from the director, which is connected with the electrometer E.

Shocks are never administered by our most eminent medical electricians, till all the before-mentioned methods have been found of no effect.

# PART THE SIXTH.

## *Method of ascertaining the Power of electrical Machines.*

When philosophers endeavour to communicate to each other the indications of power in their respective electrical apparatus, they either describe the length and appearance of the simple spark from a conductor, or the explosion from a certain measure of coated surface; or else the distance to which the attractive power of the prime conductor is rendered perceptible upon a thread or pendulous body. The first of these methods is subject to variation from the magnitude of the conductor itself, the figure of its termination, and, particularly, that undulation, of which the first account was given in Nicholson's Journal, vol. i. page 83; and the last method being subject to modification, not only from the structure of the less essential part of the machine, but also from the dimensions and figure of the apartment in which the experiments are made, has been accordingly very little used; electricians have therefore, with considerable reason, been disposed to avail themselves of the second method, according to the simple computation described in the work last referred to, page 87; but to this method also, I have serious objections, in consequence of which I repeated some experiments at Mr. Nicholson's request. These experiments, together with his observations, and such remarks as have occurred to myself, is the subject of the following:

The Honourable Henry Cavendish, from a series of experiments upon the charges of electrical jars, has deduced, that the quantity of electricity which coated glass of different shapes and sizes will receive, with the same degree of electrification, are directly as the area of the coating, and inversely as the thickness of the glass; and that when the intensities vary, the quantities of electricity, in like circumstances, are nearly as the length of the spark. My experience has led me to modify these general conclusions. I have found that, in great intensities, the length of the spark is much more than in proportion to the charge; and from some facts hereafter to be related, there is reason to think, that a real charge of low intensity cannot be measured, either by the length of its very short spark, or even by the number of turns of the machine. Electricians in general, use the very best glass they can procure in their vicinity, whence their conclusions are, for the most part, applicable to one kind of glass only: but I have observed, that the different kinds of white glass, and still more the green, will require very different quantities of electricity, to charge equal surfaces and thicknesses to the same height. I have had a jar, of which the coating had been cut away until its capacity, as determined by the number of turns of the machine, became equal to that of another similar jar of the same thickness; the coated surface of the former of these two jars might be estimated at more than one-third part less than that of the latter; hence the necessity of some other test of electrical power different from that which includes the dimension of the jar. As one of its elements is evident, I offer the explosion of steel wire for this purpose, the result of the facts I observed, that equal quantities of electricity in the form of a charge, will cause equal lengths of the same steel wire to explode, whether the jar made use of be of greater or less capacity within certain limits. The principal object of the following experiments were directed to establish this proposition.

Two electrical machines were taken, the first consisted of a single glass plate of twenty-four inches diameter, constructed as has been already been described. The other machine was of the same dimensions, but had two plates. Fig. 78, commonly called the discharging jar electrometer, was first used to ascertain the power and steadiness of the excitation.

### Exp. 137.

The above apparatus being applied to the conductor of the single plate machine, as is represented by the figure, it exploded five times in seven turns and three-quarters of the winch, the balls k d being half an inch distant from each other.

### Exp. 138.

Upon applying the same test to the double plate machine, it was found to afford very nearly or rather more than twice the quantity of electricity, the jar exploded five times in three turns and an half.

*The acting Power of electrical Machines indicated by the Wire-melting Electrometer.*

EXP. 139.

Fig. 79. was applied to the prime conductor, after four turns, some ramified flashes struck into the uncoated part, and at the sixth turn, a spontaneous explosion took place over the clear glass; a glass tube was then inserted into the jar nearly to the bottom, and breathed twice through it, in order to render it more capable of retaining its charge. This is contrary to the received opinion of electricians, who carefully avoid all dampness. It is considered to be of the same nature as the experiment of Brooks, who found that a jar, the naked part of which was soiled by handling, would retain six times the charge without exploding, which it would have held if perfectly clean; and, accordingly, this process had the same effect, for the jar did not afterwards exhibit any flash or disposition to explode, though it was occasionally charged with ten or twelve turns: the clear portion of the wire which formed part of the circuit was exactly five inches in length; an explosion was passed through a moderate interval of spark, and this interval was gradually increased, till

at last the shock became so strong as completely to ignite the wire, and divide it near the positive end, where a sparkling globule or two flew out; ten turns of the machine were required to produce this effect, and the length of the explosive spark one inch and a quarter.

### Exp. 140.

Another jar was added to the above, and applied to the prime conductor. Their outside coatings were connected together, the same quantity of wire as in the last experiment was placed in the circuit, and by the same method an explosion was obtained, which ignited and broke the wire with nearly the same appearance as before; in this case the number of turns were nine and two-thirds, and the length of spark three quarters of an inch. Repeated with the double plate machine, it produced the same effect in half the number of turns.

These experiments evidently confirm that the quantity of electricity to disperse a given portion of wire will be the same, even though the charged surface should be greatly varied; but it appeared desirable to ascertain the proportional quantities of electricity required to explode different lengths of the same wire.

### Exp. 141.

For this purpose two inches and three-tenths of the same wire were exploded by five turns of the winch, which was probably too great a quantity, for the ignition was very strong, and deflagrating globulus were thrown about; but, by a more careful repetition of the experiment with two inches and a half of wire, the ignition and partial melting of the wire were very nearly the same as in the experiments which had been made on lengths of five inches. From these experiments there seems reason to suppose that the quantities of electricity may be as the lengths of the wire deflagrated.

### Exp. 142.

A battery of fifteen jars, containing about seventeen square feet of coated surface, was then used to explode five inches of wire; nineteen turns rendered the wire faintly red hot, but twenty turns caused it to explode in the same manner as in the experiments with the jars.

### Exp. 143.

Half the length of wire, namely two inches and a half, was in the next place submitted to the explosion of the battery; twelve turns ignited the wire, and fifteen turns caused it to explode with somewhat more violence than in the experiments with the jars.

At this stage of the process, as the battery had required twice the quantity of electricity to produce the effect which had before taken place with a smaller quantity of coated surface, it became a question, whether the length of the circuit, which was six feet on each side, might have influenced the results; and also, whether the state of excitation had become less intense. For these reasons, the disposition of the apparatus was altered: so that the circuit with the battery was the same as had before been used with the jars; and the trial jar, with Lane's electrometer, was again applied to ascertain the power of the machine. Five explosions were afforded by seven turns and three quarters as at first. This experiment was twice repeated, and shewed that the action of the machine continued to be the same as at first.

### Exp. 144.

In this new disposition of the battery, five inches of the wire were exposed to the explosion. No effect was produced by twelve turns, but by twenty-one turns, the whole of the wire was dispersed in globulus by the strong ignition. I suppose that twenty turns might have dispersed it in the same manner as in the first experiment.

### Exp. 145.

Two inches and a half of the wire were then placed in the circuit, this portion was not affected by an explosion of twelve turns, but by thirteen turns it was ignited and broken by the dissipation of a globule or two. Lastly, one inch of the wire was exposed to the shock; it was ignited, and partly dispersed in globules by turns.

The whole of these experiments employed upwards of three hours; during the greatest part of which time the machine was in action. At the conclusion, the trial jar was applied; it exploded five times in little more than eight turns. The trial was repeated twice, and serves evidently to shew the steadiness of the excitation, which had diminished only about one-tenth part during this course of the work.

Upon a review of the foregoing experiments, it is obvious that they would require to be repeated and extended. If the general course of the former processes were not to be admitted, in confirmation of the position, that equal quantities of electricity will ignite and disperse equal quantities of the same wire without requiring any particular adjustment of the quantity of coated surface, provided the intensity be considerable. From the experiments with the battery, it seems reasonable to conclude, that the quantities of electricity required to produce like effects upon wire, will be the greater the lower the intensity, when the quantity of surface is greatly increased; in which case the velocity of the electric fluid may be supposed insufficient for the whole charge, to exist in the conducting wire at one and the same time, or its impetus may be less; or, lastly, there may be a considerable waste from the conducting particles floating in the very thin stratum of air through which the explosion at last passes.

# PART THE SEVENTH.

## *Of Improvements made in electrical Batteries.*

In the year 1774, Mr. E. Nairne made an electrical machine far superior in acting power to any that had been made before; and also a battery more judiciously constructed, and larger than any former one, with which he had made a number of interesting experiments. O e in particular, affords an accurate measure of the power of his battery, compared with such batteries as have been made since that time; I mean the experiment of igniting or exploding metallic wires. His battery contained fifty square feet of coated surface, and he found that it was capable of receiving a charge so high that the dicharge ignited forty-five inches of iron wire, one hundred and fiftieth part of an inch in diameter, which answers to about seven-eighths of an inch in length for each square foot; this was the greatest length of wire ever ignited. We have no account of this experiment having been afterwards repeated, on a scale of any considerable magnitude, till the year 1785, when I constructed a battery for the Tcylerian Society at Haerlem, containing one hundred and thirty-five square feet of coated surface; with this battery, one hundred and eighty inches of the same sort of wire were ignited, which seemed to be much more than in proportion to the size of the battery, as this was about one inch and three-tenths for each square foot. This battery was afterwards increased to two hundred and twenty-five square feet of coating; and with this, three hundred inches of the same sort of wire were ignited, which was also at the rate of one inch and three-tenths for each square foot. Some time after this, I made another battery for the same Society, containing five hundred and fifty square feet of coating, composed of one hundred jars of five square feet and a half each. The same sort of wire was not tried with this, but it could be calculated from other sorts of wire which it ignited, that it was capable of igniting six hundred and fifty-five inches, being also at the rate of one inch and three-tenths for each square foot. This increase of power gained upon each foot, which is almost double that of Mr. Nairnes, might be attributed to the acting power of the machine; for though Mr. Nairne's machine possessed the strongest acting power of any machine made at that time, yet it could not be supposed to possess that high charging property of the Haerlem machine.

Since my return to London, I have made several batteries, commonly composed of fifteen jars each, containing about one hundred and sixty-eight square inches of coated surface, consequently the whole battery contains about seventeen square feet of coating. This battery, according to the proportion of that made by Mr. Nairne, should ignite fifteen inches and a half, and in proportion to the Haerlem batteries it ought to ignite twenty-two inches; but instead of following that proportion, it is found to ignite sixty inches, which is an astonishing increase of force; for this battery is only about one-third part of that of Mr. Nairne's, and it ignites a much greater length of wire; and though it is only one-thirty-second part of that at Haerlem, yet it ignites one-tenth of the length of wire. It seems difficult, at first sight, to account for this advantage. I have before remarked, that the proportional difference between the charge of the battery at Haerlem and Mr. Nairne's might be accounted for from the high charging power of the great machine; but the result of the last mentioned experiments overturns that notion, as it can by no means be supposed, that a single two-feet plate machine, which I have used to charge the battery of seventeen square feet so high as to ignite sixty inches of wire, can have a higher charging power than that at Haerlem, so that it must proceed from some other cause.; it might be questioned whether all the batteries were alike judiciously constructed: as to Mr. Nairne's, it had certainly faults, both with respect to the coating and the mounting of the jars; but the batteries at Haerlem were as judiciously constructed as my present one, which I am speaking of, and which exceeds them in such an astonishing degree in its proportional force. The only difference between my present batteries and those at Haerlem is in the glass; they were composed of glass blown in Bohemia, and those I make here are of white flint glass. I mention this fact, but am not inclined to think that the cause of the difference depends on the glass, because I remember to have melted the same quantity of wire with one jar of that kind of glass, when in Amsterdam, as I do at present with white flint glass; so that it only remains now to be sought for in the manner of using or charging each battery, and here we shall probably find means of solving this paradox.

*Method of increasing the Power of Batteries.*

With regard to the batteries at Haerlem, they were never attempted to be charged but in dry weather, being such as was then commonly called favourable for electrical experiments. There was no convenience in the room where the machine and batteries were used for making a fire, which was therefore ill calculated for electrical experiments. The batteries, previously to charging, were made as clean and dry as possible; and if they received a charge so high, as to cause a spontaneous explosion, they were then looked upon to be in their most favourable state.

It was about this time that we were told by Mr. Brooke, that a coated jar would take a higher charge when dirty that when clean; but the degree of dirtiness was so ill defined, that I must own, I never could dirty a single jar so as to answer, or to come near what was said of it; and to pretend to bring all the jars in a large battery, containing upwards of two hundred, into that state of dirtiness, was never attempted: neither does it appear, that Mr. Brooke ever thought of dirtying his battery jars, as he only mentions trying two small bottles, whose charging property was very differently increased by his method of dirtying.

Some time afterwards, in the year 1792, I happened casually to discover, that a coated jar, when it was a little damp in the inside, (which is always the case when a jar is fresh coated) would take a higher charge than it would do after it had been coated for some time, and was quite dry in the inside; also, if the atmosphere was in a moist state, and the jar not dried in the inside, it would take an equally high charge. From this, it appeared evident, to me, that if I could by any means render the inside of jars regularly damp, it would answer the same purpose. Breathing into a jar was tried, and the success was such, that it would receive and retain nearly double the quantity of electric fluid; it could retain when dry, and in trying to ignite wire with the charge of one jar in a dry state, no more than five inches could be ignited; though after breathing into it, twelve inches were fused.

This method appeared, at first sight, to have increased the force more than double; but notwithstanding so evident and striking an effect, I did not think of trying what would be the result of charging a battery after the jars had been breathed into, being deterred, as I suppose, from the idea of its being so contradictory to the common method of using batteries, which was never attempted to be done but when the atmosphere was in a tolerably dry state, and the jar previously cleared. But, in March, 1796, being engaged in a course of experiments when the atmosphere was so very dry, that a spontaneous discharge always took place before I had a sufficient force to answer my purpose; it then occurred to me, to try what the effect of breathing into the jars of the battery would be. In this trial, or research, it became necessary; first, to ascertain the real charge that the battery was capable of receiving before a voluntary explosion took place. This battery contained seventeen square feet of coated glass, and was composed of fifteen jars; it was found, in the then state of the atmosphere, to be incapable of igniting a greater length of wire than eighteen inches; but after breathing into each jar through a glass tube, it took a charge which ignited sixty inches, to my very great surprize and satisfaction, as I then thought, I had obtained a method of making one battery perform the function of three, because three times the quantity of wire was ignited, as appears by comparing this with what had been performed by increasing the surface of batteries by former electricians. This notion seemed to be justified by observing in Dr. Van Marum's works, that I had enlarged his batteries at three different times; his first contained one hundred and thirty-five square feet coating, the second two hundred and twenty-five square feet, and the third five hundred and fifty; the highest charge of the first was just sufficient to ignite one hundred and eighty inches of iron wire of one-hundred and fiftieth part of an inch diameter, or six inches of iron wire of one-fortieth part of an inch diameter; the highest charge of the second ignited three hundred inches of the first mentioned wire, or ten inches of the last mentioned; the highest charge of the third ignited twenty-five inches of the last mentioned wire. We find that these batteries increased in power, nearly in the proportion as the coated surface was increased. I was present when the wire was ignited by the two first mentioned batteries, but not at the third; however, we have no reason to doubt Dr. Van Marum's report. These experiments supported me in my first notion, that I had discovered a method of increasing the force of a battery to three times its usual power; but being unable to account for it to my own satisfaction, I resolved to make a course of experiments in order to throw some light on the subject.

The chief experiments have been made on the force of batteries by Mr. Brooke, at Norwich, in the year 1786, and by Dr. Van Marum in 1785 and 1795. The results were very different; some experiments which I made in Holland, and afterwards repeated here, did not seem to confirm either of the two. All that had been done, either by Dr. Van Marum or myself, was done without the help of such an electrometer as could indicate the proportional quantities of electric fluid, with a sufficient degree of accuracy,

Mr. Brooke was possessed of an instrument of his own invention, with which it was possible to ascertain the comparative strength, if managed with the same dexterity as Mr. Brooke himself possessed; but this instrument came so high in price, and was so very difficult in its use, that few electricians provided themselves with it, which, perhaps, is one reason why this subject has so long remained in obscurity. I have lately had the good fortune to invent an electrometer which has all the properties that such experiments require, and is very simple in its use; with this I found myself enabled to go through such experiments as were necessary, with greater accuracy than any which had been made before.

The electrometer is represented, fig. 80, pl. VII, A B, is a long square piece of wood about eighteen inches long and six inches broad, in which are fixed two glass supports D E, mounted with brass balls. Under the brass ball E, is a long brass hook; the ball b, is made of two hemispheres, the under one being fixed to the brass mounting, and the upper turned with a groove to shut upon it, so that it can be taken off at pleasure; it is screwed to a brass tube about four inches long, fitted on to the top of D; from its lower end proceeds an arm carrying the piece F C, being two hollow balls and a tube, which together makes nearly the same length as that fitted on to D. G H is a straight brass wire, with a knife-edged centre in the middle, placed a little below the centre of gravity, and equally balanced with a hollow brass ball at each end, the centre or axis resting upon a proper shaped piece of brass fixed in the inside of the ball b; that part of the hemisphere towards H is cut open, to permit that end of the balance, to descend till it touches E; and the upper hemisphere b, is also cut open; to the under side of a is hooked a brass wire about four inches long, hanging freely in a hole at the top of F; the arm G, is divided into sixty grains, and furnished with a slider, to be set at the number of grains the experiment requires; k is a common Henley's electrometer, screwed upon the top of b.

It is evident from the construction, that if the foot stand horizontally, and the ball G be made to touch F, and the slider set at o, it will remain in that position; but if it should by any means receive a very low charge of electric fluid, the two balls F G will repel each other; G will begin to ascend, and on account of its centre of gravity being above the centre of motion, and the slider so loose as to slide forward towards b, as soon as G H is out of its horizontal situation, the ascending will continue with an accelerated motion till H strikes upon F. If the balance be set again horizontal, and the slider set at ten grains, it will cause G to rest upon F with a pressure equal to that weight, so that more electric fluid must be communicated than before, before the balls will separate; and as the weight towards G is increased or diminished, a greater or less quantity of electric fluid will be required to effect a separation.

When this instrument is to be applied to a jar or battery, for which purpose it was invented, one end of a wire must be inserted into a hole in the ball F, and the other into a hole of any ball proceeding from the inside of a battery or jar fig. 81; k must be screwed upon b, with its index pointing towards H; the reason of this instrument being added, is to shew, while the index continues to rise, that the charge of the battery is increasing, because the other part of the instrument does not act till the battery has received its required charge.

If this instrument be examined with attention, it will be found to consist of three electrometers, and answers three different purposes; namely, a Henley's electrometer, Lane's discharging electrometer, and Brooke's steel yard electrometer; the first is not improved, but the two last, which were very defective when first invented, I flatter myself, are here brought to perfection: as the only use of Henley's electrometer to this instrument, is, as I have said before, to shew that the battery continues to receive a still stronger charge, it required no improvement; but Lane's electrometer, in its primitive state, could by no means answer the required purpose for batteries, because the ball intended to discharge the battery, was necessarily placed so near to the ball of the battery, that dust, and many conducting particles, always floating in the air, were attracted, and repelled between the two balls so as to render a regular intended high charge impossible; whereas, in this, they are placed at four inches distance, and when the desired height of charge is obtained, and not before, the ball of the electrometer moves of itself nearer to the ball, which is connected with the outside of the battery, and causes a discharge. The defect in Brooke's steel-yard electrometer were, 1st, that that it could not cause a discharge; and 2dly, the difficulty of observing the first separation of the balls, caused great error, if it were not placed in an advantageous light, (which the nature of the experiments does not always permit) it could not be seen without the attention of an assistant, which is sometimes unpleasant, and cannot always be commanded. But this instrument, which I have described, requires no attention or assistance; for, as soon as the separation takes place between G and F, the ball H descends, and discharges the battery of itself.

By this combination and improvement, we possess, in the present instrument, all that can ever be required of an electrometer; namely, by k, we see the progress of the charge; by the separation of G F, we have the repulsive power in weight; and, by the ball H, the discharge is caused when the charge has acquired the strength proposed.

*Experiments made with a View to determine in what Degree the charging Capacity of coated Jars is increased by breathing into them before the charging.*

### Exp. 146.

Prepare the electrometer in the manner shewn fig. 80, with the jar M annexed, which contains about one hundred and sixty-eight square inches of coating—set the slider at fifteen—take two inches of watch pendulum wire, hook one end to m, and the other to the wire communicating with the outside of the jar—let the uncoated part of the jar be made very clean and dry, and let the prime conductor of an electrical machine, or a wire proceeding from it, touch the wire proceeding from the inside of the jar: then if the machine be put in motion, the jar and electrometer will charge, as will be seen by the rising of the index of k; and when charged high enough, G will be repelled by F, and H will descend and discharge the jar, through the wire, which will be ignited and run into balls.

### Exp. 147.

Put eight inches of the same sort of wire as before, in the circuit—set the slider at thirty, all the other part of the apparatus remaining as before, and the uncoated part of the jar being previously cleaned and dried, the machine being put in motion, the jar and electrometer will charge as shewn by the rising of the index, as before; but, as soon as the jar has received a greater quantity of electric fluid than before, a spontaneous explosion will happen, without affecting the seperation of G F, because the discharge will have passed along the uncoated part of the jar, from the inside coating to the outside, whence it follows, that while the jar remains in that clean state, it is incapable of receiving a charge high enough to affect the balls, or even a higher charge than it had received in the first experiment—let the uncoated part of the jar be therefore rendered in a slight degree damp, which is easily done by breathing into the inside through a glass tube—put the machine in motion—no spontaneous explosion will happen, but the balls will repel, as in the first experiment; the discharge will happen from H to E and pass through the wire placed in the circuit, though it be eight inches in length it will be ignited in the same degree as two inches in the last experiment; namely, the wire will be red-hot the whole length, and then fall in balls.

Very different degrees of ignition are caused by electric discharges, which may cause great mistakes if not well attended to; it is proper to adhere to the degree abovementioned, and particnlar care ought to be taken to lay the wire intended for ignition straight, without any bendings or angles in it. The wire used in the two last experiments, was that which is commonly called watch pendulum wire, which is flattened, and as it approaches very near to such a sharp edge, as might be supposed to affect the experiment by permitting a dissipation of the electric fluid in its passage, round wires were tried, and the result was the same.

By the last experiment, it appears that breathing into the jar, increases its charging capacity, nearly in the same proportion as it had done the batteries after breathing, for it received a charge sufficient to ignite four times the length of wire it did when clean; but, by the weight in the electrometer, and also by the greater number of revolutions given before the discharge happened, it might be supposed that the jar had receivod only a double charge.

*The following Experiments will shew the Length of Wire which are just fused by various Quantities of electric Fluid at the same Intensity.*

### Exp. 148.

*With Two Jars—One removed.*

For this purpose a second jar was placed at the prime conductor: the slider was set at fifteen —two inches of the same sort of wire as used in the last experiment, were placed in the circuit: every other part of the apparatus remained unaltered; the machine was then put in motion till G began to ascend, when it was stopped, and before H could reach E, one of the jars was pushed from the conductor, to do which there is always sufficient time while the electrometer is in motion. The discharge was effected, and the two inches of wire were just ignited.

### Exp. 149.

*With Two Jars.*

The jar which was put away in the last experiment, was discharged, and placed at the conductor as before, and eight inches of the same sort of wire were placed in the circuit: the outside coating of the jars either touched each other, or had a metallic communication; all the other parts of the apparatus remained as before, and the machine was put in motion till G begun to ascend; the jar was not removed as in the last experiment, but suffered to discharge with the other, and the eight inches of wire were ignited in the same degree as the two inches in the last experiments.

It is evident from the position of the apparatus, that the quantity of electric fluid discharged in the last experiment, must be double that of the former, yet, in repeating the experiment I had different results, which made me again suspect the edges of the wire, I therefore resolved to take round wire, and of as large a diameter as could be conveniently ignited.

### Exp. 150.

*With Three Jars.*

Iron wire of one hundred and fiftieth part of an inch in diameter, and six inches in length, was placed in the circuit—three jars were placed so that the balls proceeding from their insides, touched the wire, and their outside coastings touched each other: the machine was turned till G began to ascend; the discharge was caused, and the whole length of the wire was just fused into balls.

### Exp. 151.

*With Three Jars—One removed.*

Two inches of the same sort of wire were placed in the circuit, in the same manner as the last, and the three jars remained; the machine was turned till G began to ascend, then one of the jars was drawn away, consequently only two were discharged, and the wire just fused into balls as the last.

### Exp. 152.

*With Four Jars.*

Wire of one-hundred and fiftieth part of an inch was taken, and four jars placed in contact with the wire, with their outside coatings in contact with each other—eight inches of this wire were placed in the circuit: the slider in the electrometer bar remained as before; the machine was then put in motion till G began to ascend—the discharge was, effected, and the wire was ignited and fused into balls. The experiment was repeated with the same sort of wire, eight inches and a half long; the discharge was just sufficient to melt it into balls. I repeated the trial with nine inches of the same sort of wire, and the discharge caused it to be red-hot the whole length.

### Exp. 153.

*With Four Jars—Two removed.*

Two inches of the same sort of wire were placed in the circuit—all the jars remaining as in the last experiment; the machine was put in motion till G began to ascend, then two of the jars were drawn away, the discharge was caused, and the wire was ignited and run into balls.

The trial was repeated with the same sort of wire, two inches and a half long, the discharge caused it to be red-hot the whole length.

### Exp. 154.

*With Fourteen Jars.*

Wire of one-hundred and fiftieth part of an inch diameter was taken eight inches long, and the trial was according to experiment 152—it was ignited and melted into balls.

### Exp. 155.

*With fourteen Jars—Seven removed.*

Two inches of the same sort of wire were taken and employed according to Experiment 153—it was ignited and fused into balls.

The results of the foregoing experiments prove sufficiently, that double quantities of electric fluid, in the form of a discharge, will ignite four times the length of wire of a certain diameter; and experiments 150 and 151 prove that when one-third part is added to two, three times the length of wire were ignited.

These experiments give reason to apprehend some error in Dr. Van Marum's experiments, because he found his batteries to increase in power only in the same proportion as the coated surface was increased, *viz.* that double surface of coated glass only could ignite double lengths of wire of the same diameter.

The Doctor might perhaps have been led into a mistake in the following manner: First, he might not have charged the batteries to an equal height, as he did not at that time possess an electrometer of sufficient accuracy for that purpose: and secondly, he might not have been aware of the different degrees of ignition, caused by electric discharges, but only judged of the force by the wires being converted into balls, by which great mistakes will happen; for if a wire be taken eighteen inches long, and of such a diameter, that when a jar or battery is charged to such a height as just to cause it to run into balls, much shorter lengths of that same sort of wire may be subjected to the same force, and still be only converted into balls. If only seven inches were taken, nothing but balls will appear; the only difference will be, that the balls will be smaller, and dispersed to a greater distance, which might be easily overlooked. If six inches of the same sort of wire be taken, it will be converted into balls and flocculi, or brown oxide of iron; so that to be accurate in this point, the lowest degree of ignition must be had, which is known when the charge has passed, the wire will be red hot the whole length, and afterwards falls into balls.

Having now sufficiently proved by experiment, in what proportion different quantities of electric fluid act upon different lengths of wire, which were required to be known in order to explain in what proportion the charging capacity of a jar or battery is increased by breathing into it before the charging begins, I shall proceed in the next place to explain this point.

The opinion that I had at first entertained (though supported by Dr. Van Marum's experiments,) that I had found out a method of increasing the charging capacity of batteries to three times their usual force, was not supported by the facts, that the usual power of a clean and dry battery, containing seventeen square feet coated surface, namely, that of igniting from eighteen to twenty-two inches of iron wire, one hundred and fiftieth part of an inch in diameter will be increased by breathing into the jars, so as to become capable of igniting sixty inches. If the first mentioned effect be taken at a mean it will be twenty, then the increased effect gained by breathing will be just two-thirds; and experiments 142 and 143 prove, that in order to produce such an increased effect, an addition of one-third part of the coated surface must be added to the battery, which is about eight hundred and sixteen square inches. This would amount to an addition of fifty-four square inches to each jar, or in other words, if that quantity of coating could be added to each jar, the same effect would be produced as when breathed into; but this would require the coating to be within an inch of the top, which would render the battery unchargeable, at least to that degree. A battery of fifteen jars constructed in the usual manner, will therefore by this treatment, become equivalent in power to twenty-one jars of the same kind, when clean and dry.

To explain the effect of breathing into the jars appears to be a matter of some difficulty. This experiment has been shewn to several electricians, and different opinions have been advanced, most of which seem to imply that breathing acts as a coating to the uncoated part, which will appear in the sequel to be absurd. Mr. Nicholson's opinion (see Philos. Journal 11, 219.) comes much nearer to the truth, though it does not appear to me to be sufficient to account for the effect produced. I admit with him that a spontaneous explosion over the uncoated part is most commonly caused by undulation; but that this undulation is caused by the discharging of different charged zones will be difficult to prove, because such zones cannot exist upon clean and dry glass.

When the uncoated part of a Leyden jar is made perfectly clean and dry, and the jar set to the conductor of a machine in action, it will begin to charge, and while charging, the coated part of the jar, and the wire which is connected with it, becomes equally charged, and each endeavours to throw off that surplus of electric fluid which is forcing into them; the coating from its edges upwards, and that part of the wire which is above the coating and within the jar, will endeavour to throw it in all directions, which will cause it to be surrounded by an electric atmosphere, increasing in density as the charge increases. This atmosphere, together with that given out by the coating, fills the whole jar. Part of the electric fluid forced into the coating, enters the surface of the glass, but the uncoated part being clean and dry, both withinside and without, the inside resists the fluids entering its surface, which is kept suspended at a distance, because the natural electric fluid contained on the outside finds no means of escape. But the action of the machine still continuing, presses it still closer to the surface, and at last overcomes that resisting force, and some of the particles on the outside give way, which causes an undulation in the inside, and the electric fluid closes instantly in upon its inside surface, and forces a greater quantity from the outside. Flashes or coruscations are thus caused which are always seen when a jar is charging in the abovementioned circumstances; the charge still continuing to be made, forces another quantity from another part of the outside of the jar, and causes a second coruscation and undulation, which may be so strong as to cause a spontaneous discharge; or two or three more coruscations and undulations may happen before the discharge, according to the steadiness or unsteadiness of the action of the machine, the quantity of electric fluid thrown off from the outside at each undulation, and also the degree of dryness and cleanness of the uncoated part of the jar, a discharge sometimes happens, without having previously occasioned any perceptible coruscations. This is the case when the first undulation has been so strong as to cause the whole discharge with the first coruscation, the one being so quickly followed by the other that it is imperceptible.

A jar will sometimes, while charging, give a great many small coruscations, quickly succeeding each other, which afterwards cease, without having caused a spontaneous explosion, though the action of the machine be continued; this happens when the uncoated part is nearly clean, and dry, but not perfectly so, its surface still containing some conducting particles, but not so connected that the electric fluid can pass from one to the other without leaps, or small coruscations on the outside, which permit the electric fluid to spread gradually over its inside surface, and prevent the undulation from being so strong as to cause a discharge.

After this explanation of the cause of the flashes of coruscations, which are seen upon the uncoated part of a jar while charging; and also that such coruscations produce undulations, which terminate in a spontaneous explosion; it remains now to explain how a jar is charged when the coruscations are prevented by breathing upon the uncoated part.

When a coated jar is breathed into, and then subjected to the process of charging, the electric fluid is forced into it along the wire in the inside to the coating, where it instantly spreads itself over the whole coated part, and at the same time, though with difficulty, and consequently gradually, it spreads itself over the uncoated part, taking the condensed film of humidity for its conductor, as it proceeds from the edges of the coating upwards towards the mouth of the jar, according to the arrangement of the particles of moisture, and rises higher or lower, depending entirely on their arrangement, and the force with which it is repelled from the machine. If the conducting particles be almost uniformly diffused over the uncoated part, the whole jar in the inside will become charged, though in a much less degree than the coated, on account of the imperfection of the conducting particles, which has adhered to its surface; no coruscations will be perceived on account of the gradual and equal diffusion of the electric fluid, over its inside surface, and though the charging be continued, yet if the exhaled conducting particles be favourably diffused, no spontaneous explosion will happen from one coating to the other; along the uncoated surface, but the jar will either be perforated, or if it be of sufficient strength to resist that effect, the electric fluid will be seen to run in a stream over the mouth of the jar, as quickly as the machine supplies it. Whenever a spontaneous electric explosion happens, it must be from a body of sufficient bulk, and conducting property to contain that quantity of electric fluid, at the point from which it explodes, otherwise no explosion can happen. But the humid conducting particles are just sufficient merely to admit the electric fluid by the action of the machine, to be spread over the surface of the glass, but in no part of sufficient density either to receive, or contain an explosion. If, therefore, a spontaneous explosion do happen, it must either proceed from the coating, or the wire which is connected with it to the outside; and if we examine the state of the coating, we shall understand that the edge of the coating (from which part only it is ever possible to explode) and also above it to a short distance upwards is as strongly charged as the coated part, and by the action of the machine it is so strongly loaded with electric fluid that it is repulsive in all directions, which keeps back or entirely stops a spontaneous explosion, from the edge of the coating. With regard to the wire, the only place from which it explodes spontaneously, is that part which is nearly of an equal height with the edge of the mouth of the jar; the fluid is nearly as much condensed on this part as on the other, so that an explosion from the wire is hindered by the same cause as from the coating. A jar, under such circumstances, cannot therefore explode spontaneously, but the fluid will run over the edge of the jar as quickly as the machine furnishes it when its charging capacity is full.

I have stated in experiment 147, that a jar of the dimensions there given, being clean and dry, can only contain a charge sufficient to ignite two inches of a certain wire, and when breathed into, its charging capacity will be so much increased that it will contain sufficient to ignite eight inches of wire of the same sort, and a battery of fifteen jars, in the first mentioned state, can only ignite twenty inches, and in the last mentioned sixty. This increased charging capacity proceeds, no doubt, from the particles of moisture, though not from their acting as a coating, as has been supposed, but by their being brought into a state or capacity of resisting a spontaneous explosion, so that a stronger charge can be forced in upon the coated part. Some of the electric fluid which was forced upon the unooated part to a certain height, (perhaps half an inch more or less, according to the degree of dampness, and the situation of the particles,) may indeed be discharged along with that from the coated part, but this is of little importance, and by no means capable of producing that increased effect, which, as I have shewn by experiment, would require an addition of seven jars to a battery of fifteen.

*To prove that the abovementioned battery is capable of igniting sixty inches of wire.*

### Exp. 156.

Take sixty inches of iron wire of one hundred and fiftieth part of an inch diameter, hook one end to the wire, which proceeds from the receiving ball E, of the electrometer, fig. 81, plate VII, and the other end to the outside annexion of the battery, the middle being kept extended, in the form of the dotted line, and freefromthe ground, without any sharp corners or bendings, (glass bottles will answer very well for that purpose) to prevent a dissipation of the charge in its passage, which it never fails to do when any angles or short bendings are in the wire, through which it must pass. The most advantageous form in which a wire for ignition can be placed is, in a direct line from the hook of the discharging electrometer, to the outside connexion of the battery, but this cannot be done with so great a length of wire. The slider of the electrometer must be set at the greatest repulsion that the battery can bear, which must be previously ascertained by experiment. If a spontaneous discharge should happen while the battery is charging, which frequently happens in very dry weather, each jar separately must be breathed into, through a glass tube, without removing the jars, see exp. 147. If a glass tube should not be at hand a roll of paper will answer the purpose.

# PART THE EIGHTH.

## *Metallic Oxides produced by electrical discharges.*

The discovery that metals could be ignited by electric discharges, gave rise to a supposition that they might also be converted into oxides by the same means. Many attempts have been made to ascertain this, but the fact remained without proof till, in the year 1787, Dr. Van Marum and myself, produced flocculi from different metals, by subjecting them to strong electric discharges; and also formed beautiful figures upon paper, by exploding metallic wires, extended at a small distance from its surface. We imagined that the flocculi, as well as the coloured figures upon the paper, were oxides of the metals we used, aad in order to prove this we entered upon a course of experiments; but having, perhaps from improper management, the misfortune to break several glasses in the process, Dr. Van Marum declared himself so much discouraged by these accidents, as to decline prosecuting the subject. When we consider, however, the opulence of that society, of which he was director, it is not easy to conceive that so trifling an accident as the fracturing of a few glasses should be a sufficient reason for his relinquishing this investigation, more especially as he had the command of an electrical apparatus which I made for that society, not only the most proper for that purpose, but unequalled in the whole world, and from which I now fear we have little to expect.

In 1792,--1793, I undertook two different courses of experiments at Amsterdam, upon the same subject, but both ended with very little more information than we before possessed.

On my return to London, after delivering a course of lectures upon electricity, I once more returned to the abovementioned subject. My previous experiments had taught me that it was necessary to have an apparatus, into which atmospherical air, or gas could be introduced, and any desirable quantity of metallic wire, so that it could be exploded at pleasure, and the diminution or the air accurately measured; I invented the following apparatus, which possessed all the requisites.

*Description of an apparatus, in which metallic wires are converted into oxides, by electric discharges.*

Fig. 82, A B is a glass receiver about ten inches high, and six inches in diameter; to the widest end is cemented a large round brass plate, perfectly air-tight; the other end is mounted with a brass collar, upon which a brass cap is screwed, also perfectly air tight; F is an air cock, one end of which is screwed into the brass cap at B, and the other into a foot, on which the instrument stands; n o are two air cocks screwed to the broad brass plate, with holes communicating with the inside of the receiver. To each of these cocks is screwed a glass tube, bent as is represented; their communication with the inside of the receiver is opened or shut by means of n and o. In the inside at B is a wheel and axis moving upon two pivots, serving to wind up a quantity of wire in readiness for exploding; m is a brass tube, about three inches long, and three-quarters of an inch in diameter, stopped at each end with cork, and the middle filled with hog's lard; this serves to draw the wire through ready for exploding.

The wire which is intended for use must be bound to a packthread of the same length, at different places, and at about four inches asunder; it must be wound upon the axis of the wheel;—the tube m must be screwed off from the plate, and the end of the wire must be directed through the hole inside of m by means of a long brass needle, which must be pushed through the cork and hog's lard in m, with the packthread and wire in the eye of the needle; when it is drawn through, the packthread and wire will follow and be kept air-tight by the hog's lard and cork; m must be screwed to the plate as before, and the packthread drawn through m till it is seen nearly straight in the receiver, as at h. In this state, pour into the lower bend of k, about half of an inch of mercury, and the lower bend of i, a little water, represented by the dots in each. It is evident from the construction of the instrument, that if all the screws be perfectly air-tight, the cock F shut, and the cocks n o open; the least alteration that happens to the air in the inside of the receiver, with respect either to increase, decrease, density or rarefaction, will be shewn either by the mercury or water, in either one or both gages; if considerable, the mercury will shew it, and if too little to affect the mercury, the water gage will shew it. If by any process the temperature of the air within the receiver should be raised, it will cause the air to expand and the mercury and water in the gages to move towards u u: but if it should be lowered, the mercury and water will move in the contrary direction, so likewise, if any alterations, with respect to temperature, happens in the surrounding air, the gages will shew it accordingly; and as this is continually changing, it is necessary that the apparatus, after it is prepared for the experiment, and ready for exploding the wire, should be set in some medium which is not so changeable, for this purpose water seems to be most convenient: but as it is a conductor of electricity, the apparatus must not remain in it when the discharge is caused, so that before and after the discharge only, it must be set into the water, care being taken to let it remain a sufficient length of time, that the air in the inside may become of the same temperature, which will be shewn by the gages being stationary. If this circumstance be not observed with great attention, errors in the conclusion will be the consequence.

### Exp. 157.

A sufficient quantity of leaden wire, of one ninetieth part of an inch diameter, was bound to a cord at different places, about four inches distant, as has been already mentioned, and wound upon the axis of the wheel c d; the end of it by means of the long brass needle was drawn out of it at the top of the receiver, through the tube m, which was afterwards screwed in its place, and the cord drawn tight as represented at h. The cock F was then closed aud the whole instrument set in the water, so deep that the brass plate was about one inch under the surface of the water. The cocks n o were opened to admit the external air into the receiver, as the air within became condensed by the coldness of the water. When it had remained nine minutes under water the gages were screwed on to the cocks, perfectly air-tight; and both appearing stationary, the cocks were shut, the instrument was then taken out of the water, wiped dry, and set near to the discharging electrometer, in the room of L M, which must be removed. The cock F, by means of a metal wire was connected to the hook proceeding from E of the electrometer, and another wire proceeding from the brass plate was connected to the outside connexion of the battery, which was then charged till the ball H of the electrometer, loaded with twenty-six grains descended, and directed the discharge through the wire h: which was converted into a blueish white impalpable powder, at first appearing like a white cloud, and filling the whole receiver. The cord was left entire. The instrument was then released from the electrometer, and set in water as before. After it had remained there five minutes, the cocks under the gages were opened; no change could be perceived in the mercury gage, but a motion in the water gage was just perceptible. Hence I concluded that the powder thus produced had absorbed no air.

### Exp. 158.

The apparatus was taken out of the water, and another length of wire drawn forward, placed at the electrometer and battery as before; the battery was charged till the electrometer caused the discharge, which again produced the powder. The apparatus was not put into the water as before, but was left to remain till another length of wire was drawn forward, and the discharge directed through it. This process was repeated with five discharges, through five lengths of wire; each length was seven inches. In this manner, therefore, thirty-five inches of wire was converted into a blueish white impalpable powder. The apparatus was then placed in the water as before, and after it had remained the same length of time, the mercury gage was opened; no motion in the mercury was perceived, and when the water gage was also opened, no alteration was there seen. Thus I concluded that no absorption of air had taken place, though five times the original length of wire had been reduced to powder. The air in the apparatus was then endiometrically examined, and it appeared to be of the same purity as the surrounding atmosphere.

### Exp. 159.

The apparatus was taken out of the water, and the powder which was produced in the receiver being carefully taken out, the apparatus was then furnished with the same length of wire as before; all the screws and cocks were well examined, and the apparatus set in the water as before. After it had stood a due time, the gages were screwed tight; it was taken out of the water and set to the battery, when the last experiment was repeated, and it was afterwards set in the water and the gages opened. No absorption having taken place, it was left in the water till the same hour on the following day, when the mercury gage was opened, and indicated that an absorption of about one cubic inch had taken place, The water was of the same temperature as at first. This experiment seemed to indicate that the metal was first divided and afterwards oxigenated by a slow process.

### Exp. 160.

The last experiment was repeated with double length of wire, and the result was the same.

### Exp. 161.

A smaller receiver was now taken, being only four inches diameter, which was half the diameter of the former. The same kind of powder was produced, and a diminution of air happened, when thirty-five inches had been reduced to powder, which caused the water gage to rise one inch, and the mercury one twentieth part of an inch.

### Exp. 162.

Wires of different diameters were now prepared (in the last receiver)of one hundredth, and one hundred and fortieth part of an inch diameter, and of each in length thirty-five inches. The result was the same with respect to air, but the powder was whiter.

From the result of the three last experiments it appeared, that the absoption of air by the exploded metal, apparently depended upon the diameter of the receivers wherein explosion was caused, for which reason I determined to repeat the experiments in receivers of much less diameter,

## Exp. 163.

Instead of the last mentioned receiver, fig. 83, was taken; being a glass tube of about one inch diameter, and nine inches long, it was mounted in the same manner, but on account of its diameter, only one air cock could be applied; it was furnished with lead wire of the eighty-fifth part of an inch diameter, being the same as that used in the three first experiments. After it had been placed in water with the cock only above the surface, open, and after it had remained three minutes the cock was shut, the instrument taken out and wiped dry; one end of it was annexed to the electrometer, and the other end to a wire which was in communication with the outside of the battery; the same strength of charge was directed through the wire by the electrometer as in the last experiments, and the same kind of powder with respect to colour appeared; the instrument was again laid in water with the cock above the surface, and the water gage was screwed on to the cock; when three minutes were expired the cock was opened, and there appeared so extraordinary a diminution of air that the water in the gage run over the upper bend into the instrument; this diminution was sufficient to make a mercury gage sensible.

## Exp. 164.

The instrument being cleaned and provided with thirty-five inches of wire of the same diameter as above, five separate discharges were directed through the wire, seven inches were exploded at each discharge, and the same process, with respect to laying it in water before and after each discharge was observed.

| | inches. |
|---|---|
| First discharge caused so extraordinary a diminution that the mercury rose in the gage ...... | 1 |
| Second discharge.............. | 1,3 |
| Third ..................... | 1,5 |
| Fourth..................... | ,5 |
| Fifth ..................... | ,3 |
| In the whole...... | 3,6 |

which is nearly equal to two cubic inches; the contents of the whole instrument were nine cubic inches.

The air thus diminished in the instrument was left to stand till the same hour next day, but on opening the cock no further diminution took place.

### Exp. 165.

The state of this residue of air was tried by the test of flame, and it extinguished a candle eight times. Azotic gas in the same glass extinguished the same candle ten times, so that all the oxigen gas contained in that quantity of atmospherical air, was nearly absorbed; the powder produced was nearly the same as that in the large receiver.

### Exp. 166.

This last experiment was repeated with wires of a less diameter, with nearly the same result; the five discharges produced a diminution which caused the mercury to rise between three and four inches.

The result of the last experiment induced me to try receivers of a still less diameter, so one of four-tenths of an inch diameter, and eight inches long was taken, but on account of its smallness of diameter no more wire could be exploded than the length of the tube without admission of fresh air.

### Exp. 167.

Accordingly one discharge of the same degree of force was directed by the electrometer through one length of wire of one fifty-second part of an inch diameter.

| | | inches. |
|---|---|---|
| The mercury gage rose | | ,3 |
| Second discharge through wire of. . | $\frac{1}{100}$ | 3,3 |
| Third | $\frac{1}{85}$ | 3,3 |
| Fourth | $\frac{1}{150}$ | 3,3 |

The wire through which the first discharge was directed was only converted into numberless small particles, retaining their metallic lustre. The second, which shewed the greatest degree of absorption, was but just converted into powder, mixed with particles of lead. The residue of this air was tried by flame, in a glass five inches high, and one inch and a quarter diameter, but at the mouth only three-quarters; the candle was extinguished in it nine times.

These experiments I think will be found sufficient proofs, that the smaller the diameter of the receiver in which lead is calcined by an electric discharge, the greater proportion of air will be absorbed, and the 165th experiment prove that what is absorbed is the oxygen gas, which is by the process separated from the azote of the atmosphere.

It is well known that metals require certain degrees of temperature, to give them the property of absorbing the greatest quantity of oxygen gas; this is the point which I had in view when I used wires of different diameters, because I know no way how to increase the temperature communicated by an electric discharge to metallic wires, but by diminishing the diameters or lengths in a certain proportion, or increasing the force of the discharge, which is the same thing; and the last experiment shews that it makes very little difference whether wire of one eighty-fifth part of an inch, or wire of only half that diameter, be used, so that it does not seem here to follow the same law as common heat.

### Exp. 168.

To conclude with this metal, the first mentioned large receiver was taken, and one hundred and thirty inches of wire of the eighty-fifth part of an inch in diameter were prepared in the same, being nearly four times the quantity that was used before. This was exploded and converted into an impalpable powder, by twenty separate discharges, and when the gages were opened there appeared to have been no air absorbed.

## Exp. 169.

The powder or calx was preserved and put into a very small retort, with an intent to try what would take place on the application of heat. No air was given out by such treatment, excepting a little common air, which I suppose was contained in the retort. The powder, which was first of a blueish white, changed into a dark leaden colour, and afterwards into a yellowish green, and when the glass was red hot, to be nearly melting, the powder was only partially melted into lead.

Lastly, twenty-four grains of this powder, which, according to the gages, had absorbed no oxygen, were taken and put into a clean crucible with a cover to it, set in a furnace and kept in a white heat about an hour. When taken out there was found in the bottom of the crucible a perfectly clear glass of a reddish brown colour. Thus we find a powder obtained, which possesses the most distinguishing properties of an oxide of lead, though it appeared to have absorbed no oxygen in its preparation.

### *Lead burns with a yellowish Flame, by the electric Discharge.*

These experiments appear to be sufficient to prove, that the absorption of the oxygen gas from the atmospherical air by the prowder thus produced, wholly depends upon the diameter of the receiver, wherein the explosion was made, for we find by the tenth experiment that when eight inches of wire were oxidated in a receiver only four-tenths of an inch in diameter, it then absorbed half a cubic inch of air. In this proportion the last wire should have absorbed sixteen times that quantity, and the result was that it had absorbed none, the reason of which is not easy to be understood.

These experiments were made in the winter season, when the temperature of the atmosphere was seldom lower than 28°, and not higher than 45°, the result was as mentioned, but not being able to reconcile myself to such paradoxical results, I showed the experiments to several Philosophers, who however, were equally as much at a loss to account for the result as myself.

On the 10th of May, 1798, I was favoured with the company of some gentlemen of the Royal Society, to see the experiments; I used only two receivers, one of an inch diameter, and the other of six inches diameter, as follows.

### Exp. 170.

A piece of leaden wire of nine inches long, and one eightieth part of an inch diameter, was exploded by an electric discharge in the receiver of one inch diameter; after it had laid in water three minutes the mercury gage rose thirteen-twentieths of an inch, which was a degree of diminution of about half a cubic inch.

### Exp. 171.

Eight lengths of wire of the same diameter were exploded in the receiver of six inches diameter, and after it had been in water five minutes, the mercury gage rose two-tenths of an inch, which was a degree of diminution of about three cubic inches and an eighth, and consequently not agreeing with my former experiments.

The result of these two experiments occasioned several repetitions, and all with nearly the same result, but on the repeating them in the winter when the temperatare was low, I found the same result as at first; namely, a diminution of air in the small receiver, and none in the large one. It then occurred to me that the temperature must have occasioned this variation, and that putting the receiver in water for five minutes, was perhaps not sufficient to bring the air in the inside of the receiver to its former temperature. I therefore placed a thermometer in the inside of the large receiver, and by exploding one length of wire the temperature was raised about two degrees; and when the receiver was set in water the air did not return to its former temperature in less than twenty minutes, consequently this pointed out to me one error, which I was not aware of, but it was not sufficient to explain the whole because this only would indicate a diminution, but less than the truth. By repeating the experiment at different times, I perceived that the first explosion in a low temperature, caused the mercury to rise near two degrees, and that every subsequent explosion affected it less. After seven or eight explosions had been given, hardly any rise in the mercury could be perceived, and also when the temperature was about 60° the first explosion did not then cause the mercury to rise to above 1°, and it would cease to rise after the third or fourth explosion. When the temperature was at about 70°, hardly any rise in the mercury could be perceived, even at the first explosion; this unfolded the whole, because it appeared that when the temperature was low, the explosions raised it so much as to cause an expansion in the inclosed air, which kept up the pressure upon the mercury in the gages, and of course, prevented them from indicating any loss; and when the temperature was high, the explosions did not cause such expansion, consequently permitted the gages to indicate the true loss, or quantity of air which had been absorbed by the divided metal.

I thought it proper to mention the above in full, not only for the advantage of those who may undertake such experiments, but likewise to prevent wrong conclusions being drawn from the result of the first set of experiments with large receivers, as they have been shewn to many, and some authors have brought them forward to support their own erroneous notions.

We may conclude from these facts that the difference of diameter of the receivers, wherein leaden wire is exploded, neither favours nor prevents the diminution of the atmospherical air therein contained. If two leaden wires of equal lengths and diameters, be exploded by equal electric discharges in unequal receivers, the diminution of the air which they contain will be in proportion to their contents; and if the receivers contain atmospherical air, that which is seemingly lost by the process is oxygen gas, absorbed by the exploded metal, which becomes converted into a true metallic oxide.

## Exp. 172.

### *Tin.*

Sixteen inches of tin wire of one hundred and twentieth part of an inch in diameter, was put into fig. 82, and after it had been laid in water so long that the air in the inside was become of the same temperature as the water, the wire was exploded by two discharges, and by that means converted into an impalpable powder, nearly the same as the lead wire, but of a purer white; the apparatus was then again laid in water till the air had gained its former temperature; when the cock was opened the mercury rose three inches and the air by the test of flame seemed to be as highly azotic as that in which lead had been exploded in the hundred and sixty-fifth experiment.

The last experiment repeated with wire of one hundredth part of an inch in diameter, and the result was the same.

Tin burns with a vivid yellow flame when exploded.

### Exp. 173.

*Iron.*

Thirty-two inches of iron wire, of the two hundred and thirtieth part of an inch diameter was put into fig. 82, and exploded by five discharges, the mercury rose three inches.

The wire was converted into an impalpable powder of a reddish brown colour; the residue of air seemed to be the same as that left in the hundred and sixty-fifth experiment, wherein lead and tin had been exploded. It extinguished a candle nine times.

Wires of different diameters were taken, with a view to try what degree of ignition was required to cause the greatest absorption of air, or in other words to make the most complete oxide.

The same degree of strength of charge was directed through a wire of one hundredth part of an inch diameter—no air was absorbed; the wire was only red hot.

| | inches. |
|---|---|
| Wire of $\frac{1}{100}$ was exploded and converted into balls, the mercury rose | ,6 |
| Wire of $\frac{1}{130}$ converted into very small powdered balls | ,6 |
| Wire of $\frac{1}{150}$ into flocculi and balls | 1. |
| —— of $\frac{1}{240}$ into an impalpable powder of reddish brown colour | 1,1 |

## Exp. 174.

### *Copper.*

Thirty-two inches of copper wire of the two hundred and sixtieth part of an inch diameter was prepared in fig. 82, and exploded by five discharges; the mercury in the gage rose one inch and one-tenth. It was converted into an impalpable powder of a purple brown colour; the residue of air extinguished the flame of a small wax taper twice.

This metal burns with a green flame when exploded.

All the foregoing experiments were made by myself, at my house in Poland Street, but the following were made at the house of Mr. Campbell, in South Audley Street, who honoured me with his assistance. The apparatus which we used was of my own construction, being a double plate machine; each plate twenty-six inches diameter, and a double battery of thirty jars, of my common size, containing about thirty-four square feet coated glass. The electrometer was the same as that described in Nicholson's Journal, Vol II, page 528, excepting that instead of using pins of certain weights to put into B, the arm C B was divided into grains with a slider upon it, which was set to the weight required, as I commonly make them at present, being more convenient. See fig. 80.

### Exp. 175.

*Pure Silver.*

Forty-five inches of silver wire of the one hundred and thirtieth part of an inch diameter was exploded by five discharges; the slider upon the electrometer was set at forty grains; it was converted into an impalpable black powder; the mercury rose in the gage about half an inch, and the flame of the taper was extinguished nine times.

Silver burns with a greenish flame, nearly resembling copper.

### Exp. 176.

### *Grain Gold,*

Fifty-four inches of wire drawn from grain gold, of one hundred and twenty-fifth part of an inch diameter, was exploded by six discharges; the slider upon the electrometer was set at forty-two grains; it was converted into an impalpable powder of a dark brown purple colour; the mercury rose in the gage about a quarter of an inch, and the flame was extinguished four times.

### Exp. 177.

Nine inches of the same sort of wire, but of a less diameter, being one hundred and thirtieth part of an inch, was exploded in the same receiver, by one discharge; the mercury rose about two tenths of an inch, and the flame was extinguished four times.

## Exp. 178.

### *Platina.*

Twenty-seven inches of platina wire, of one hundred and thirtieth part of an inch diameter, were exploded by three discharges. When the gage cock was opened, the mercury rose a quarter of an inch; but on applying the flame to the residue, it was not extinguished.

As platina is easily ignited by electricity, the slider upon the electrometer was only set at twenty-two grains, for the last and residue of air did not extinguish the flame. It was supposed that too low a charge had been used; the slider was therefore set at thirty-two grains, and the experiment was repeated with the same length and diameter of wire, and exploded by the same number of discharges. When the cock was opened, the mercury rose about one inch, and the flame of the taper was extinguished five times. The metal was converted into a black impalpable powder, resembling that of silver.

## Exp. 179.

### *Zinc.*

Nine inches of zinc wire of one hundredth part of an inch in diameter was exploded by one discharge. When the gage cock was opened the mercury rose half an inch, and the residue of air extinguished the flame of a taper twice. The metal was converted into an impalpable powder of a white colour resembling that of tin.

This metal being so difficult to draw into wire, I was obliged to conclude with the above-mentioned length. The method of making this metal malable was at this time not known.

From the result of the foregoing experiments it may he safely concluded, that all the ductile metals can by electric discharges be sublimed, and converted into proper oxides, by absorbing the oxygen of the atmosphere; and though some of the metals resist the action of common fire, and require different solvents to convert them into different oxides, yet they all yield to the action of the electric fluid.

It is remarkable that platina, though it resists the action of common fire, is more easily exploded by electric discharges than copper, silver, or gold, and seems to be as greedy of oxygen as any of the other metals; but these experiments have not been sufficiently extended to settle the last mentioned property.

It is well known that all metals which are sublimable by common fire, absorb oxygen in different degrees, and likewise in different proportions, according to the different degrees of heat employed; this seems likewise to take place when they are sublimed by electric discharges, but the proper degree of discharge for each metal remains for investigation; and as different metals differ as conductors of the electric fluid (which has never yet been well defined), this furnishes matter sufficient for a future pursuit.

The latest experiments upon the conducting power of metals, were made by Dr. Van Marum and myself, at Haerlem, but as I had not at that time invented the electrometer which I have at present, and which the nature of the experiment required, I have some reason to think that they are not perfectly accurate. I have concluded these experiments without proceeding to the non-ductile metals, because I know no way of arranging them so that they can be acted upon with sufficient accuracy.

The experiments which have been made upon different metals mentioned, have been very numerous excepting zinc, but for the sake of brevity, and to avoid tautology I have only mentioned those which I thought to be absolutely necessary.

# PART THE NINTH.

## *Oxides of Metals formed by exploding Wires stretched parallel to the surface of Paper or Glass Planes.*

These experiments were first done at Haerlem by Dr. Van Marum and myself, in the year 1787, with a battery containing 135 square feet coated glass, but I have since found that one of my common sized batteries of only 17 square feet, is quite powerful enough for that purpose, (when my method of increasing the charging capacity of the jars is attended to,) and the figures formed by it are in every respect equally perfect and beautiful; the metals for this purpose must be drawn into wire of certain diameters, regulated according to their conducting property; the apparatus is represented fig. 81. M L is a mahogany board about fourteen inches long and five broad; at about an inch from each end are two upstanding pieces through which two wires slide, bent in the form of a hook at one end; these pieces have screws to stop the wires at any distance from each other, the wire that is intended for oxidation must be turned up at each end, so as to form an eye, which is done by bending the ends round the hook, and twisting it round between the fingers; the wire between those eyes should be about ten inches long; then a piece of paper to receive the oxide must be stretched along the board as flat as possible, the eyes of the wire for oxidation must be hooked to the sliding wires on the board and drawn perfectly straight, and at about one-eighth of an inch distance from the paper; one of the sliding wires of the board must be connected with N, and the other to the outside of the battery, by means of a metallic wire represented at L O.

### Exp. 180.

Take ten inches of lead wire of one ninetieth part of an inch diameter, extend it over a paper on the board as before directed; set the slider on the moveable arm of the discharging electrometer at 20 gr.; connect the electrometer, and the conductor of the machine with the battery, as is represented 81—then turn the machine—

when it is charged high enough, the electrometer will direct the discharge through the wire, which will explode; and a white cloud of oxide will rise up in the air, and a beautiful figure, the whole length of the wire, will be left upon the paper, of a black grey colour intermixed with blue.

### Exp. 181.

If tin wire of the same length and diameter be subjected to the same process, with the difference only that the slider must be set at thirty grains, on account of its not being so easily fusible by electricity as lead; a cloud of oxide will arise of a whiter colour than that of lead, and a figure will be left upon the paper as beautiful as that of lead, but of a very different colour, being chiefly yellow intermixed with grey.

### Exp. 182.

Zinc wire of the same length and diameter requires a greater quantity of electricity than the foregoing metals, to convert it into an oxide; the slider must for that reason be set at forty-five grains. At the explosion, a cloud will arise of a blueish white colour, and the figure left upon the paper will be of a dark brown colour, with a tinge of yellow at the outward edges, resembling the figure made by the tin. This wire was drawn from the newly invented malcable zinc; probably it may have a small mixture of tin to favour its malcability.

### Exp. 183.

Iron wire being the next fusible metal, by electricity, but on account of its being much more refractory than tin, the diameter must be the hundred and fiftieth part of an inch, and the slider of the electrometer set at thirty-five grains. At the discharge, a cloud like oxid will rise up in the air of a dark grey colour, and the figure left upon the paper is nearly the same colour as that which rises up.

### Exp. 184.

Copper wire being the next fusible by electricity, and is so nearly the same as iron that there needs no alteration in any part of the apparatus nor diameter of the wire. At the explosion, an oxide will rise nearly of the same colour as that of iron, but the figure left upon the paper is much more beautiful, being mixed with various colours, remarkably bright.

## Exp. 185.

Platina wire, though so refractory to common fire, yields to electricity nearly the same as the last mentioned, so that the same length and diameter must be taken, and the slider to the same number of grains; at the explosion, a dark coloured oxide will arise, and the figures left on the paper will be of a dark grey colour with little variation.

## Exp. 186.

Silver wire of the same length and diameter as the last, but on account of its not being so easily fusible by electricity, the slider must be set at forty grains; at the explosion a dark grey coloured oxide will rise, and the figure left on the paper will be of a dark grey colour resembling that of platina.

## Exp. 187.

Gold wire, of the same length and diameter; the slider must remain at forty, because it is nearly of the same fusibility as the last mentioned; at the explosion, a dark brown oxide will rise, and the figure left on the paper will be of a purple colour, with much variation, resembling that of copper.

All the above figures may be struck upon glass in the same manner, and by the same apparatus; the only difference is, that a plate of glass must be laid under the wire instead of paper, and the figures are surprisingly beautiful.

The beauty of the figures depend much on the wire being extended at a right distance from the paper, which is learned by experience. The nearer the wires are to the paper the more striated will the figures appear; the height of the charge being governed by the number of grains to which the slider is set, and that which I have mentioned for each experiment is the lowest;—to save the trouble of turning the machine longer than necessary, it may be set to a higher number; the experiment will succeed equally well, and some of the figures will be more beautiful.

It is very remarkable that the oxide of lead produced by experiment 158, was white, and also the cloud wich appeared at the explosion experiment 180, that the figure left on the paper should be a brownish black, intermixed with blue. All the figures produced by the above experiments are very different from their real oxides, when produced in receivers, and though some bear a resemblance of each other, in some particulars, yet they are all easily distinguishable.

All metallic wires undergo several changes by being subjected to electrical discharges of different degrees of power; the most remarkable are those of iron; it is first yellow, then blue, then very little different from its natural colour, then red hot, then appears a string of balls, then drops in balls; then disperse in balls; then in balls and flocculi; then into an impalpable powder lighter than air.

When metallic wires are reduced to powder by electricity, it is never of an equal fineness, however violent the discharge may be in proportion to the diameter of the wire; part of the metal, the whole length of the wire, will be reduced to a powder lighter than air, and another part, the whole length, into a powder heavier than air, and it is this last part of the wire which forms the figures upon paper, and glass, or any thing else laid under to receive it; if they are exploded in close receivers, some of the powder falls immediately to the bottom, some falls gradually and some remains suspended in the air for a considerable time.

## Exp. 188.

Take a cylinder of about two inches diameter, and eight or nine inches long, mounted at both ends, so that a wire can be extended and exploded in the inside, with the same degree of power as in experiment 158. Suppose the wire to be lead—at the instant of the explosion, the cylinder, which was before clear and transparent, will then be filled through its whole length, with a white powder; and when the cylinder is opened, the powder which fell down last will be of the purest white; the same will be the case if tin is exploded, but a great quantity of the powder will be white. Malcable zinc seems to possess the same property, but all the powder or oxides of the other metals will be of different colours.

# PART THE TENTH.

## MAGNETISM BY ELECTRICITY.

It has been observed that compass needles after a thunder storm at sea have been affected by it; sometimes they have lost their magnetic virtue, at other times only weakened, and at others reversed; artificial electricity has the same power when the needles are made in a proper proportion to the size of the battery; steel wire of the fortieth part of an inch diameter seems to be of proper proportion, or watch spring clipped lengthways in two; they are easier suspended upon a point when a hole or rather a dent is made in the center.

### Exp. 189.

If an unmagnetic needle four inches long be laid in the magnetic meridian, and a charge of twenty grains repulsion from the abovementioned battery be directed through it, it will become magnetic, and that end which lay southward will be the south pole.

### Exp. 190.

If a needle four inches long, and weakly magnetic, be laid in the magnetic meridian, with its north pole towards the south, and a charge of twenty grains repulsion be directed through it, its magnetic virtue will be either destroyed, or its poles reversed; if it should only happen to be destroyed, a second discharge will reverse its poles, but if it was reversed by the first discharge, a weaker charge would only have destroyed it.

### Exp. 191.

Set an unmagnetic needle in a perpendicular direction and direct the abovementioned discharge through it; its uppermost end will be the south pole of the needle; if it be turned, and a second discharge directed through it, its virtue will be either destroyed or reversed; if only destroyed, a stronger discharge would have reversed the poles, but a second will answer the same as a stronger would have done at first.

If an unmagnetic needle be laid in the magnetic equator, it will be sometimes magnetic, and at other times not, in whatever direction the discharge is passed.

It has been universally supposed that it was the direction of the electric fluid passing through a needle that made it magnetic; experiments have however taught us that this makes no difference in whatever direction; the success of the experiment depends wholly upon the direction of the needle, and the power of the discharge, which may be too strong, as well as too weak, to have the desired effect.

The above experiments sufficiently prove that electricity has the property of giving as well as destroying the magnetic virtue in metallic needles; hence it was supposed that it would have the same effect upon loadstones, but when a loadstone was subjected to the discharge of a sufficient degree of power, its virtue was entirely destroyed; all attempts to restore it by electricity have proved unsuccessful.

Electricity, when applied in too great quantities, is fatal to both animal and vegetable life, of which we have many instances. It has been supposed, and even supported by experiment, that when properly directed it is favourable to vegetation, and propagation of animal life; but these are questions of much controversy and generally disbelieved.

# PART THE ELEVENTH.

## *Description of an Electrical Kite Apparatus.*

Plate IX. A B is a wooden frame, wherein a roller turns upon a brass axis, divided into two parts. B C and C A is that part on which the string of the kite D is wound. The frame is supported by three mahogany legs, upon the top of which are fixed three pieces of glass covered over with brass funnels a b c, to prevent the rain from wetting the glass; h is a small apparatus for the purpose of letting the electric fluid (when it comes too strong) pass away down into the water, as is seen at E when a thunder storm is expected. A second roller as F must be used, pushed fast in the ground at about twenty or twenty-five feet distance from A B. Upon F is wound a silk cord, oneend of which is made fast to the roller between A C, which part is much larger in diameter than the other. When the kite rises higher it will cause the silk cord upon F to be wound upon A C, which is governed by the handle G without any danger. By turning the handle the contrary way, the silk cord will come back again from A C to F, and the kite will be drawn down. The cord of the kite is made of strong packthread with brass wire twisted in it, and a brass wire passing from the cord is connected with an insulated conductor H, standing upon a table at which all the experiments can be made with it, as if it was the prime conductor of an electrical machine.

*Experiments made with the Electrical Kite.*

### Exp. 192.

The apparatus being arranged, as is represented in the plate, the kite let fly with three hundred feet length of cord, sparks were drawn from the conductor standing upon the table, about the tenth part of an inch in length, which was so strong that it was felt to pass through the whole body. A bottle was set to the conductor but it charged very weakly, and no ways in proportion to the strength of the spark, when com pared with those taken at the prime conductor of an electrical machine.

## Exp. 193.

The wind being favourable, the kite took three hundred feet more length of cord, the sparks were then so painful that each spark was as a strong shock, as received from a Leyden bottle, but not longer than before; the above bottle was set to the conductor; it charged but a very little stronger than before, no ways in proportion to the increased strength of the spark; this was thought to proceed from the length of the cord only, and not from any increase of the electricity received from the atmosphere by rising so much higher than before.

## Exp. 194.

The kite was drawn down and the strings altered so as to make it fly afar of, but not rise to such a great height as before, and when it had taken the same length of string as before, I found the sparks of the same strength, and the bottle charged to the same height as before, which confirmed the conjecture that the strength of the spark was caused by the length of the conductor, and not by any increase of electricity collected by flying higher; it remained to be proved whether the many unavoidable points and smallness of the wire in the string of the kite was the reason why the sparks were so short, and the low charge of the Leyden bottle.

## Exp. 194.

To prove this, I stretched the string of the kite horizontally in the field, supporting it at different distances with insulating sticks, and annexed one end of the string to the prime conductor of an electrical machine, whose striking distance, when not annexed to the string was about one inch; and when annexed to the string about the eighth part of an inch. In taking the spark from the conductor in this situation, the same sensation was felt, as in taking the spark from the string when annexed to the kite. A coated bottle was set to the string, and it was charged to about the same height as when it was charged by the kite. This appeared a sufficient proof that the points in the string, and the smallness of the wire was the reason that the bottle could not be charged higher; also that the quantity of electricity was nearly equal, excepting in a thunder-storm. when the points could not act so as to diminish the strength to such a degree as when there was no thunder, the latter in some respects being different from the former, because in a thunder storm the cloud which causes the thunder is supposed to be positive; the earth may then be said to be hungry and gaping for electricity, the cloud being drove forwards by the wind, and meeting the kite discharges its contents, with a force in proportion to the quantity of electricity contained in it, which is sufficient to break through all interruptions without making use of the points to fly off: because it cannot fly off there into a conductor to carry it to the desired place, with a velocity equal to the quantity.

### Exp. 195.

Some time after I had formed the above stated conjectured ideas, I met with a phenomenon sufficient to confirm them. Being one day in the country, in company with a friend, we raised the kite (the weather seeming rather favourable) to its usual height, and we had then nearly the same quantity of electricity as usual. After it had been up about an hour we saw a thunder-cloud in its way to the kite, and as it appoached, the electricity increased, till it began to run in a successive stream to the apparatus, which I contrived to receive the electricity which would be too formidable for any common experiment. I immediately placed the apparatus at the distance of four inches; it continued still going over, not in a stream but in balls of fire, with loud explosions; coated bottles were no sooner placed at the conductor than they were immediately broken; this continued for about the space of five minutes; when the cloud seemed to be nearly discharged, it was driven off by the wind in a direction from the kite. This then sufficiently explains what I have advanced concerning the points and the smallness of the wire contained in the string of the kite; that they can act as discharges of electricity in ordinary cases of the atmosphere, and as conductors when the atmosphere is overcharged with the same.

If a greater height should be required than can be obtained by one kite, two, three, or more may be let fly above each other, from the same string, so that almost any height required can be obtained. The first kite is as usual without any alterations, but the middle stick of the rest must have a long slit in the middle, of such width that the cord can freely move in it, in any direction. When the first is let fly as high as it can, the end of its string is put through the slit of the second and tied to its string, if it be then held to the wind it will rise, and the first also; when the two first have risen to their greatest height, a third may be added and connected in the same manner, and so on to any number. It sometimes happens that the wind in the higher parts of the atmosphere blows in a different direction from that below; when this is observed the kites should be drawn in or they will fall.

*Experiment with three Kites.*

EXP. 196.

Some years ago, in the month of May, I let a kite fly with 500 feet of cord, which seemed to be as great a weight as it could carry, but as no sparks could be got from the wire in the string, and the kite would not rise higher, I fastened a second to it and they both continued rising till the second had 500 feet more cord, but still it shewed only faint signs of electricity; a third kite was then added, which took 500 feet more, and then sparks were drawn, but very weak, only just felt in the finger. The wind was south-west, and the sky was covered with clouds. I had observed that in such a state of the atmosphere, little or no electricity could be obtained, and that the electricity was the strongest when there were no clouds, of very few, excepting in thunder storms. I often repeated such experiments at that time, and always found the electricity from the kites to be positive, but other writers make mention of having had both positive and negative.

# APPENDIX.

## Galvanism.

To treat upon Galvanism in a deserving manner, would lead me far beyond my intended bounds; however, as its effects, in my opinion, are purely electrical, and as it is a subject which has engaged the attention of the most eminent philosophers, and upon which several volumes have already appeared, it would be inexcusable in me, when treating of electricity, to pass it over in silence: at the same time, I must excuse myself from offering any theory of my own; or from entering into a refutation of those offered by others; all of which have turned out to be mere hypothesis, being unsupported by that extensive range of facts which alone can constitute a true theory.

The apparatus commonly termed the galvanic pile owes its birth to the celebrated professor Volta; and is still with very little improvement on the Continent; but since Mr. Cruickshanks' invention of the trough, the piles are seldom used in this country.

Signor Volta's electrical pile is composed of a number of plates of zinc, copper, and pieces of wet cloth, all of equal size, piled one upon another: first a plate of copper, then of zinc, then of wet cloth; then of copper again, of zinc, and of wet cloth, until a pile of twenty, forty, or sixty plates of each is raised. The cloth should be wetted either with salt and water, diluted nitrous acid, or any other oxidating menstruum.

### *To produce a Shock by Volta's electrical Pile.*

EXP. 197.

Take two instruments represented by fig. 103, grasping the thick end close in each hand (the hands being previously wetted in the same solution the cloth is wetted in); then with the point of the instrument touch the lowermost plate, holding it there by one hand, while with the other you touch the uppermost plate; a shock will be felt something similar to that of a charged Leyden phial, but not perfectly so, because when each side of a charged Leyden phial is touched in the same manner as above, the whole contents of the electric charge passes instantaneously from one side of the phial to the other, and its action ceases; but when each end of a Volta's pile is touched, part of the contents passes off instantaneously but not the whole; it continues running in a stream without intermission, for a considerable time: this is proved by a variety of experiments, amongst which are the continued decomposition of water and several other fluids; also when it has sufficient power, an iron wire may be kept red hot for a space of time.

Mr Cruikshank's galvanic trough, plate VIII, fig. 104, is made of baked wood, wherein grooves are made opposite each other one-tenth part of an inch deep, and sufficiently wide to admit a plate of zinc and copper soldered together; three of these grooves are made in the space of an inch; an interstice being left between each pair of plates, represented by the white part in the plate, which is to be filled with diluted nitrous acid, or any other oxidating menstruum, to answer the same purpose as the wet cloth in the pile. The pairs of plates after being soldered together must be cemented into the grooves.

*To produce a Shock by the Galvanic Trough.*

EXP. 198.

Fill each interstice with the abovementioned menstruum, which is easiest done by elevating one end, and pouring the liquid into the first interstice; the rest will successively fill of themselves, taking particular care not to fill the trough so that the tops of the plates will be covered with the liquid when laid down level. Then hold fig. 103, as before directed, in each hand one; put the point of one into the first interstice, and the point of the other into the last, a shock will be felt exactly the same as with the pile, provided the number and dimensions of the plates are the same.

*To direct a Galvanic Shock, or pass the galvanic fluid through any particular part of the body, for medical purposes.*

EXP. 199.

Suppose a person is to be galvanized through the head; place the patient and trough as is represented in fig. 104; the interstices of the trough being filled with diluted nitrous acid, put one end of each director in the holes at the end of the trough, the other ends beiug directed to the place where the galvanic fluid is intended to act;—having previously screwed to the ends of the directors two button-like pieces of metal, covered with cloth, which must be well soaked in the same liquid as is used for the trough; hold them to the patient as is represented in the figure, and press them gently to the part. On the first application the patient will feel a shock, and see a flash of light—if the ends of the directors are not removed the patient will experience no more shocks; but a current of galvanic fluid will run through the head, entering in from that end of the director which is annexed to the zinc end of the trough, and passing out to the copper end, by the other director; this current will be felt, or not, by the patient, according to the size of the trough, or number of plates. If it is desired that the patient should have shocks, one of the directors must only touch the patient by intervals; the other being kept close to the part each touch will produce a shock. In the above method the power of the whole trough is felt—if it should be too severe, screw on to the end of either of the directors the spring clasp c, and instead of fixing it to the end of the trough, slip it on any of the plates, and the shock will be moderated, according to the number of plates included by the directors.

It is this shock given in different directions, which produces muscular motion in animals, after animation is suspended, from whence it was supposed it might be of use in resuscitation under such circumstances, &c. This I have tried on two malefactors, but without success.

The apparatus used for the above purpose, consisted of three troughs combined together, each of which contained forty plates of zinc and copper of about one inch and a quarter square surface. When one of the conductors was applied to the mouth and the other to the ear, the jaws began to quiver, the adjoining muscles were horribly contorted, and the left eye actually opened. (For a farther account of these experiments, *see an Account of Galvanism by John Aldini, printed for Cuthell and Martin, London*, 1803.) In this work the writer says, that the effects produced by galvanism on the human frame are different from those communicated by electrical machines. This he has not proved; it is certain that muscular motion can be produced by common electricity, as powerfully as by galvanism, but not in such quick succession, because when muscular motion is to be produced by common electricity, it must be by discharges, either from coated glass or a very large insulated conductor, which takes some time in charging; more or less depending upon the power of the electrical machine; indeed there has not yet been made an electrical machine that can throw off so much electric fluid, in a given time, as can be produced by a galvanic trough of only thirty-two pairs of plates. The latter is capable of igniting eight inches of iron wire, with the same power as two highly charged jars, and the experiment can be repeated several times by the latter, before the jars can be charged to such a degree, as to produce the same effect once. Galvanism has also the advantage over common electricity, that it can be administered in all circumstances where common electricity can, and in some circumstances where common electricity cannot; it is therefore very much to be lamented that something has not yet been set on foot, in order to give it a fair trial in cases of suspended animation.

## *Description and Method of using the self-acting Galvanic Trough.*

### Exp. 200.

Fig. 105 represents a person galvanizing himself. C Z is the trough; c, d, a director, which by means of a wheel at t, is caused to move upon an axis, lifting and depressing the ends of c d as it goes round, being turned by means of machinery contained in i. The end d is made to touch the zinc end of the trough at z, and the other end moves in a groove at c, fixed to a metal cup filled with salt and water, in which the patient holds one hand; m k is the other director, the end k is put into a hole at C, the copper end of the trough; or by means of the clasp e, fig. 104, fixed to any of the intermediate plates, in order to lower the shocks, which are felt at the moment the end d touches Z. When the patient applies it to himself as is represented, the shock enters the left hand and goes out at m. When shocks are not required, but a current of the fluid to pass through the parts represented in the figure, the machinery must not be wound up, but the wheel must be set in such a position that d shall rest upon Z, the current will be in the same direction as the shocks. The interstices of the trough are supposed to be previously filled with some of the solutions before mentioned.

*To Ignite Iron Wire.*

EXP. 201.

Fill the trough a b, fig, 109, as mentioned before; put into the holes at each end of the trough a brass wire; hold the wire which is intended to be ignited with one hand, close to a, or, which is better, wind it once round the wire, to be certain that it is in contact; with the other hand draw the wire straight, and move it so as to touch b, and the wire will be ignited; if the trough should not be powerful enough to ignite the whole length, bend a b towards each other, till the distance is such as the power of the trough requires.

It must be observed that a galvanic instrument has its greatest power on its first beginning to act, and grows gradually weaker:

## *Decomposition of Water by Galvanism.*

### Exp. 202.

Take a b, fig. 107, which represents a glass tube with a platina wire about one inch long, hermetically sealed, perfetly air-tight, and mounted with brass for the convenience of connection; b is a brass cup, with a brass pin passing through it; its under end is put into a hole at z, which prevents the cup and glass tube from falling, and at the same time renders the connection with the zinc end perfect; in the other end of the pin is a hole for the reception of any part of wire, which is intended to be used. Fill the glass tube and cup with water; put one end of a platina wire into the hole at the top of the brass pin, in a perpendicular direction; invert the glass tube over it; put the end a, of a director into a hole at the copper end of the trough at c, and let the other end only rest upon the brass mounting at the top of the tube (the trough being previously filled), the decomposition will immediately begin, and two currents of gas will be seen to ascend to the top of the tube; that passing from the lowest wire will be oxygen gas, and the other hydrogen gas. If the process be continued till the gas produced occupies about one half of an inch of the tube, and inclined so that it remains between the ends of the wires, and a spark directed through it from an electrical machine, the gas will take fire and an explosion will happen.

### *To produce Hydrogen Gas.*

### Exp. 203.

Take the platina from the brass pin, and in its place put a piece of wire made from any of the oxidable metals, as tin, copper, &c. then if the galvanic action be applied as before, gas will be produced at the upper end only; at the lower wire will be produced an oxide, which will be seen floating in the water, and gradually precipitating. The gas produced at the upper wire will be hydrogen gas; if it be submitted to an electric spark as the last mentioned, it will not take fire nor any explosion happen; if a little oxygen gas be admitted, or common atmospherical air, about the same quantity as the hydrogen gas, and then an electric spark introduced an explosion will happen; a certain proof that the gas produced was hydrogen gas.

### *To produce Oxygen and Hydrogen Gas separately, in two different Receivers.*

EXP. 204.

Fig. 108, a b represents a wine glass with two holes drilled opposite each other, wherein are cemented two glass tubes bent, with a platina wire passing through each; the outward ends of the wires are bent in the form of a hook or eye and the ends on the inside of the glass are bent downwards; the glass is filled with water, as also two small glass receivers, which are inverted over the ends of the bent tubes; the end of one director is put into the hole at z, the zinc end of the trough, and that of the other into the hole at c, the copper end, and their other ends must be connected to the outward ends of the platina wires; the trough being previously filled with the proper liquid, oxygen gas will be produced by that wire which is connected with the end of the trough z, and hydrogen by the other, each being received in its respective receiver.

## *To Hydrogenise Metal.*

### Exp. 205.

Fig. 109 is a straight glass tube half filled with pure water, about six inches long, and half an inch wide, with platina wire about one inch long passing through the end B and hermetically sealed; at the end A is another platina wire passing through a cork and pushed down past the end of the other wire so as to be parallel to each other.

Set the tube in a perpendicular direction and annex the end of the wire at B to the zinc end of the trough, and the wire at A to the copper end; gas will be produced at both wires as in the foregoing experiments; but by continuing the galvanic action the short wire will acquire a gold-like colour, and the other become black, so far as they passed each other in the water; if the annexing wires be changed so that that which was connected with the zinc end of the trough be connected with the copper, and that which was connected with the copper end be applied to the zinc end, the black powder will leave that wire which was black, and become perfectly bright, and afterwards obtain a gold colour; and the other which was before of a gold colour will become black. The gold colour seems to be only a slight tinge upon the surface of the metal, but the black looks like a powder lying upon the surface of the metal. When other metals are submitted to this process other combinations are formed; some of them are oxidised; some combined with hydrogen; others unite with pure water by the galvanic influence.

This colouring matter has not yet been investigated. I observed it in Feb. 1805, and gave an account of it in the philosophical magazine for March 1805; and Mr. Brugnatelli had observed the same in Sept. 1805, and has denominated it Hydroret of hydroginated platina, *i. e.* hydroginised platina combined with water. How far he is justifiable in giving it this denomination, time only can determine.

### *Oxymuriatic Acid formed by the Galvanic process.*

#### Exp. 206.

Take a glass tube about three or four inches long and half an inch wide, represented by A B. fig. 84 The end B is covered with a bladder bound perfectly water-tight; the other end is loosely fitted with a cork, through which passes platina wire, reaching nearly to the bottom of the tube. It is half filled with pure water, and standing in a wine glass which also contains pure water, one end of another piece of platina wire is put into the water so as to touch the bladder, and the other end is connected with the copper end of the trough, and the first mentioned wire with the zinc—then if the galvanic action be continued an hour or more, according to its actingpower, the liquid will whiten the nitrates of silver and mercury, and turn the blue tinctures into a lively red.

*Soda Solution neutralized.*

EXP. 207.

If instead of water a weak solution of soda be introduced into the above apparatus, and galvanised in the same manner, its alkaline properties will disappear.

*Oxymuriatic Acid and Soda formed separately.*

EXP. 208.

Let two tubes fig. 85, be prepared as the above described, and set in a glass with water; annex the wire proceeding from the inside of one to the zinc end of a galvanic trough in action, and the other to the copper end; muriatic acid will be obtained in the first and soda in the other.

N. B. Some of our most eminent chemists, are of opinion that the products obtained in the three last experiments, proceed rather from a defect in the apparatus than the sole action of galvanism.

### *Deflagration of Charcoal by Galvanism.*

### Exp. 209.

Charcoal for this experiment must be made of some very close grained wood, such as box-wood, or lignum vitæ well charred and cut into small pieces about one inch long, one end being scraped to a point, and the other so that it can be held in a port crayon fixed to the end of one of the directors; then approaching the point of the charcoal to the end of the other director, light will either appear or the charcoal will be set on fire. The particular management required is soon obtained by trials. The light when properly managed exceeds any other artificial light ever yet produced.

## *To charge a Leyden Phial by the Galvanic Trough.*

### Exp. 210.

When coated glass is to be charged, a Leyden phial, such as can be easily grasped in the hand is proper for that purpose. Lay one end of the directors of the trough flat against the outside coating of the phial; grasp them in the hand, so that the director and coating may be in perfect contact—move the hand so as to strike the other director with the inside connexion of the phial, and the phial will be charged; the other ends of the directors are supposed to be in their respective holes, at each end of the trough, or fixed upon so many pairs of plates as are intended for trial, and supported from touching any other conducting substance. If the charging power of the trough be very weak, then the condensor and condensing electrometer will be required to make the gold leaf diverge, and if strong the gold leaf of itself will shew the degree of the charge. See Exp. 211.

*To produce Motion, and Contractions of the Muscles in the Body and Head of an Animal after Separation.*

The trough or troughs ought to be regulated in proportion to the size of the animal. To produce the best effect, a number of small troughs answer better than large ones, see page 250. For the head, and body of an ox, less power than is therein mentioned would not have the desired effect; but for smaller animals that number of troughs is not necessary.

*To produce Contractions in the Head of an Ox, after Separation from the Body.*

The head and galvanic troughs being placed in a convenient situation, instead of the common dircetors, wires must be used, and plated copper wire seems to answer best, about one fortieth part of an inch in diameter, and of a convenient length. Put one end of one wire into the hole upon the top of the first pair of plates, or in the interstice between the two first pairs immersed in the liquor, and the other end into one of the ears, which must be well wetted with salt water, and the end of another wire into the other ear, likewise well wetted. These two wires held in that position, an assistant must dip the end of the last wire into the liquor contained in the last interstice by intervals, and every time that the liquor is touched contractions will be produced; the eyes will open; the ears shake; the nostrils swell, and the tongue, which before hung out of the mouth, will be drawn in with violence.

Frightful convulsions may be produced in the head of a dog by the same application. The mouth will open, the teeth will gnash, the eyes roll in their orbits, appearing as if the animal was restored to life, and in a state of agony. These experiments I had the honour of performing in the presence of their Royal Highnesses the Prince of Wales, Duke of York, Duke of Clarence, and Duke of Cumberland.

*To produce Muscular Contractions in the Body of an Animal after being beheaded.*

The best method is to apply one of the connecting wires into the spinal marrow, and the other into the anus, or it may be applied to any other parts, but the ends of the wires ought to be made so sharp that they can be pushed through the skin, or else the skin must be well wetted with salt and water, because dry skin obstructs the passage of the galvanic fluid.

*Method of applying the combined Condensers to show the degree of Galvanic power, excited by one piece only of Zinc, Copper, and a Wet Cloth.*

EXP. 211.

Put the short end of m into e of the large condensing plate (the instruments being combined as mentioned in the description, page 132); bend the end downwards, at such a distance from the table, or whatever it may stand upon, that the two pieces of metal, zinc, and copper, as at n, can be put under it, and drawn away from under it again, without its touching the table when the metal is drawn away. Take two pieces of metal, zinc and copper, about the size of half-a-crown or upwards, either separate or soldered together, with their flat sides in contact, and push them under the end m. After remaining a short space of time, a quarter or half a minute, draw them away from under the point, and take notice that the point does not touch the table, or any other conductor; then turn back the moveable plate of the large condensor; move the electrometer so that its plate does not touch the pin of the large plate, and then turn its moveable plate back; the gold leaf will remain undisturbed.

### Exp. 212.

Turn up the condensing plates to their first position; place the two instruments together as before, taking particular care that the fixed plate of the electrometer condensor touch the pin proceeding from the large plate. Lay upon the pieces of metal before used, a piece of woollen cloth, well soaked in a solution of muriate of ammonia, or any other liquid commonly used for galvanic experiments, either upon the zinc or the copper, and push them under the point of m again. Press the point down upon them, that it may be perfectly in contact; after they have remained the time before-mentioned, draw the metals away, and separate or turn back the large condensor plate, and also the small one, after separating it from the pin of the large one, and immediately the gold leaf will diverge—if the zinc be uppermost, then the gold leaf will diverge with positive electricity; but if it be underneath, the gold leaf will diverge with negative electricity. It makes no difference in the general effect, upon which metal the wet cloth was laid; or whether two pieces of cloth were used, one under the metals and the other above; or only one, either above the metals or under them. But if the cloth be only laid upon the copper and not upon zinc, the electric fluid brought into action will be so weak, that the combined instrument can hardly shew it: if laid upon the zinc, the divergency will be about one fortieth part of an inch; sometimes more and sometimes less.

*To shew the Power of the Charge of a Leyden Phial by the combined condensors, when charged by a Galvanic Trough.*

EXP. 213.

After combining the condensors as above, cause the inside connexion of the phial, charged as in experiment 210, to touch the insulated plate of the large condensor, and perform the operation of opening as in the last experiment, and the gold leaf will shew the degree of the charge. If the phial had been charged by a pile of 20 or 30 pairs, the gold leaf will shew it without the help of the condensing plates.

*Electricity excited by touching and separating two Metallic Plates, one of Zinc and the other Copper, is the basis on which Sig. Volta's Theory of Galvanism rests.* (Nicholson's Journal, octavo, vol. II, page 281.)

### Exp. 214.

Take two metallic plates, about four inches diameter, one of copper and the other of zinc, both being provided with insulated handles, —hold the copper in the hand, and lay the zinc upon it; take the zinc off from the copper by its insulating handle, and it will be found to be positively electrified and the copper negatively. To prove this both the condensor and condensing electrometer must be used; when they are properly combined, and the zinc taken off from the copper by its glass handle, touch the insulated plate of the condensor with the zinc plate; if the atmosphere be favourable, once touching will be evident, and if touched ten or twelve times it will be more so—then separate the condensing plate and the gold leaf will diverge with positive electricity; if the copper plate be taken from the zinc by its glass handle, and the condensor touched by it, it will be found to be negatively electrified.

*The electricity of Zinc and Copper is more evident when one is reduced into Filings, and sifted through holes made in the other.*

EXP. 215.

Let a copper plate be bent a little concave and several small holes drilled through it; lay some zinc filings upon it and sift them through the holes, letting them fall upon a plate of metal, upon the top of the condensing electrometer, while sifting, the gold leaf will diverge without the help of the condensing plates, and will be found to be positively electrified; if copper filings are sifted through zinc, the electrometer will shew negative signs, which correspond with the plates, but is much more evident. This last experiment was invented by Mr. Wilson for another purpose (see Nicholson's Journal for January, 1805); but it is in fact the same experiment as the zinc and copper plates, only its application is different; it is the touching and separating of the plates that excites the electricity in them; and in this the office of touching and separating is performed, and multiplied as each particle of zinc, which has passed through the copper sieve has performed the office of touching while passing through the hole in the sieve, and separating when passed and fallen upon the electrometer, or any insulated plate connected to it, where it deposits its surplus of electricity, consequently must be much more evident than when performed by two single plates. It is not only zinc and copper that has this property, but all bodies, whose natural capacity for electricity are different, have the property of exciting the electricity in them, when applied together, under such circumstances as the nature of electricity requires. This appears to me to be one cause of the action of metallic galvanism, and that Signior Volta's theory may be well founded, though some of his explanatory experiments appear to be faulty.

*Some remarkable and distinguishing properties between Metallic Galvanism, and Electricity.*

When iron wire is ignited by a common electric discharge, in such a degree as just to produce a red heat the whole length, the discharge is accompanied with a loud explosion, and the red heat produced in the wire, lasts no longer than the body of metal can contain that heat; but when produced by a galvanic discharge, no explosion happens, and the red heat that is caused, continues for a sensible length of time longer than when it is caused by an electrical explosion. This proves, that a current of galvanic fluid follows the discharge. In the above experiment care must be taken not to have the charge in either so powerful as to convert the wire into globules.

Deflagration of iron wire may be produced by galvanism, as well as by common electricity, so far as to produce globules, but the difference is, that an electric discharge will disperse the globules to a great distance, which does not happen by galvanism.

An electric discharge can convert iron and other metallic wires into an impalpable powder, so as to float about in the air, which cannot be done by galvanism.

Common electricity charges coated glass, and so does galvanism, but in a very inferior degree. Though not universally allowed there is no doubt of this fact.

Galvanism decomposes water and several other fluids; so does electricity, but in a very inferior degree.

A double quantity of galvanic fluid in the form of a discharge, can only ignite double the length of wire, but a double quantity of electricity in the same form will ignite four times the length of wire.

When water is to be decomposed by electricity, exp. 125, it makes no difference whether both the wires which produce gas, be connected with both conductors of the machine or not; if a good conductor continued to the ground be connected to the hydrogen wire, it will answer equally well; but, when water is to be decomposed by galvanism, exp. 202, both the gas producing wires must be connected to their respective ends of the trough.

When water is to be decomposed by electricity, as small a portion of metal as possible must be opposed to the water, and, by galvanism long projecting wires are required.

The quantity of electric fluid given out by a galvanic trough, when compared to the quantity given out by an electrical machine is worth attention.

The deflagration of charcoal, Exp. 209, has never been effected by common electricity.

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Pl. 1

Fig: 1.

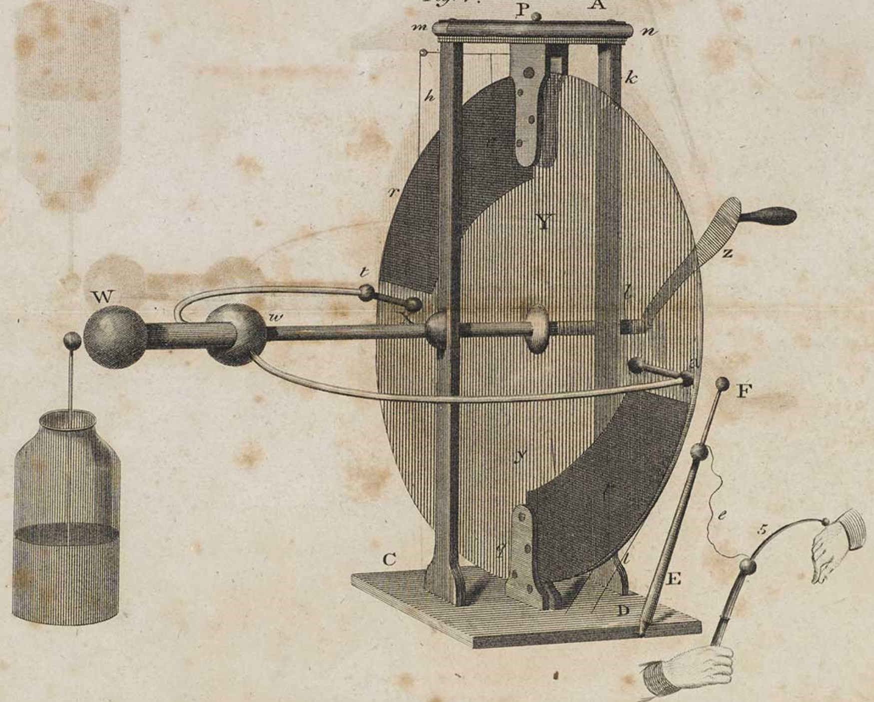


Fig: 3.

Fig. 2.

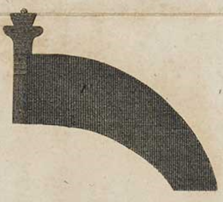

Fig: 4.

a  b

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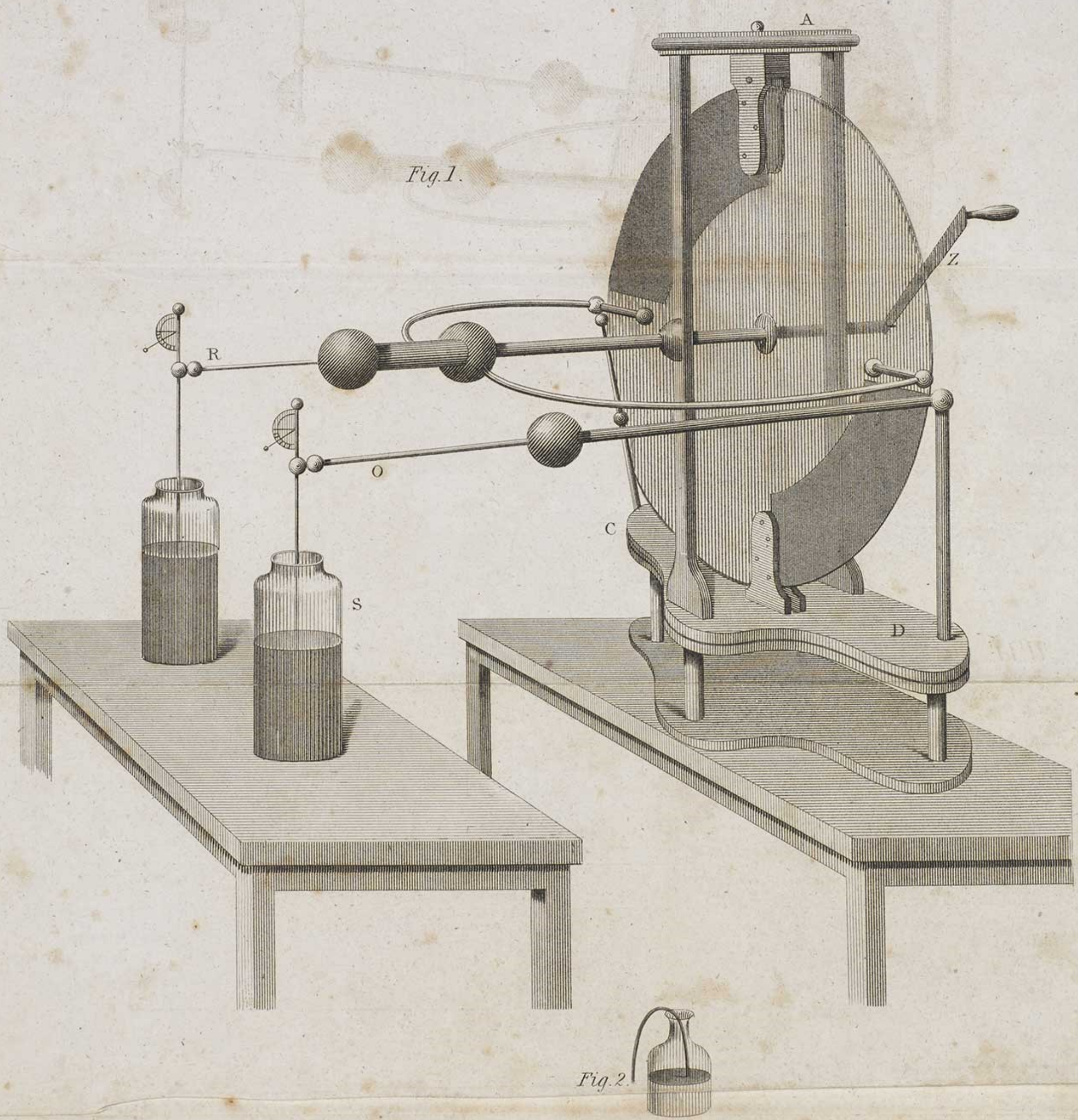

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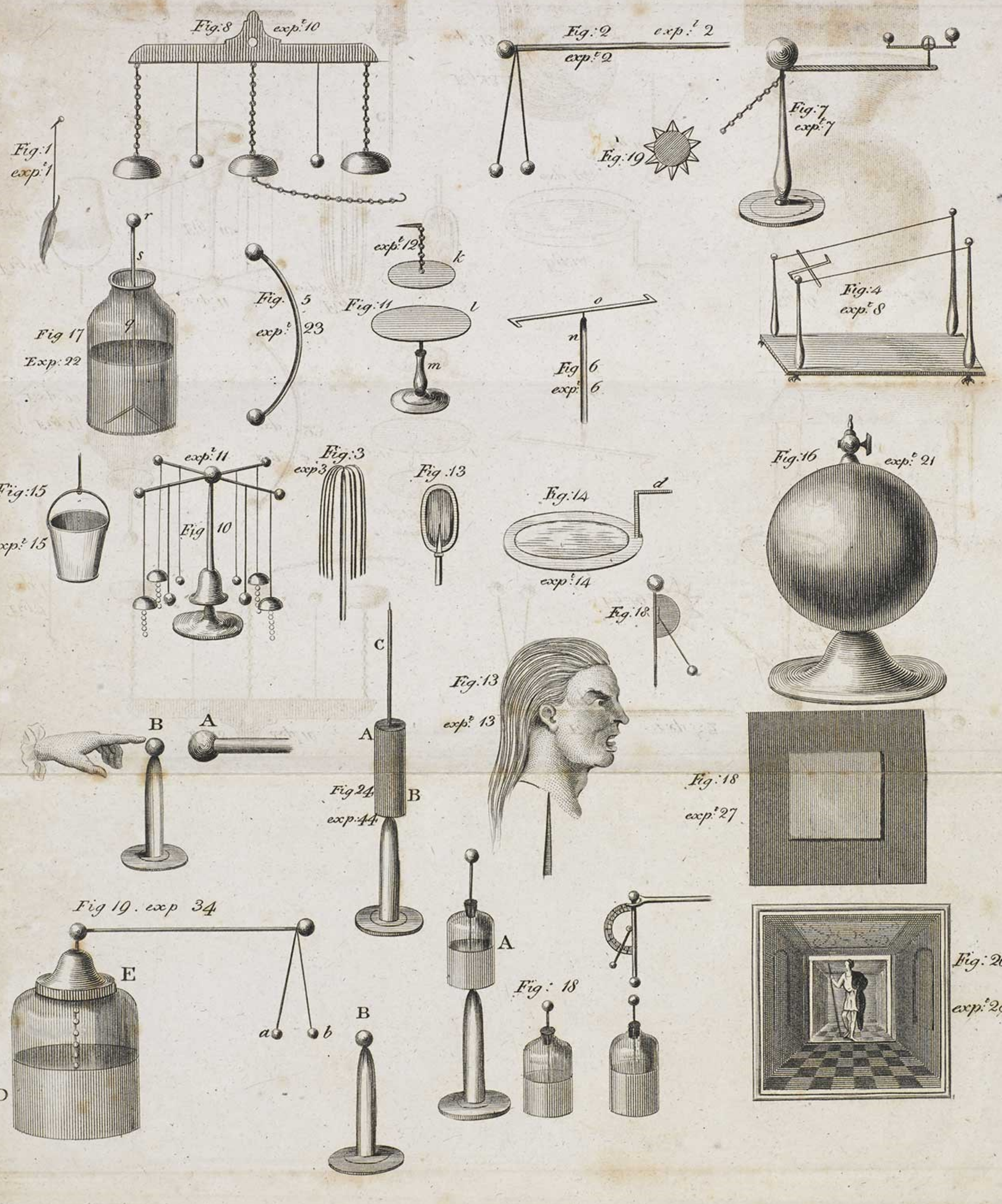


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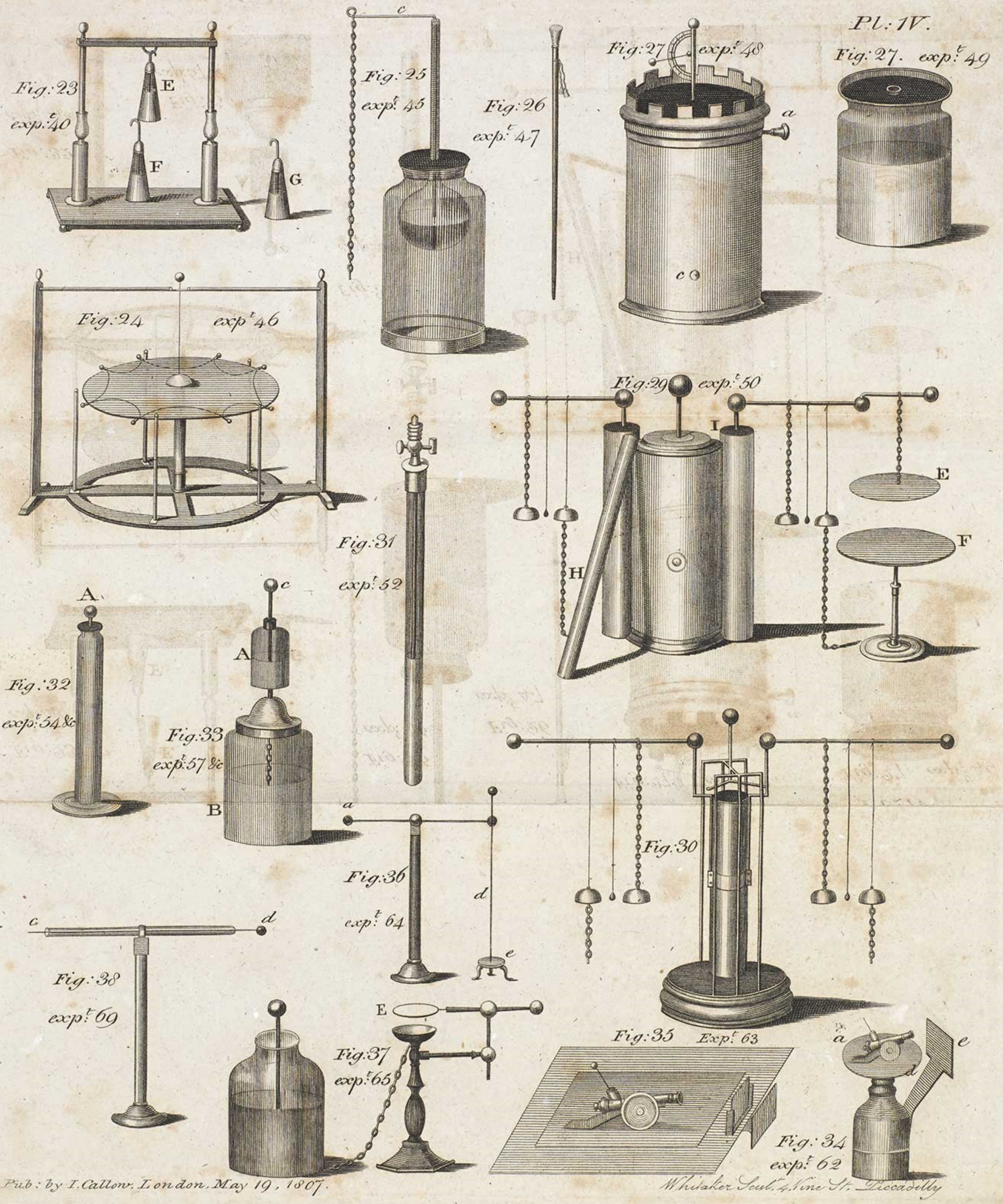


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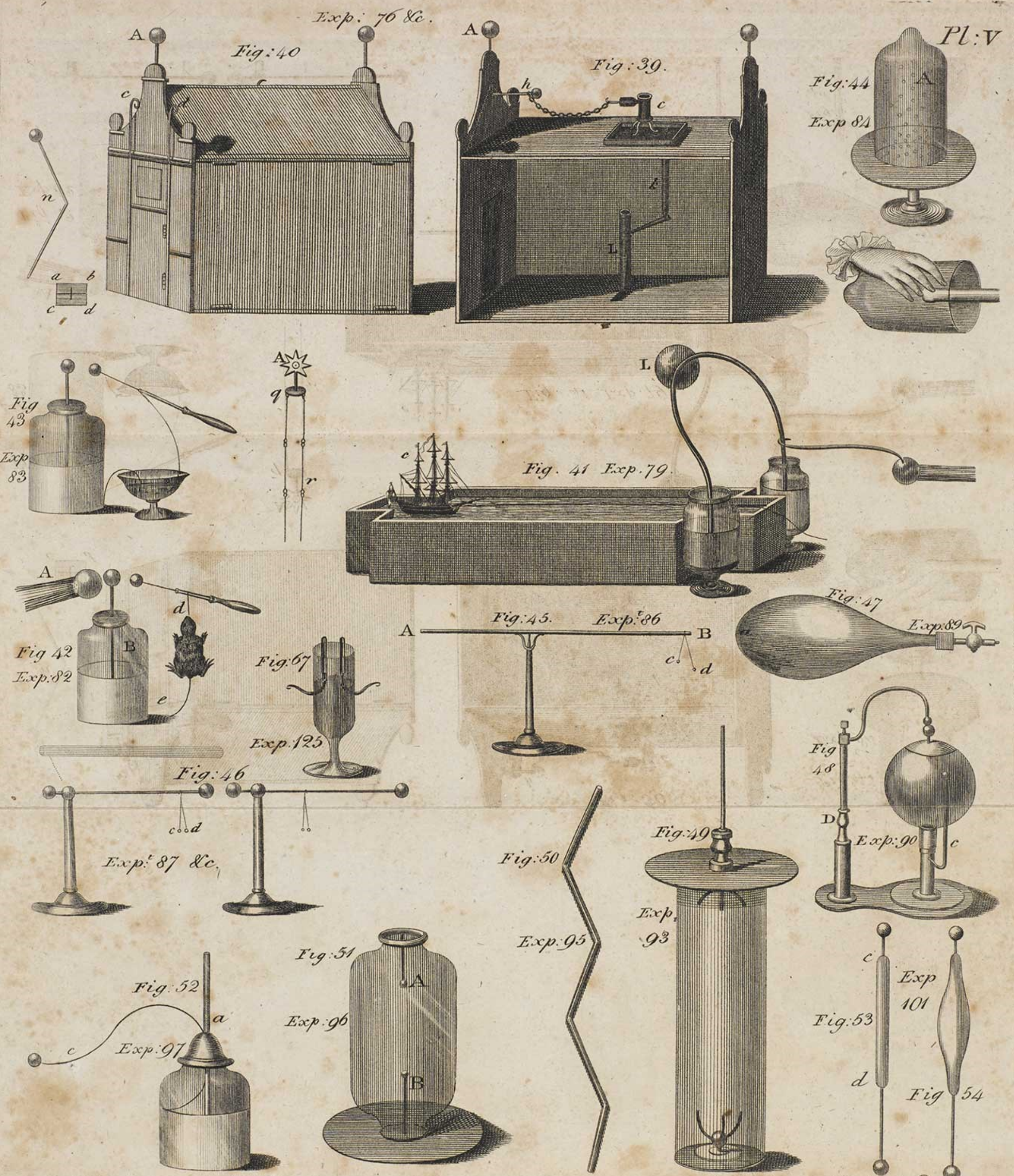


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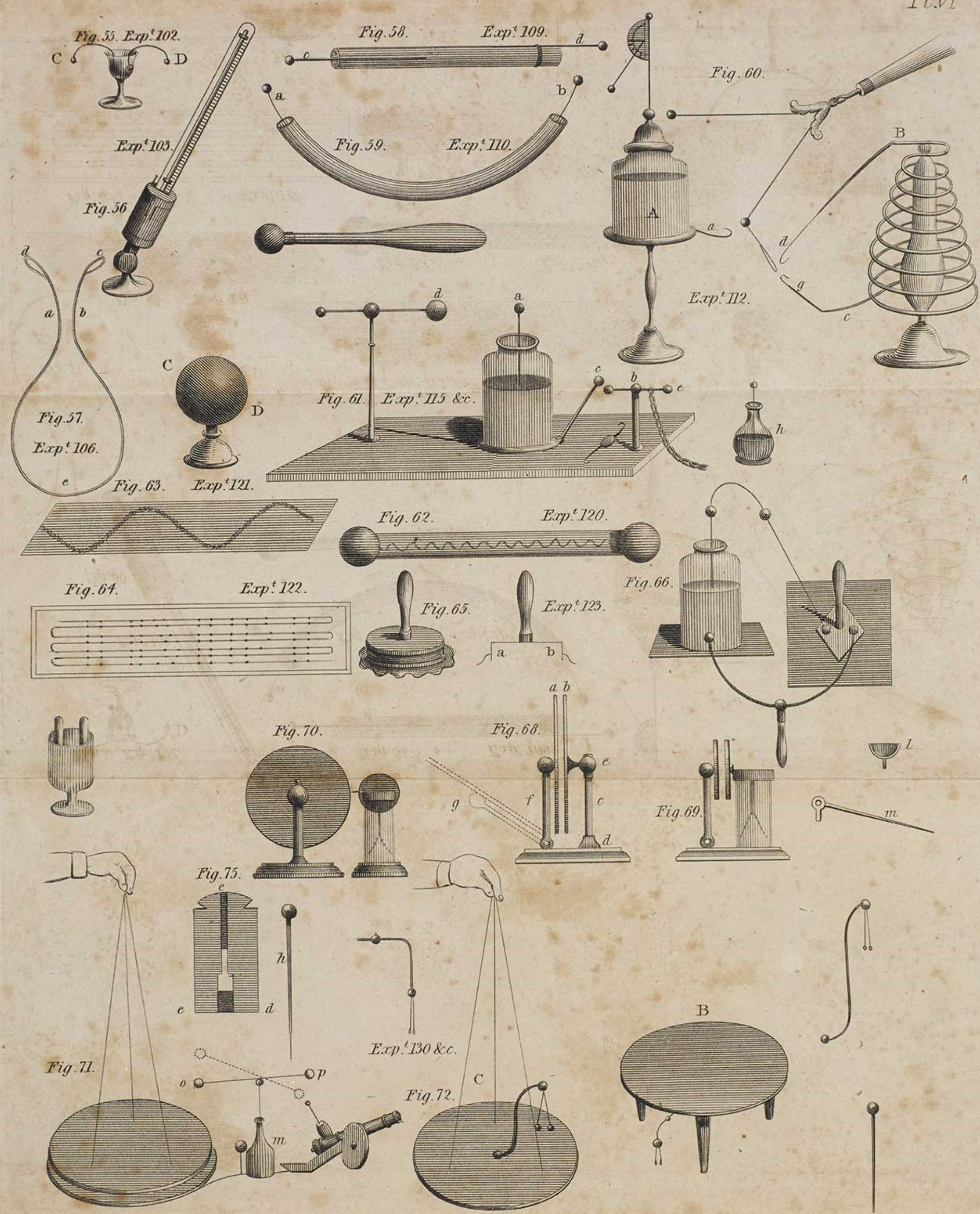
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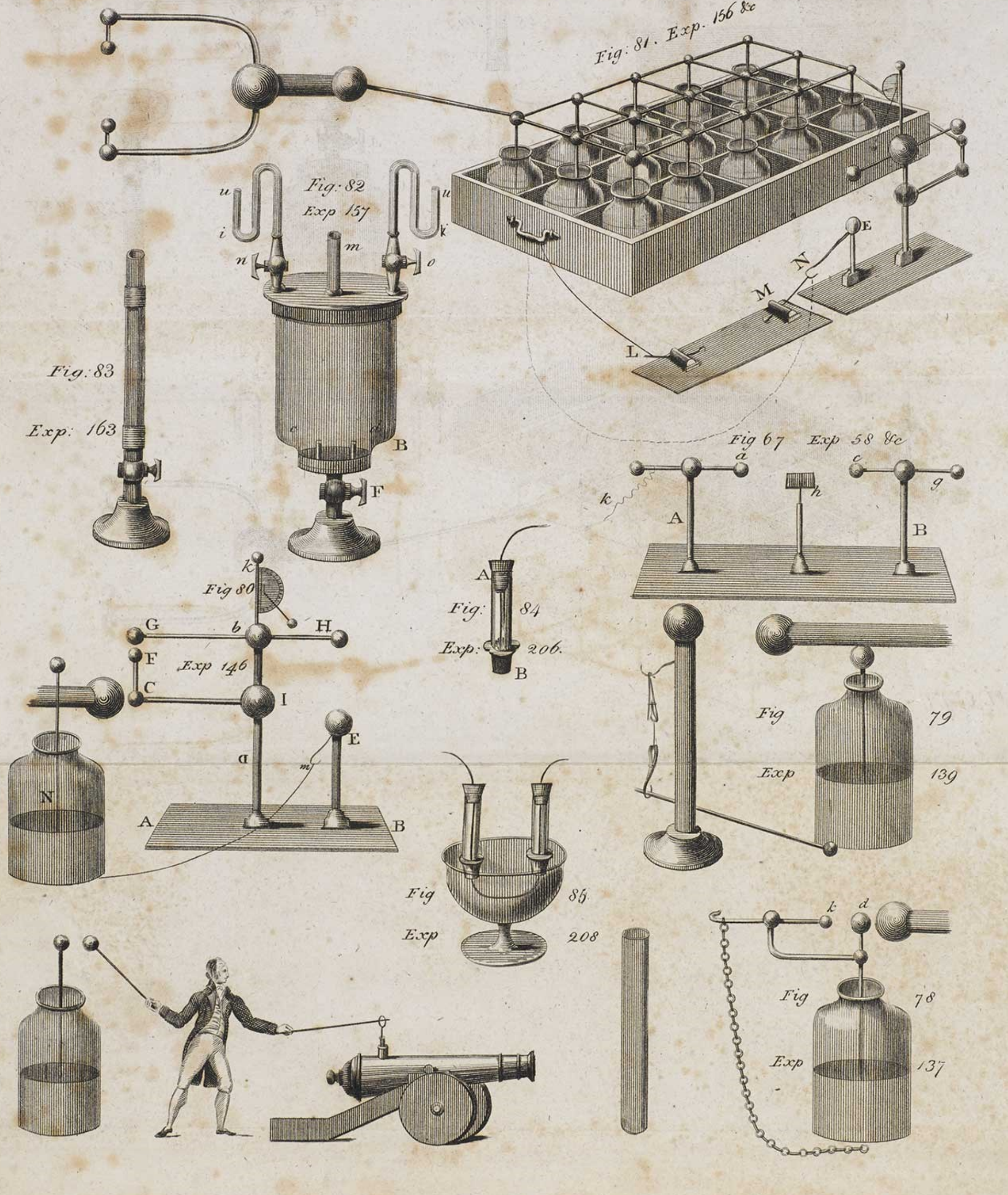


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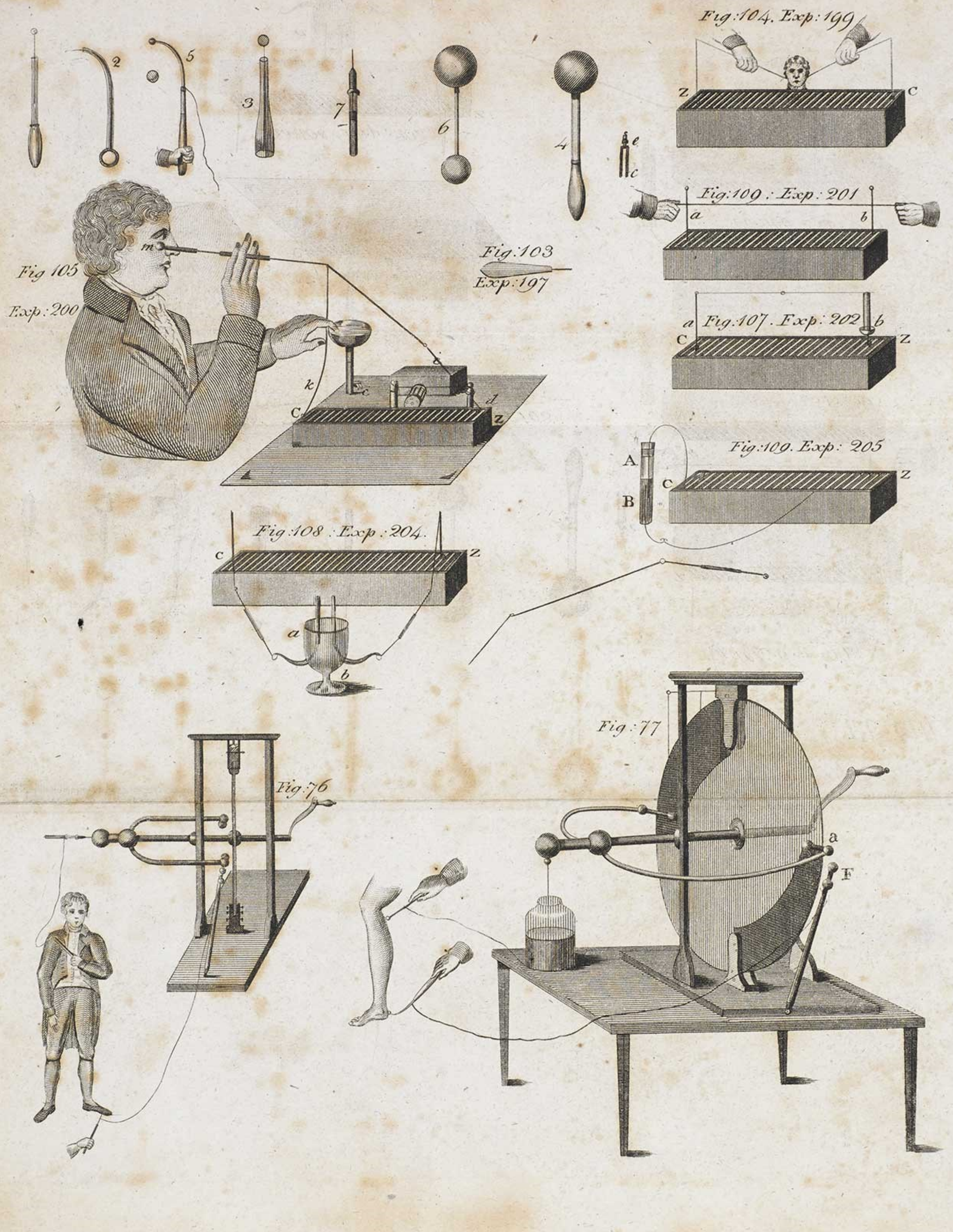


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