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A
BRIEF EXPOSITION
OF
THE SCIENCE
OF
MECHANICAL ELECTRICITY.

SUBSIDIARY TO THE
COURSE OF CHEMICAL INSTRUCTION

IN THE
University of Pennsylvania,
WITH ENGRAVINGS AND DESCRIPTIONS OF THE APPARATUS EMPLOYED.

BY
ROBERT HARE, M.D.
PROFESSOR OF CHEMISTRY.



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PREFACE.

A Knowledge of Electricity, a fundamental part of Modern Chemistry. Propriety of giving precedence to Electricity in a Chemical course; and of treating of Caloric, and Light, next in succession.

At the period when the medical school, in which I have the honour to hold the chemical professorship, was founded, the science of chemistry extended to little more than a knowledge of some acids, alkalies, earths, and salts, of which the most important ingredients were unknown. Even the composition of atmospheric air, and of water, was not understood; the existence of the all-important elements, oxygen, hydrogen, and nitrogen, not having been detected. The discovery by Dr. Black, of the latent agency of heat, was the first step in a department of our science, which at this period occupies, in a course of chemical lectures, a large portion of the time. The discovery of the same great chemist that atmospheric air was not to be considered as a fluid *sui generis*—that there might be more than one kind of air; by leading to a knowledge of the gases, added another topic, which, in all its bearings, practical and theoretical, may be considered as no less entitled to attention, than the material cause of heat.

The invention of the Voltaic pile, and the employment of its wonderful powers in effecting chemical decomposition, besides leading to a knowledge of many

chemical facts and agents, connected, either in theory or practice, the whole science of electricity, whether galvanic or mechanical, with chemistry.

To these topics have latterly been added the electromagnetic properties of matter; which by their association with electricity, with a power of chemical decomposition, and of giving shocks to the animal frame, force themselves upon the attention of the chemist and physiologist.

Both the theory and nomenclature of our science, are at present grounded upon the electrical habitudes of chemical agents. Under these circumstances, a knowledge of galvanic and mechanical electricity is of fundamental importance; and to impart this knowledge, where it has not to a sufficient extent been made part of the student's previous education, should be a preliminary object. I now therefore consider it expedient to deliver those lectures on electricity, at the commencement of my course, which were heretofore delivered at the termination, from the idea sufficiently authorized at the period of its adoption, that in chemistry electrical knowledge was auxiliary, not fundamental. I am encouraged in pursuing this order, and in treating electricity, galvanism, and electromagnetism,* as objects meriting attention in a medical school, by the fact, that all of them are occasionally employed as medical remedies. The question whether or not to resort to them, will often be presented to the practitioner, who consequently ought not to be ignorant of their nature, or the means necessary to their application, however their influence on the vital functions may be involved in doubt and obscurity.

I shall assign to caloric the second place in my work,

* Of the time employed in my course, I allow only one-eighth to electricity and galvanism, and at *most* about one-thirty-second part to electromagnetism

and to light, the third. Thus the illustrations of the three imponderable agents, whose existence is generally admitted by chemists, will be exhibited in immediate succession, and the diversity of their features rendered more striking by their proximity.

There are additional reasons for giving precedence to these imponderables. There is no other science which stands so much by itself, as that of electricity, or which requires so little preliminary knowledge to render it intelligible. This remark applies more particularly to that portion of the science, which is necessarily first treated of; being usually designated as mechanical, in contradistinction to Voltaic electricity. The same remarks are to a great extent applicable in the case of caloric, and that of light; and I shall treat of these principles in succession next to electricity, not only in obedience to considerations which have been stated, but on account of the interesting illustrations with which, in treating of caloric, we are enabled to allure the attention of beginners, without reference to subjects yet untaught, or the use of agents of which they are ignorant.

CONTENTS.

	Page
<i>History of Electricity</i> - - - - -	1
<i>Electricity experimentally illustrated</i> - - - - -	4
<i>Order pursued in the experimental illustration of Electricity</i> - - - - -	5
<i>Generic description of the Electrical Machine</i> - - - - -	5
1.—Description of an electrical plate machine - - - - -	6
2.—Electrical machine with a plate four feet in diameter - - - - -	7
3.—Engraving and description of an electrical cylinder machine - - - - -	7
<i>Of the usual means of producing Electricity</i> - - - - -	7
4.—Experimental illustration - - - - -	8
<i>Of the communication of Electricity</i> - - - - -	8
5.—Experimental proofs that electricity does not pass from one part of an electric to another, through or by means of an electric - - - - -	9
6.—Peale's experiment - - - - -	9
7.—Modification of Peale's experiment - - - - -	10
8.—Additional illustration - - - - -	11
9.—Experimental proofs that metals, charcoal, moisture, flax, or hemp, are conductors of electricity, and that sulphur, resins, glass, silk, and wool, are non-conductors - - - - -	11
<i>Of different kinds of Electricity</i> - - - - -	12
10.—Description of Bennet's gold leaf electrometer - - - - -	13
11.—Experimental illustrations - - - - -	13
<i>Of Electric Poles.—Of Electric Circuits</i> - - - - -	13
<i>Means of accumulating Electricity</i> - - - - -	15
12.—Experimental illustrations - - - - -	16
13.—Coated pane - - - - -	16
14.—Of the Leyden jar - - - - -	17
15.—Of the common discharger - - - - -	17
16.—A charge is imparted, equally well, by the contact or communication of either coating with either conductor - - - - -	18
17.—Experimental proofs that the different surfaces of a charged electric are oppositely electrified - - - - -	19
18.—Chime of bells - - - - -	19
Metallic coatings of use in conveying the charge—but it does not reside in them - - - - -	20
19.—Pane with moveable coatings - - - - -	20
20.—Glass vessel so situated that water is made to perform the same office as metallic coatings in the Leyden phial; illustrating the original experiment of Cuneus and Mushenbroeck - - - - -	21
21.—Experimental demonstration that the charge of a Leyden jar does not reside in the coatings - - - - -	21
<i>Of Electrical Batteries</i> - - - - -	22
22.—Of an electrical battery of 32 jars, each 13 inches in height, and 5 inches in diameter - - - - -	23
23.—Description of Henley's universal discharger - - - - -	23
24.—Battery discharger for deflagrating wires - - - - -	24

	Page
<i>Of Electrical excitement by induction</i> - - -	25
25.—Apparatus for the illustration of electrical induction - - -	25
26.—New apparatus for the illustration of electrical induction - - -	25
<i>Means of detecting or measuring Electricity</i> - - -	27
27.—Description of the condensing electrometer - - -	28
28.—Description of the single leaf electrometer - - -	28
29.—Description of Henley's quadrant electrometer - - -	29
29½.—Of Coulomb's electrometer - - -	30
<i>Of the effects of Electricity</i> - - - - -	31
<i>Of Electrical Attraction</i> - - - - -	31
30.—Revolution of a sun, planet, and satellite - - -	31
31.—Electrical tree - - - - -	32
32.—Electrical hail - - - - -	33
<i>Electric Light illustrated</i> - - - - -	33
33.—Experimental illustration of the egress and access of the electric fluid during the charging and discharging of coated surfaces as rendered evident by means of a discontinuous coating of metallic filings - - -	33
36.—Long zigzag or erratic spark, contrasted with the short straight spark - - -	35
37.—Of the electrical brush - - - - -	36
38.—Globe, illuminated panes, and tubes - - - - -	37
39.—Illuminated columns - - - - -	38
40.—Carreaux etincelantes, (sparkling panes) - - - - -	38
41.—Illuminated eggs - - - - -	39
<i>Electric Light in vacuo</i> - - - - -	39
42.—Aurora borealis - - - - -	39
<i>Electrical Ignition experimentally illustrated</i> - - - - -	40
43.—Ignition of cotton by the electric spark - - - - -	40
44.—Inflammation of ether by the electric spark - - - - -	40
45.—Ignition of inflammable matter by the electric spark.—Ignition of hydrogen with oxygen - - - - -	41
<i>Of mitigating the effects of Electricity</i> - - - - -	41
Of the proper mode of constructing, and putting up, lightning rods - - -	42
46.—Experimental illustration - - - - -	43
<i>Additional means of producing Electricity</i> - - - - -	43
Of the electrophorus.—Of electricity evolved by the friction of caoutchouc, by pressure, by chemical changes, and by the contact of heterogeneous metals - - - - -	43
47.—Of the electrophorus - - - - -	43
Evolution of electricity from caoutchouc by friction - - - - -	44
Of electricity evolved by pressure - - - - -	44
48.—Evolution of electricity from caoutchouc by pressure - - - - -	44
<i>Theoretical Explanation of Electrical Phenomena</i> - - - - -	45
Of the theory of two fluids - - - - -	45
Additional remarks explanatory of Franklin's hypothesis - - - - -	46
Rationale of electric light and ignition - - - - -	47
49.—Means of Electrifying a Patient with Sparks - - - - -	47
50.—Apparatus for Electrifying a Patient by Shocks - - - - -	48

LECTURES

ON

ELECTRICITY.

A BRIEF HISTORY OF ELECTRICITY.

AN attractive power is acquired by resins, sulphur, glass, and a variety of other substances, when rubbed; and if the masses, thus excited, be sufficiently large, the phenomena of light, of mechanical concussion, and ignition, may result; and even a feeble imitation of thunder and lightning.

As it was in amber, in Greek called *Electron*, that the attractive power, arising from friction, was first observed; the principle to which it was ascribed, was called Electricity; and all substances, in which it could be produced, Electrics.

We are informed, that Thales, of Miletus, who flourished six hundred years before Christ, was so much struck with this effect of the friction of amber, as to imagine that it might be endowed with animation. Subsequently, it was ascertained, that the attractive power, which had been observed in amber, when subjected to friction, might be produced, by the same means, in other resinous substances; and, in the tourmaline, or lyncurium, as it was then called, by exposure to heat.

No further progress was effected in electrical knowledge, until the seventeenth century, when after considerable additions had been made to the catalogue of electrics by Gilbert and Boyle, Otho Guericke discovered

that light and sound might result from electric excitement. His observations were made by means of a globe of sulphur, cast in a glass vessel which was fractured to extricate the casting. Little was it suspected by the ingenious operator, that the glass globe, thus broken, would have answered better for the purpose in view, than the globe of sulphur, in the moulding of which it was sacrificed.

The discovery of the usefulness of glass, as a mean of producing Electricity, appears to have been made by Hawkesbee, who wrote in 1709. To Grey, who followed Hawkesbee, we owe the remark, that the electrical excitement of glass, and other electrics, was communicable to other bodies, when insulated, not only by direct contact, but by wires or threads of great length; and by this Electrician, in conjunction with another named Wheeler, it was first observed, that this property, of conducting the electric virtue, while belonging to flax or hemp, did not belong to silk; also, that by the class of bodies, in which Electricity can be excited, it cannot be conducted; whilst in those by which it may be conducted, it cannot be excited. Thus were two classes of bodies distinguished; one as electrics, or non-conductors; and the other as non-electrics, or conductors.

It was ascertained, however, that a conductor, if supported by a non-conductor, might receive the electric virtue from an excited electric. A conductor, so supported, was said to be *insulated*.

Du Faye, soon after, ascertained the important truth, that there are two kinds of electrical excitement. One of these, being observed in glass, was called vitreous; and the other, resinous, because observed in resins. By the communication of either species of excitement, light bodies were made to separate from each other; but, the bodies excited by means of resins, were attracted by such as were excited by means of glass; and when these opposite excitements were made, in due proportion, in different insulated conductors; on bringing the conductors together, a neutralization, and of course an apparent annihilation, of the electricity in both, was the consequence.

The means of collecting the electric fluid, were, soon after, much improved in Germany; where sparks sufficient to kill birds, and ignite spirits and other inflammable

matter, were produced by the joint influence of several globes simultaneously excited.

In the year 1746, the Leyden phial was invented. Cuneus and Mushenbrœck, attempting to charge, with electricity, the water contained in a phial, a shock was experienced by Cuneus, who happened to touch the conductor with one hand, while grasping the phial with the other.

This phenomenon was soon after explained by Franklin. He had ascertained, that whenever either kind of electricity is communicated by friction to one body, the other kind will be created in the mass by means of which the friction is effected, provided it be insulated.

When a glass is rubbed by the hand, it takes electricity from the hand, and the person to whom it belongs. If standing on a non-conductor, the person will be electrified, at the same time that the glass which he rubs may, by contact, excite another body; but, then, the electricity of the person who rubs the tube, and that of the body to which he presents the tube, are of opposite kinds; the former being the resinous, the latter the vitreous electricity, of Du Faye. A stick of resin would cause the opposite result, producing vitreous electricity in the person rubbing it; and resinous, in a body touching the resin, subsequently to its exposure to friction.

These phenomena were thus accounted for by Franklin. Some bodies, (glass for instance) by friction, acquire additional power to hold the electric fluid; and hence draw it from the conducting body rubbing them, and give up the excess to any adjoining conductor, when the friction ceases. Resins, on the other hand, have their capacity for the electric fluid lessened, by rubbing; and hence, while subjected to this process, give it out to the rubber, and afterwards draw on any adjoining body, to supply their deficiency. Glass and resin, therefore, produce both kinds of electricity, which are merely the result of an accumulation, or deficiency, in an insulated body, of a fluid which pervades all nature. A conductor, charged in either way, will produce an electrical current, when presented to other bodies in connexion with the earth. In the one case, electricity will flow into the conductor; in the other case, it will flow out of it.

Franklin, also, discovered, that when an electrical stream is directed into a phial, situated like that of Cu-

neus, there is, at the same time, a stream proceeding from the outside; so that, in proportion as one surface gains, the other loses; and, accordingly, in a charged phial, one surface will be found vitreously, or redundantly, excited; the other, resinously, or deficiently; and a light body, after touching either surface, will be repelled by it, and attracted by the other.

He inferred, that there was only one electric fluid; to different states of which, the names of vitreous, and resinous, electricity, had been applied erroneously. The latter he called negative, the former positive, electricity.

Franklin, afterwards, identified lightning with electricity, by drawing this fluid from the clouds, by means of a kite; availing himself of a contrivance, which had previously been appropriated to juvenile recreation, to make a most sublime and useful discovery.

ELECTRICITY, EXPERIMENTALLY ILLUSTRATED.

The ingenuity of practical electricians, has given rise to a great number of contrivances, which amuse the spectator by producing some striking movements, or changes, consequent to electrical excitement. The various apparatus thus originated, has been treated too much as a mean merely of affording amusement. There is not a modification of electrical apparatus which is not dependent, for its appropriate effect, upon some property of the electric fluid, which it may consequently serve to illustrate.

I shall endeavour to use the various contrivances, above alluded to, in such order, and with such associations, as to make their employment contribute both to the amusement, and instruction of my pupils.*

* The student who aims merely at that general knowledge which may be required at his examination for a degree, is not obliged to study all the matter comprised in my text books. So far indeed am I from exacting attention to every topic thus comprised, that my motive for printing many engravings, descriptions, and some abstruse rationales, is to obviate the necessity of occupying much time with them, during my lectures. Yet there can be no doubt that a student, who will, before, or during the

ORDER TO BE PURSUED, IN THE EXPERIMENTAL ILLUSTRATION OF ELECTRICITY.

DESCRIPTION OF ELECTRICAL MACHINES.—OF THE ORDINARY MEANS OF PRODUCING ELECTRICITY.—COMMUNICATION OF ELECTRICITY.—DIFFERENT KINDS OF ELECTRICITY.—MEANS OF ACCUMULATING ELECTRICITY.—MEANS OF DETECTING ELECTRICITY.—EFFECTS OF ELECTRICITY.—ADDITIONAL MEANS OF PRODUCING ELECTRICITY.—THEORETIC EXPLANATION OF ELECTRICAL PHENOMENA.—ON THE QUESTION, WHETHER THERE BE TWO ELECTRIC FLUIDS, OR ONE ONLY.—MEANS OF ELECTRIFYING PATIENTS; EITHER WITH SPARKS, OR BY SHOCKS.

GENERIC DESCRIPTION OF THE ELECTRICAL MACHINE.

A description of the electrical machine, should be applicable to every apparatus which bears the name. I am unacquainted with any apparatus, designated as an electrical machine, which does not consist of an electric, so situated as to be conveniently subjected to a friction calculated to produce electric excitement; one, or more collectors, attached to a prime conductor properly insulated; and one, or more cushions, for rubbing the electric. The cushions, in the more perfect forms of the machine, are associated with another insulated conductor.

Experience has shown, that of all the electrics, glass is the best for the construction of electrical machines; and of all the possible forms, only two are much in use, those of the cylinder, and of the circular plate. In either case, the friction is produced by the rotation of a shaft occupying the axis of the cylinder, or plate, and fastened by screws or cement. The shaft or axis being secured in one or more collars like the mandril of a lathe, is turned by a winch, or by a band and wheels; which are so proportioned and arranged, as to quicken the motion. In cylinder machines, it is usual, besides the cushion, to have a silken flap, of which, one border is sewed to the edge of the cushion, so that it may extend from the cushion, till the other border approximates the collectors.

course, study them attentively, will be much better prepared to understand, with accuracy, the general truths which my apparatus is intended to illustrate; and it is but right, that those who prefer this accuracy of knowledge, from taste or ambition to excel, should have every facility afforded to them in making the effort.

I shall endeavour to indicate the relative importance of the matter by the size of the type.

Plate machines are sometimes furnished with silk flaps.

1. DESCRIPTION OF AN ELECTRICAL, PLATE, MACHINE;
the Plate mounted horizontally, and so as to show both Negative and Positive Electricity.

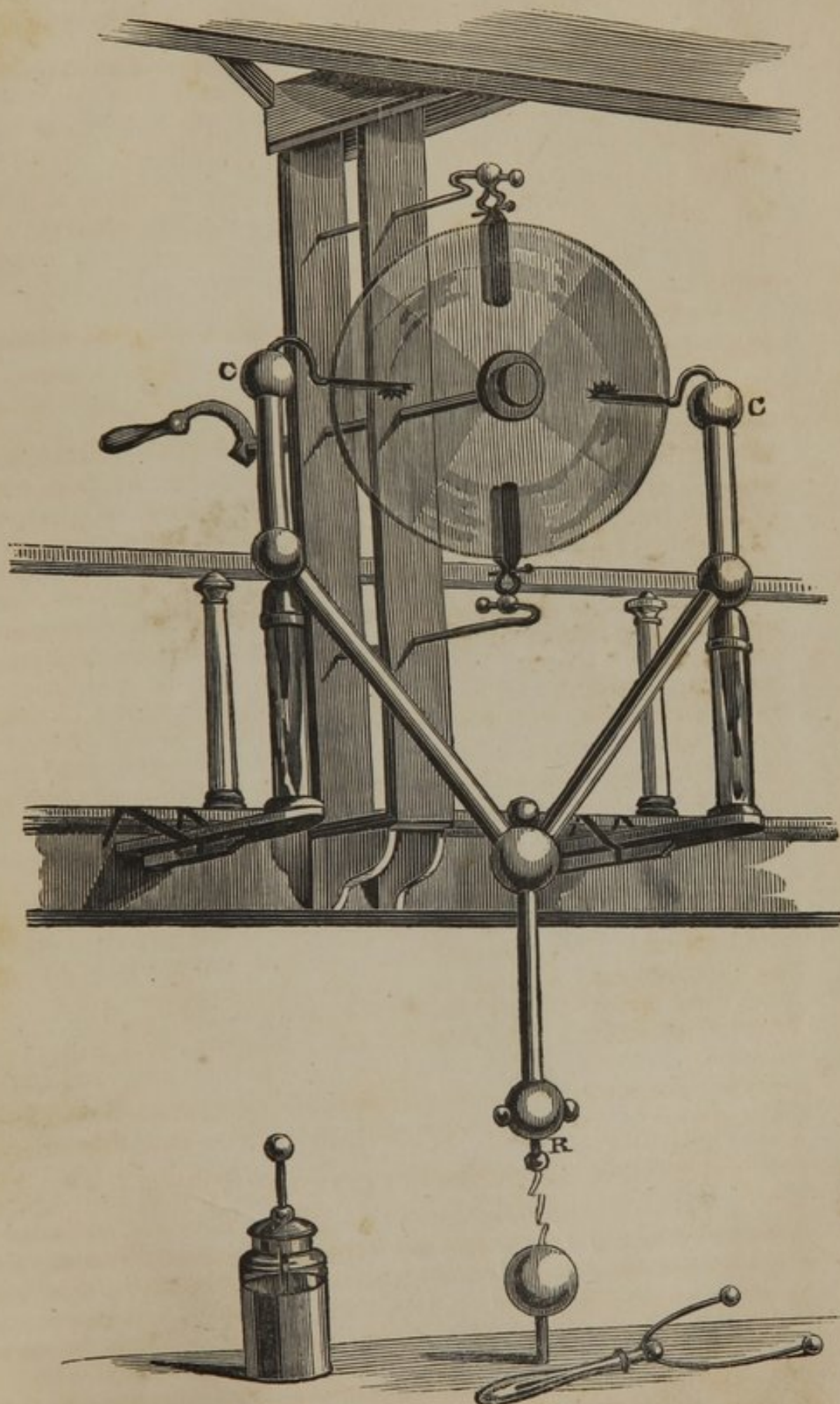
The power of Electrical Plate Machines, has been generally admitted to be greater, than that of machines with cylinders.—The objection to the former has been, the difficulty of insulating the cushions, so as to display the negative electricity.—Excepting the Plate Machine contrived by Van Marum, I have read of none in which this difficulty has been surmounted. It is still insisted upon, by respectable electricians, as if it had not been sufficiently removed by his contrivance.

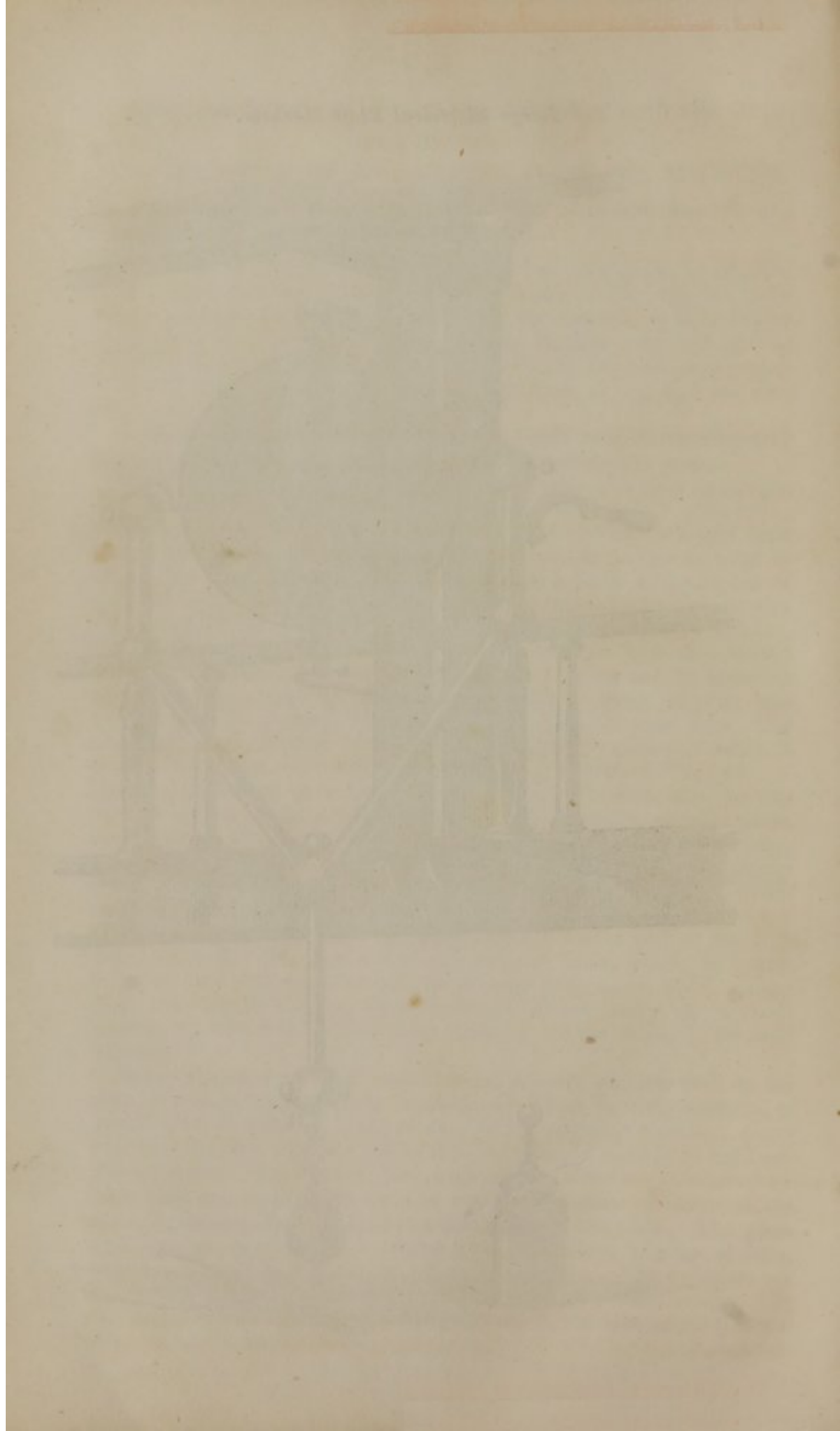
I shall now describe a Plate Machine, by which both electricities may be produced, and which I have used successfully for twelve years.

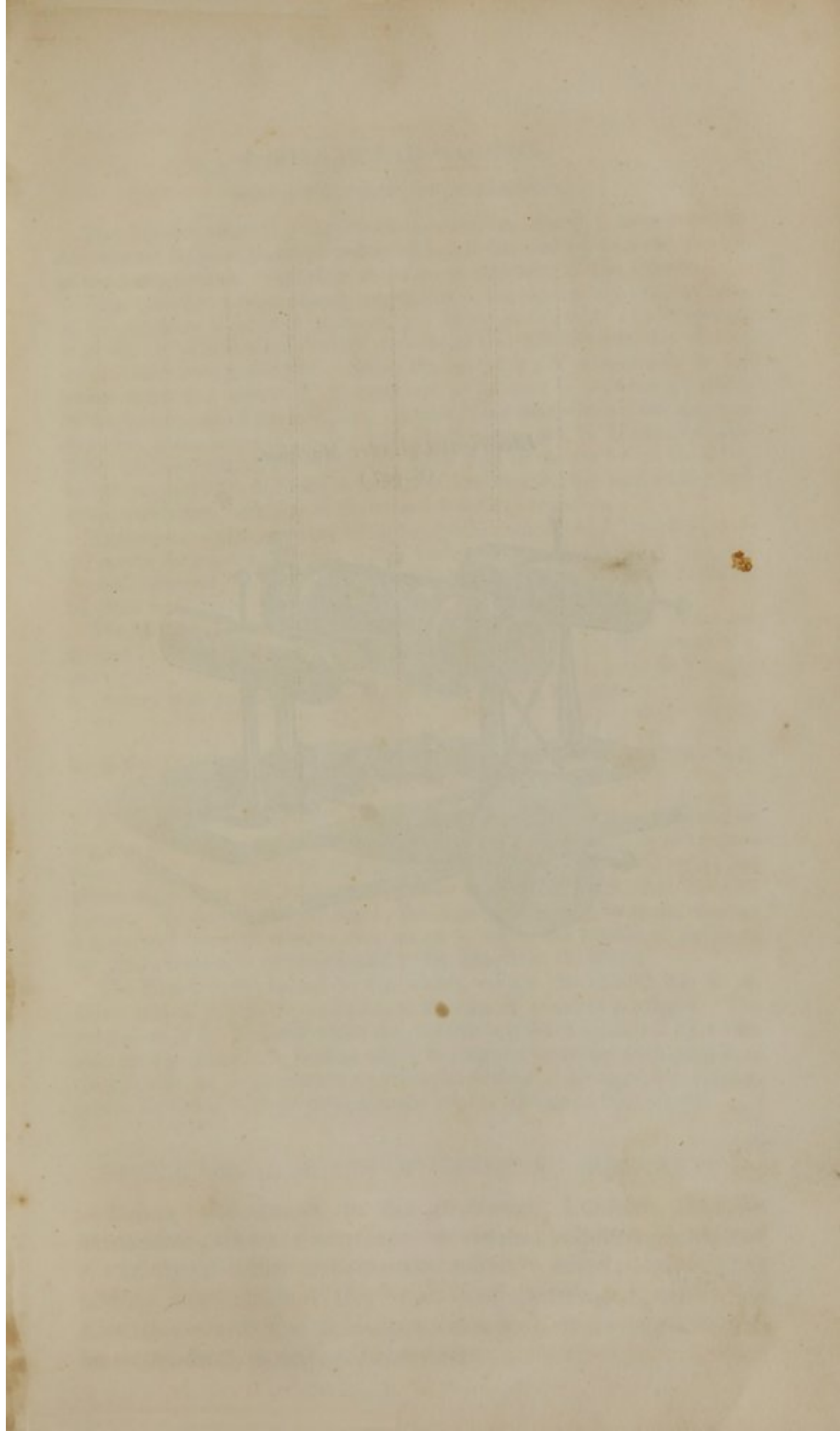
The Plate (thirty-five inches in diameter) is supported upon an upright iron bar, about an inch in diameter, covered by a very stout glass cylinder, four inches and a half in diameter, and sixteen inches in height, open only at the base, through which the bar is introduced, so as to form its axis. The summit of the bar is furnished with a block of wood, turned to fit the cavity, formed at the apex of the cylinder, and cemented therein. The external apex of the cylinder is cemented into a brass cap, which carries the plate. The glass cylinder is liable to no strain. It is only pressed where it is interposed between the block of wood within, and the brass cap without. The remaining portion of the cylinder bears only its own weight, while it effectually insulates the plate from the iron axis. The brass cap is surmounted by a screw and flange—by means of which, a corresponding nut, and disks of mahogany, the plate is fastened. A square table serves as a basis for the whole. The iron axis, passing through the top of the table, is furnished with a wooden wheel of about twenty inches diameter, and terminates below this wheel in a brass step, supported on a cross of wood, which ties the legs of the table diagonally together. The wheel is grooved, and made to revolve by a band, which proceeds from around a vertical wheel, outside of the table. This external wheel has two handles; by means either of one or both of which it may be turned. It is supported on two strips of wood, which, by appropriate screws, may be protruded, lengthwise, from cases, which confine them from moving in any other direction. Consequently, the distance between the wheels may be varied at pleasure, and the tension of the band adjusted.

Nearly the same mode of insulation and support, which is used for the plate, is used in the case of the conductors.—These consist, severally, of arched tubes of brass, of about an inch and a quarter in diameter, which pass over the plate from one side of it to the other, so as to be at right angles to, and at a due distance from, each other. They are terminated by brass balls and caps, which last are cemented on glass cylinders, of the same dimensions, nearly, as that which supports the plate. The glass cylinders are suspended upon wooden axes, surmounted by plugs of cork, turned accurately to fit the space which they occupy. The cylinders are surrounded and secured below, by wooden rings screwed to the table. In this way, the conductors are effectually insulated, while the principal strain is borne by the wooden axes.

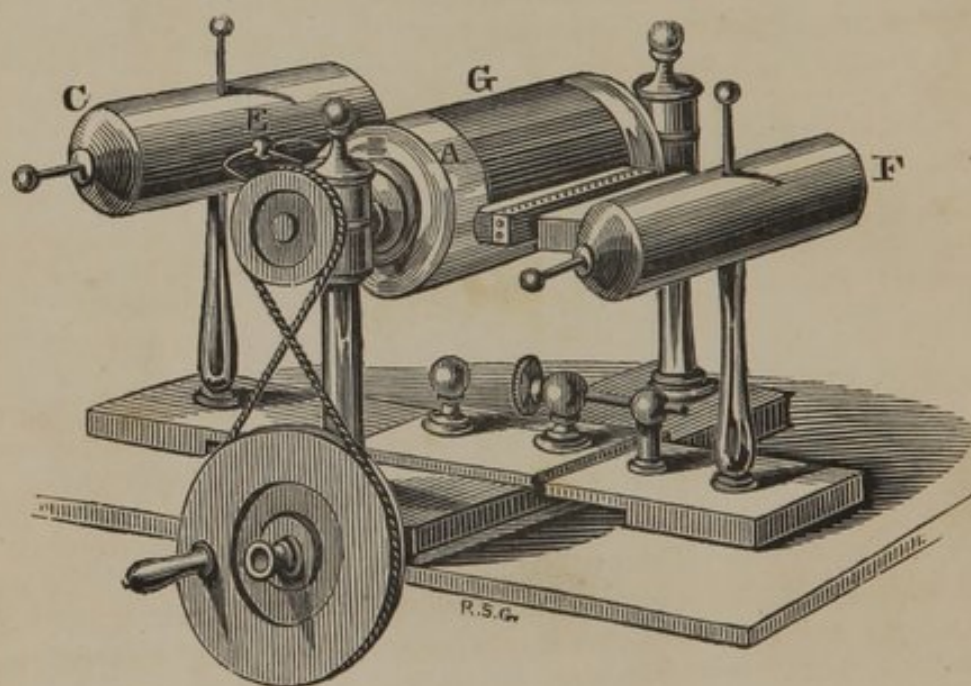
Large Electrical Plate Machine.
(E. p. 7.)







Electrical Cylinder Machine.
(E. p. 7.)



2. ELECTRICAL MACHINE, *with a Plate four feet in diameter.*

The opposite engraving represents a machine, which I have recently constructed so as to be permanently affixed to the canopy over the hearth of my lecture room. See plate at the commencement of this volume.

This situation I have found convenient even beyond my expectations, as the machine is always at hand, yet never in the way. In lecturing, with the aid of a machine on the same level with the lecturer, one of two inconveniences is inevitable. Either the machine will occasionally be between him and a portion of the audience, or he must be between a portion of the audience and the machine. Situated like that which I am about to describe, a machine can neither hide the lecturer, nor be hidden by him. With all its power at his command, while kept in motion by an assistant, he has no part of it to reach or to handle besides the knob and sliding rod of the conductor, which is in the most convenient situation.

The object of this machine being to obtain a command of much electrical power for experiments, in which such power is requisite, it was not deemed necessary to insulate the cushions and the axis, as in the horizontal plate machine.

The prime conductor is insulated upon the same plan, as those described in the last article. At C C, are the collectors. R, represents a sliding rod, which may be drawn out to such an extent, as to be brought in contact with any apparatus placed under it upon the table.

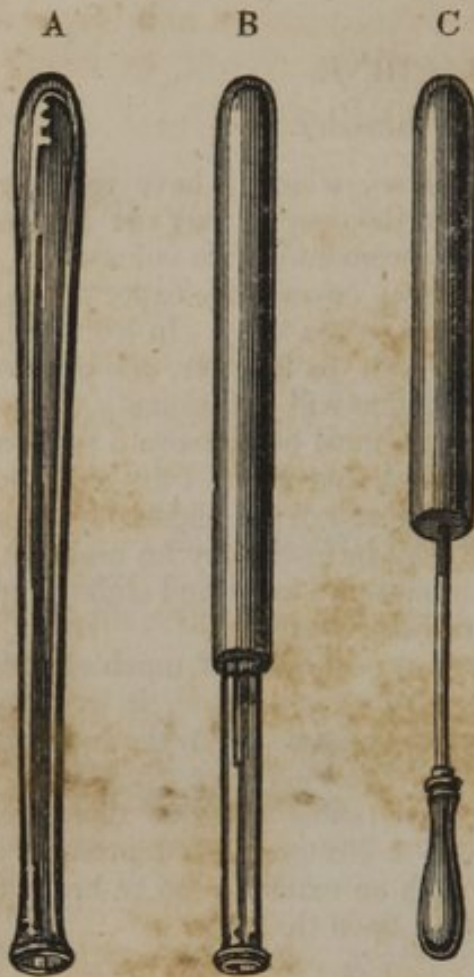
3. ENGRAVING AND DESCRIPTION, OF AN ELECTRICAL, CYLINDER, MACHINE.

A, the glass cylinder—C, the positive, or prime conductor, supported on a glass pillar—E, the collector with its points so projecting as to be quite near to the cylinder. The negative conductor F, is also upheld by a glass pillar, supporting the rubber or cushion to which the silk flap, G, is attached. By means of a set screw, the larger wheel may be made more or less remote from the smaller one, so as to adjust the tension of the band by which motion is communicated to the one, from the other.

The former being turned by the winch, causes the smaller one to revolve, and of course the cylinder, to the axis of which it is affixed. The revolution of the cylinder while the cushion is pressed against it by a suitable spring, causes the friction which is requisite to excite each portion of the cylinder as it successively passes the cushion. Each of the conductors is furnished with projecting brass knobs, whence to take sparks.

OF THE USUAL MEANS OF PRODUCING ELECTRICITY.

It has been stated, in the preceding Lecture, that an attractive power is acquired by resins, sulphur, glass, and a variety of other substances, when rubbed:—also, that bodies, susceptible of this species of excitement, are called *Electrics*—and the principle, on which it is supposed to be dependent, is called *Electricity*.



A, represents a glass tube.

B, a similar tube coated with shell lac, or sealing wax.

C, an iron rod, furnished at one end with a wooden handle, while throughout the greater part of its length, it forms the axis of a cylinder of sulphur.

Either of the instruments thus constituted, being rubbed, either with a silk handkerchief, a cat skin, or a leather coated with amalgam, will become sufficiently excited to attract leaf metal, and produce other indications of electricity. The amalgam and leather, can only be used advantageously with the glass.

4. EXPERIMENTAL ILLUSTRATIONS.

Friction of amber, glass, resin, sulphur. Large glass tubes rubbed—also, cylinders of sulphur and of resin. Thin metallic leaves attracted, at a considerable distance, either by the glass, the sulphur, or the resin.

Electrical machines put into operation.

OF THE COMMUNICATION OF ELECTRICITY.

The electric virtue cannot pass from one part of an electric which is excited, to another, without extraneous aid; nor can it pass off, from one electric, through any other.—Hence these substances are called non-conductors. Through metals, on the other hand, it escapes instantaneously. It passes with ease through flax or hemp, but not through silk. Water it pervades with great facility—or any thing which contains moisture.

Substances, which are thus capable of transmitting electricity, are called conductors; and are divided into perfect, and imperfect conductors. The metals are the

only perfect conductors. All other conductors are imperfect; and, at the head of this class, is charcoal, as being the best conductor of electricity, next to metals.

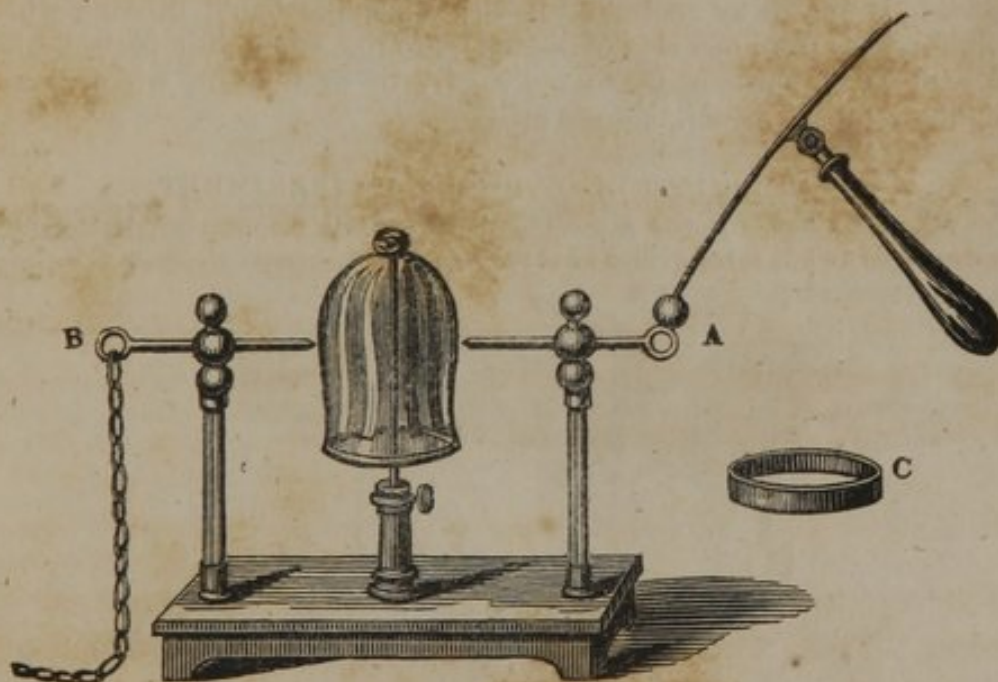
EXPERIMENTAL PROOFS, THAT ELECTRICITY DOES NOT PASS FROM ONE PART OF AN ELECTRIC TO ANOTHER, THROUGH, OR BY MEANS OF, AN ELECTRIC.

5. AN EXPERIMENTAL ILLUSTRATION.

One part of a cylinder of sulphur, or of glass, being excited by friction, so as to attract light bodies; another part, not being rubbed, is not found to attract them.

6. PEALE'S EXPERIMENT.

Among the multitude of electrical contrivances already alluded to, that which we owe, as I believe, to Mr. Franklin Peale, deserves more than ordinary praise for its simplicity of construction, and beauty of effect. One modification of Peale's apparatus is represented by the following engraving, which I shall proceed to explain.



A bell glass is balanced upon a pivot reaching internally to the apex, between wires supported on glass pillars. One wire A, communicating with the positive, the other, B, with the negative pole of the machine. Under these circumstances, if the machine be put into operation, the portion of the glass next to the wire A becomes positively excited, that near B, negatively excited. Consequently, agreeably to the general law that bodies similarly electrified separate, those dissimilarly electrified approach; each excited portion of the glass will move away from the wire similarly excited, and will seek that which is differently excited. Thus the excitements changing the situations of the excited parts, and their exchange of

situation reversing their excitements, a rapid movement must ensue, in the only mode in which it can take place freely, I mean that of a rotation on the pivot.

The bell is ornamented by strips of gilt paper, which renders the motion more sensible to the eye; but no coating is requisite to the appropriate effect—a bare bell glass is sufficient.

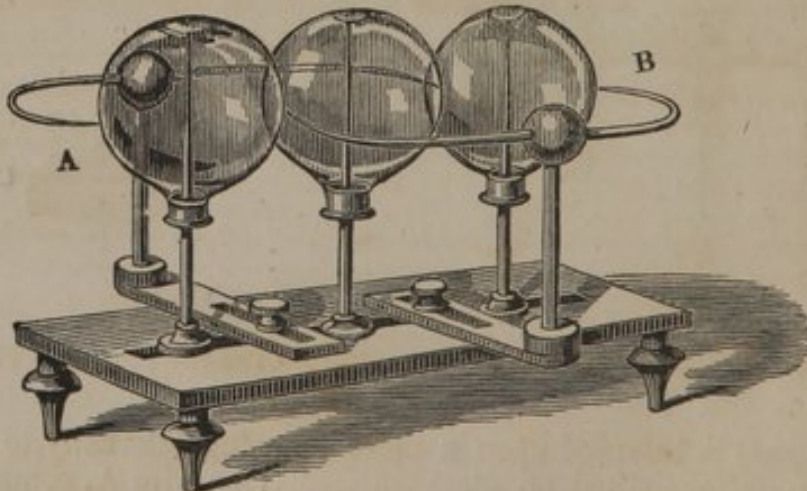
If the metallic band C be made to encompass the bell glass, it will be found incapable of receiving any motion from the electrical excitement. In fact, the electric fluid will be seen passing into it on one side, and passing out of it simultaneously on the other side; proving that it cannot, under these circumstances, retain any excitement, in consequence of the conducting power of the metallic band.

Mr. Peale's experiment was performed by means of a globular glass vessel with a short neck, or perforation for the admission of the pivot wire. The pupil will perceive that I have availed myself of this apparatus, to show that the electrical excitement communicated to one part of a non-conductor, does not extend itself to others; and that consequently in different parts of the same non-conducting mass, opposite kinds of electrical excitement may be produced. It is owing to this property, that the glass bell is put into motion. The electric fluid, being unable to pass along the glass, in its efforts to seek an equilibrium, it moves the glass along with it in consequence of an attraction arising between each wire, and that part of the glass which has a different excitement.

That the phenomenon owes its existence to the non-conducting power of the glass, is shown by encircling it with a metallic band, through which the fluid passes from one side of the glass to the other with perfect ease. Under these circumstances, that diversity of excitement, which would cause the rotatory motion, cannot arise.

7. MODIFICATION OF PEALE'S EXPERIMENT.

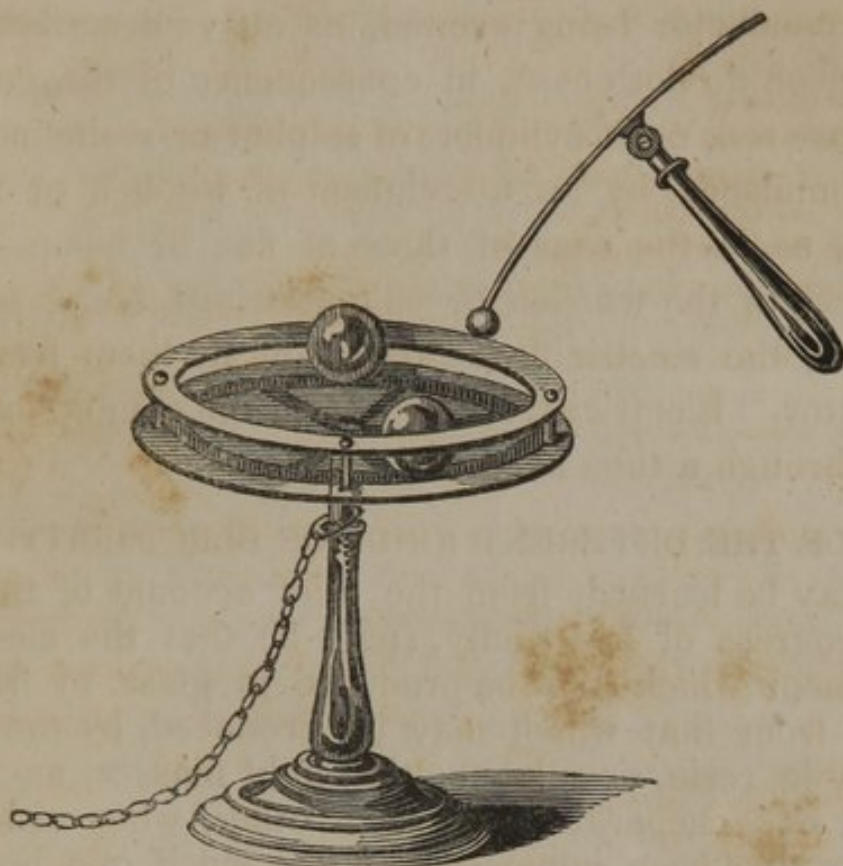
The following figure shows a modification of Peale's apparatus, by which I have contrived to put three globes in motion.



The arched wires, A, B, being severally connected with the different conductors of an electrical machine, cause opposite states of excitement upon the surfaces of the globes, in the neighbourhood of their pointed terminations. A revolution of the excited surfaces arising from the attraction of the differently excited wires, consequently ensues in a manner analogous to that already described in the case of the bell glass above mentioned.

8. ADDITIONAL ILLUSTRATION.

The principle explained by the preceding experiment receives another amusing illustration by means of an experiment, for the explanation of which this engraving is intended.



A glass ball is supported on a glass plate. On the plate, strips of tin foil are so pasted, as to form a broad circle or border near the margin of the plate, and four radii to that circle. There is likewise a flat brass ring supported, and of course insulated, by glass pillars, so as to have its inner edge immediately over that of the exterior edge of the foil.

The brass ring being in communication with the prime conductor of the machine in operation, and the tin foil in communication with the cushions, the ring and foil will be oppositely electrified. The ball, being attracted by the ring, becomes positively electrified in the part which comes in contact with it. The part thus electrified will then be attracted by the foil; and communicating its charge, return to the ring to undergo another change. Different parts in succession undergo these electrical changes, and the consequent movements; which are of course complicated and amusing.

9. EXPERIMENTAL PROOFS, THAT METALS, CHARCOAL, MOISTURE, FLAX, OR HEMP, ARE CONDUCTORS OF ELECTRICITY—AND THAT SULPHUR, RESINS, GLASS, SILK, AND WOOL, ARE NON-CONDUCTORS.

The Electrical Machine, being in operation, so as to emit sparks, or to act upon pith balls, or other light bodies—those electrical effects cease, when the conductor, which is the immediate cause of them, is touched with a rod of metal, or by a piece of charcoal, communicating with the earth—and they are enfeebled, when one end of

a hempen or flaxen string is attached to the conductor, while the other end is held in the hand, or lies upon the floor.

The conductor being excited, as above described, the phenomena do not cease, in consequence of the contact of a glass rod, or of cylinders of sulphur or resin; nor are they diminished, by an attachment of woollen or silken strings, as in the case of those of flax or hemp. The glass rod, or the woollen or silken strings, being soaked in water, the electricity is carried off by them from the conductor. Electricity escapes from the conductor, with ease, through a tube filled with water.

OF THE DIFFERENT KINDS OF ELECTRICITY.

It may be learned, from the brief account of the rise and progress of Electricity, (page 2) that the electrical excitement which may be produced in glass, by friction, differs from that which may be produced, by the same means, in resin, or sulphur: that light masses, as paper, or pith balls, separate from each other, when either excitement has been imparted to both: but if one body receives the resinous, the other the vitreous excitement, an attraction between them will ensue. Both excitements, in due proportion, neutralize each other. Also, whenever either excitement is produced, in one body, the other will arise in some other, if both bodies be supported by non-conductors, so as to prevent the escape of electricity, as soon as generated. Hence if a person, standing on a glass stool, rub a tube of the same material, he will be found resinously electrified; while any body, to which the glass may be presented, will be vitreously electrified. A stick of resin, being substituted for the glass, and rubbed in like manner, and under the same circumstances, the same phenomena will appear, in a different order. The person rubbing the resin, will be vitreously excited; while the excitement of the body, to which it is presented, will be resinous.

In like manner, when the cylinder of the electrical machine is put into motion, the insulated cushion which rubs it, acquires the resinous excitement; while the prime conductor becomes excited vitreously. If a globe of sulphur,

or resin, were substituted, the cushion would receive the vitreous excitement; while the conductor would be excited resinously.

10. DESCRIPTION OF BENNET'S GOLD LEAF ELECTROMETER.



A glass cylinder, supported by a metallic pedestal, is surmounted by a metallic canopy; from the centre of which, two tapering strips of gold leaf are suspended. Strips of tin foil, T T, are pasted on the glass, so as to terminate at the upper ends a little above the level of the lower ends of the gold leaves, and so as to be in contact below, with the pedestal. This should be uninsulated. The gold leaves are more energetically attracted in consequence of the proximity of the tin foil.

11. EXPERIMENTAL ILLUSTRATIONS.

The leaves of the Electrometer diverge, on the approach either of excited sulphur or glass; but when both are approximated to it, at once, the leaves will display no divergency.

Electrical Machine produced—each conductor being furnished with a Quadrant Electrometer. As the cylinder is turned, the pith ball of each Electrometer rises. As often as a spark is taken from either conductor, the pith ball of the Electrometer on it, falls; and when a metallic wire is made to touch both conductors, simultaneously, neither of the pith balls indicates any excitement.

OF ELECTRIC POLES.—OF ELECTRIC CIRCUITS.

There is a resemblance which will hereafter be recurred to between the reciprocal action of magnets, and that of electrics, of which, the extremities are in opposite states. Under such circumstances, the poles similarly electrified, or similarly magnetised, appear to repel each other, while those in dissimilar states, appear to exercise a reciprocal attraction.

The extremities of the magnets, from their exercising a reaction with the terrestrial poles, analogous to that

which they exercise reciprocally, were called poles; that which is attracted by the north pole of the earth being designated as the north pole, the other as the south pole. From the analogy, the extremities of excited electrics, and galvanic and voltaic instruments having properties resembling those of excited electrics, received the same appellation. Hence electricians speak of the positive and the negative poles, of the electric machine, of the galvanic battery, or of a voltaic series, whether in the form of the trough, or of the pile.

As a general definition, poles may be alleged to be those parts of an electric, galvanic, or voltaic circuit, at which ignition, light, chemical decomposition, or sensation, are perceived.

When the conductors of a machine, in operation, communicate by a wire or rod, or other competent conducting body or bodies, an *electric circuit* is said to be formed. The electric fluid flowing into the cushion from the negative conductor supporting it, is, by the electric, carried to the positive conductor, whence, by means of the conducting communication, it returns to the negative conductor. Agreeably to the hypothesis of two fluids, there is in such case a double circuit. Two fluids separated from each other by the friction, move in opposite directions, and meeting and combining in the conductors as soon as separated, the equilibrium is not sensibly altered.

In making or breaking such a circuit, sparks will appear at the time and place, when and where the interruption is such as to allow them to occur. In that case the poles are at the points through which the sparks pass.

The poles of an electric machine, and the conductors, are often mentioned as if they were identical. In fact, the poles are usually at some points in the surfaces of those conductors. They vary, however, at the pleasure of the operator; since they always exist at those parts of the conductors (or of any conducting body or bodies touching one or both) which are nearest to each other, or at which sparks pass.

It should be understood that any conductor, especially any perfect conductor, assumes the same electric state as the pole, with which it may be in connexion; and that a contact between either pole, and one extremity of a rod, or wire, transfers the polar influence to the other end of

that rod or wire. The pole is properly, that point at which the excitement is most active, and experience shows this state to exist always, either at the most prominent part of the electrified mass, or that nearest to any prominent part of the other pole.

In operating with an electric machine, of which the rubber is uninsulated, the earth usually forms a part of the circuit, and any conductor, the human body for instance, which, while it has a conducting communication with the earth, happens to be nearest to the positive pole, acts as the negative pole, when the machine is in operation, and there is sufficient proximity. This is indicated by the passage of sparks.

I have dwelt upon this subject more particularly, as the acceptation of the word pole, among men of science, has latterly, by its practical and theoretical associations, become of the highest importance.

Students who wish further information on this subject, are referred to an article in the appendix, entitled, "*Remarks on the Error of supposing a Communication with the Earth, necessary to the Efficacy of Electrical Machines.*"

MEANS OF ACCUMULATING ELECTRICITY.

In the case of the insulated conductors of an electrical machine, oppositely excited by the revolution of a glass surface which successively rubs the cushions supported by one of the conductors, and passes under metallic points projecting from the other; it has been shown that it is only necessary to make a communication between them, by a perfect conductor, in order to destroy their respective excitements. It follows that the surcharge in the one, must have been just equivalent to the deficiency in the other; and that of course the whole quantity of electricity in the conductors is the same, whether they be in a state of excitement or of quiescence.

It has also been shown, that the electric fluid does not pass through electrics, or from one part of an electric to another.

I shall now proceed to demonstrate, that if an electric, sufficiently thin and strong, (as a pane of glass for instance) be charged on either side with either kind of elec-

tricity, the other side of the pane will acquire, proportionably, a charge of the opposite nature.

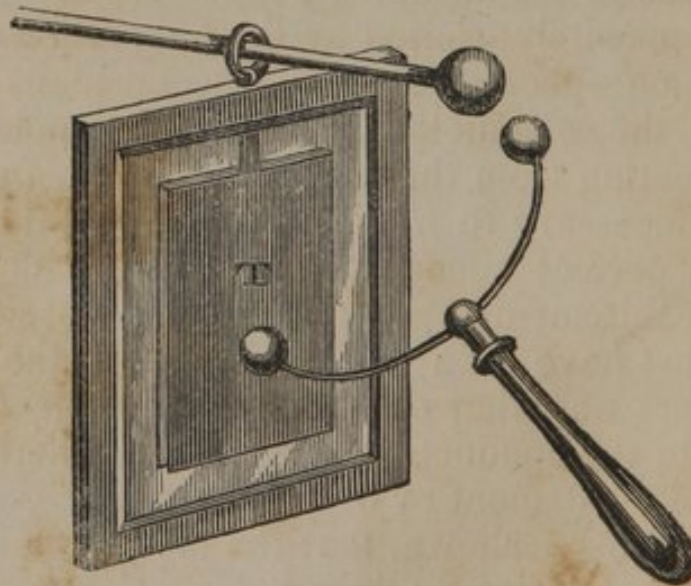
12. EXPERIMENTAL ILLUSTRATIONS.



A dry glass pane being held in one hand by its insulating handle, sparks are taken from the excited conductor of an electrical machine, with the knuckle of the other hand. The glass pane, being interposed between the knuckle and the conductor, at first does not appear to intercept the sparks; yet, as they gradually diminish, and finally cease, they are obviously intercepted by the pane, sooner or later. The pane being supported by the handle, on touching the surfaces in the part which has been exposed to the sparks, with one hand, while the part opposite on the other side of the pane is touched by the other hand, an electrical discharge takes place, a shock is experienced, and the electrical excitement disappears.

It follows, that the sparks which had apparently passed through the pane, had actually been arrested by the surface nearest to the conductor, and had appeared to reach the hand; because, for every spark received on one side, an equivalent portion of the electric fluid is expelled in the same form from the other side.

13. COATED PANE.



A pane of glass is coated on both sides with tin foil, excepting a space of about two inches from the edge all round. The two coatings are made severally to communicate, for a short time, with the two insulated conductors of an electrical machine, while in operation, the coatings being otherwise insulated. The pane being then suspended, and the different coatings

severally allowed to communicate through a metallic arc, a discharge ensues, more or less powerful, according to the power of the machine, the extent of the coated surface, and the dryness of the air.

14. OF THE LEYDEN JAR.



In the History of Electricity, (page 3) some account has been given of this celebrated invention. The adjoining cut is a representation of it in an approved form. There is no essential difference between a coated phial, and a coated pane. The existence, or the absence of curvature in the interposed stratum of glass, does not sensibly affect the result, neither in theory, nor in practice, excepting as respects conveniency.

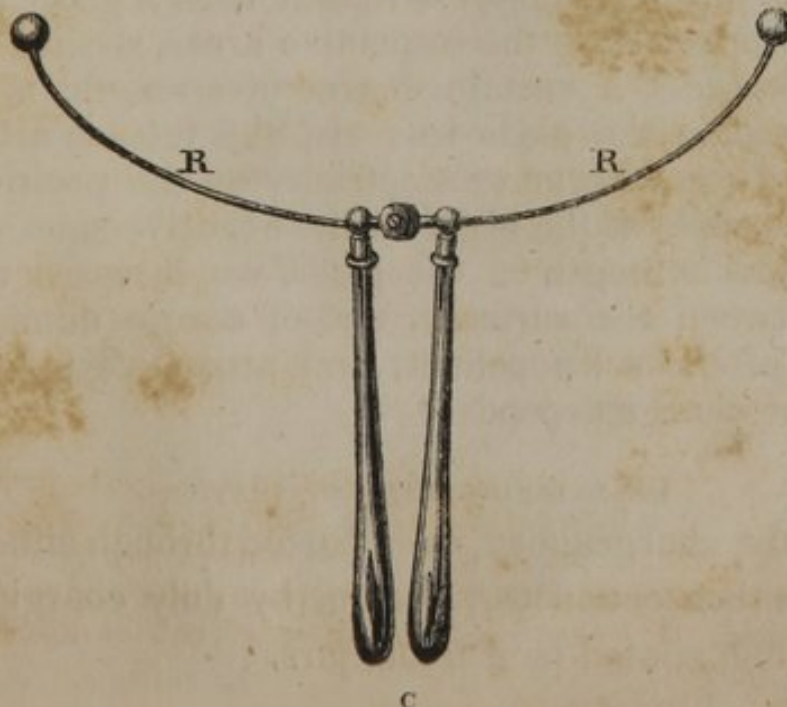
The form of the jar is more favourable to the retention of a charge, as it does not allow such free intercourse, between the inner surface and the air.

The coating, it will be observed, is represented as extending both on the inside and on the outside, till within a distance from the brim equal to about one-fourth of the whole height of the jar. The jar is closed by a broad wooden stopple,

through the centre of which passes a metallic rod, terminated above by a knob, and below by a spiral of wire, which establishes a sufficient contact with the inner coating.

The most convenient mode of charging such a jar, is to grasp it in the hand, and present it to the knob of the prime conductor, while the cushions are uninsulated, or in communication with the outer coating by means of a chain or wire.

15. OF THE COMMON DISCHARGER.



This name is given to an instrument, of which the preceding figure is a representation, and which is employed in completing the circuit between the charged surfaces; thus enabling the excess in one, to be discharged into the other.

The rods, R, R, are joined by a hinge; so that, by means of the glass handles to which they are severally affixed, the terminating knobs may be made to come into mutual contact, or to be remote from each other, as in the figure.

A charge is imparted, equally well, by the contact, or communication, of either coating, with either conductor.

The charging of a coated pane, or jar, may be effected, provided either of the surfaces are in communication with either conductor, the other surface communicating with the other conductor; one or both of the conductors being insulated. In whatever way a charge may be induced, it will be found that the one surface loses as much as the other gains; since a conducting communication is always sufficient to bring them both back to a state of neutrality. Hence as the sum of the quantities on both sides of the pane, is always the same, charging the pane, does not derange the electrical equilibrium of the surrounding medium.

The charge must vary in its strength, according to the power of the machine, the dryness of the air, and the thickness of the glass; since the self-repellent power of the electric particles, and their attraction for the negative surface of the glass, must be inversely as the squares of the distances at which they operate.

On this account as a plate of mica may, with less thickness, possess greater strength than a glass pane, it will, in proportion to the respective areas, receive a much higher charge. A certain degree of strength, is necessary to enable the glass to resist the intense attraction between the surcharge of electricity on the positive side, and the surface of the glass on the negative side. In obtaining this strength in the glass, we increase the distance between the surfaces, and of course diminish the efficacy of the self-repellant, and attractive powers, on which the charge depends.

16. EXPERIMENTAL ILLUSTRATIONS.

That the charges may be imparted through either coating, by either conductor, shown, by duly charging, and discharging, coated panes and jars.

17. EXPERIMENTAL PROOFS, THAT THE DIFFERENT SURFACES OF A CHARGED ELECTRIC, ARE OPPOSITELY ELECTRIFIED.



If from the conductor of an electrical machine in operation, a Leyden jar be suspended by a metallic hook, connected with one of its coatings, it receives no charge, until the other coating is approximated by a conducting substance, which communicates directly, or indirectly, with the other conductor of the machine.

If one or more bodies, as, for instance, little metallic balls, qualified to act as bell clappers, be suspended at a suitable distance between bells severally communicating with the coatings of a charged pane or jar, the balls will play between the bells demonstrating them to be oppositely electrified by their communication with the different surfaces.

18. CHIME OF BELLS.



The little metallic balls, *b, b*, and the bell situated between them, being suspended by silk, which is a non-conductor, cannot receive the electrical excitement communicated to the inner coating of the jar. But the two outer bells, being suspended by metallic chains from a metallic rod communicating with the inner coating, will partake of the excitement in this coating. Consequently the balls remaining neutral, while the outer bells are excited, are attracted by these, and on coming in contact with them receive a quantity of the electric fluid adequate to bring them to the same degree of excitement. Hence in the next place they separate from these bells, and are attracted by the central bell, which, by means of a chain connecting it with the external surface of the jar, is brought into the same electrical state as this coating, and must of course be in a state opposite to that of the other surface. The balls, by contact with the central bell, lose as much electricity as will bring them to the same state as this bell, and are then separated from this bell, and are attracted by the others, are again separated, and are again attracted, until by repetition, they transfer the surcharge on one surface to the other, and thus restore the equilibrium. Gravitation operating upon the balls as upon the pendulum of a clock, evidently conspires to sustain their vibrations.

The length of time, that the bells may be kept ringing by the vibration of the balls, when the air is dry, may excite surprise at first; but it should be recollected that the balls can only carry off at each stroke, a portion of the electric fluid; which is, to the whole quantity in the coating, as the superficies of the ball is to the surface of the coating, or less, probably, than as one to ten thousand.

Metallic Coatings employed, as in the preceding experiments, are of use in conveying the charge—but it does not reside in them.

The effect of the tin foil, is, simply, to cause the speedy and equal distribution of the electricity over the surface of the glass, which, not being an electric, cannot by itself convey the excitement from one part of its surface to another. Hence a pane without coatings, can only be partially charged or discharged at one contact.

19. PANE WITH MOVEABLE COATINGS.

T T represents metallic sheets, which are used as coatings to a pane, also represented in the figure. One of the sheets is insulated by being supported upon a stand with a glass leg; the other by being held by a glass handle.



EXPERIMENTAL ILLUSTRATION.

A glass pane, P, held by means of an insulating handle of the same materials, is made to touch the knob of an excited conductor of the electrical machine, on one side; while another metallic knob, communicating with the other conductor of the machine, is made to touch the pane on the other side, in the part opposite to the first mentioned knob. By varying the situation of the knobs, the pane is charged, wherever its surfaces have been sufficiently in the vicinity of the knobs. While thus prepared, it is supported by its handle, and one hand of the operator approximated to one side, while the other hand approximates the other. It can only be gradually discharged, as it was charged; the knuckles being made to assume, successively, the various positions relatively to the pane, previously occupied by the knobs. But, the pane being again charged by the knobs, with the aid of the coatings, T, T, properly applied; the surfaces are thoroughly and instantaneously discharged by contact of the hands, or other competent conductor, with those coatings. The coatings being applied to the pane, whilst charging, and then removed, the discharge can only be effected gradually.

Any other conducting substance which will accommodate itself to the surface of the glass, may be substituted for tin foil. But metals are preferable, as they are pre-eminently the best conductors.

20. *Glass vessel so situated as that water is made to perform the same office as metallic coatings in the Leyden Phial; illustrating the original experiment of Cuneus and Mushenbroeck.*



A glass vessel, containing a quantity of water, of which the surface should be about two inches below the brim, and moistened to the same height on the outside, may, as in the celebrated experiment of Cuneus and Mushenbroeck, be charged and discharged, by the same means as the pane or phial coated with tin foil, though less advantageously.

Gold, silver, or copper leaf, metallic filings, or mercury, may be substituted for the coatings of a Leyden jar. When metallic filings are glued to the surfaces of a pane or jar, within the space usually allotted to the tin foil coatings, the discontinuity of the conducting surfaces, causes the passage of the elec-

tricity from one portion to another, to be indicated by splendid corruscations, which will hereafter be fully illustrated.

21. **EXPERIMENTAL DEMONSTRATION THAT THE CHARGE OF A LEYDEN JAR, DOES NOT RESIDE IN THE COATINGS.**

That the charge does not reside in the coatings, may be proved by removing them, touching them with the hand while separated from the glass;

and afterwards replacing them, and simultaneously touching them. A shock will be received, in the same way as if they had not been removed.



Instead of tin foil coatings, a metallic case is made, just large enough to receive a tumbler with ease, and reaching about two-thirds of its height. A hollow cylinder of the same material, is made so as to fill the cavity of the tumbler, to the same height as the case reaches on the outside; and yet so loose, as to be removed without difficulty. The tumbler being charged in the usual way, the cylinder may in the first place be lifted out of the tumbler by means of a glass rod, and the tumbler in the next place grasped at the brim and lifted out of the case without destroying the charge. This is rendered evident, by reinstating the tumbler in its case, and the cylinder in the tumbler; and by means of the discharger making a conducting communication between the case and the ball of the wire communicating with the cylin-

der. An electrical spark will then pass with the usual noise. Or if the circuit be established by touching the knob with one hand, and the case with the other, a shock will be experienced.

OF ELECTRICAL BATTERIES.

A series of coated jars, being placed side by side in a box, and all the inner coatings being made to communicate with each other, and with a ball of metal, by means of metallic rods; and all the outer coatings being made to communicate with each other, and with another metallic ball, by strips of tin foil; the jars, thus associated, are called an Electrical Battery.

Charging and discharging an electrical battery, however extensive, is just as simple, and is performed in precisely the same way, as in the case of a single jar. To charge a single jar, or a battery, the different coatings must be made to communicate, severally, with the different conductors of an electrical machine, either directly, or indirectly, through the floor of the apartment, or other conducting medium.*

To effect a discharge, either one, or several conductors, must be made to form a circuit from one coating to the other, either unbroken: or, if interrupted, the inter-

* See Appendix, for remarks on the error of supposing that a communication with the earth is necessary, &c. &c.

val, or the sum of the intervals, must not exceed a certain distance, called the striking distance, and which varies with the extent and intensity of the electrical machine.

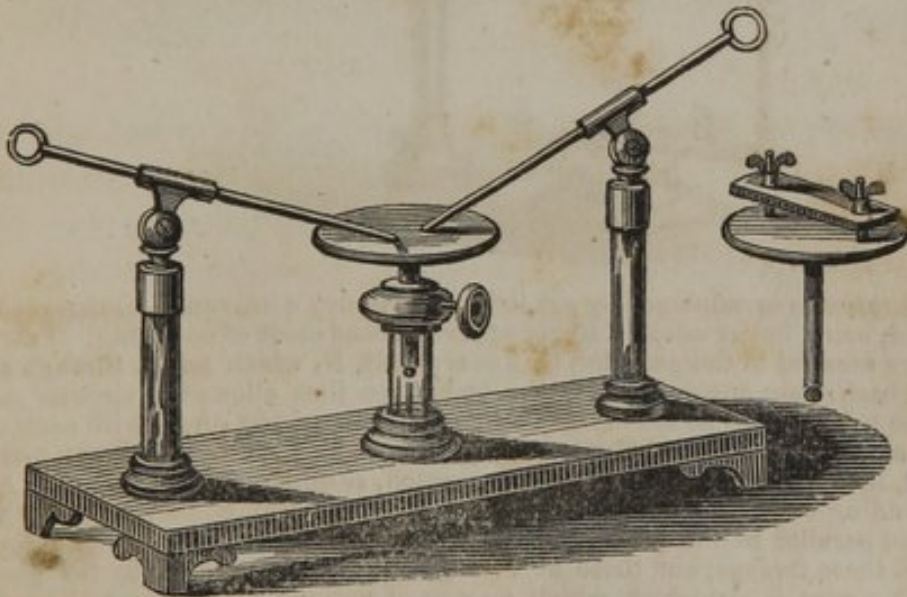
Charging a battery, will take more or less time, according to the number of jars to be supplied, and the quantity of the electric fluid, generated by the machine. But the discharge appears as quick from a great number, as from one; notwithstanding the numerous ramifications, through which the electricity has to pass.

22. OF AN ELECTRICAL BATTERY OF 32 JARS, EACH 13 INCHES IN HEIGHT, AND 5 INCHES IN DIAMETER.

My electrical battery is represented in the opposite engraving. It is situated permanently on the external edge of the canopy over the hearth of my lecture room, in the vicinity of my large electrical machine. With the positive conductor of this, it is of course easily made to communicate by a metallic rod. From the outer coatings a wire is extended to one of the iron columns of my lecture room, along which it afterwards descends to my table, and when the battery is in use, to a sheet of metal, on which, the battery discharger is placed. (22.)

23. DESCRIPTION OF HENLEY'S UNIVERSAL DISCHARGER.

This instrument has been employed to facilitate the exposure of bodies to a discharge from a Leyden jar or battery.

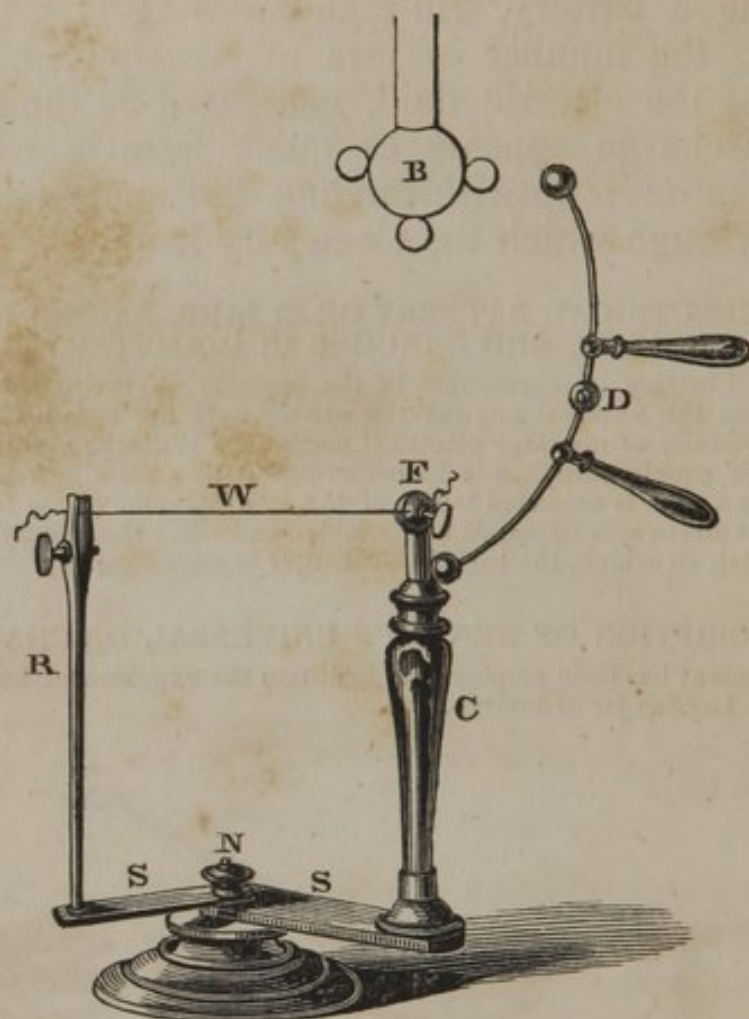


It may be understood from inspection. Two rods are supported upon glass pillars, to which they are secured by universal joints, having not only liberty to move on a pivot in almost any direction, but also to be slid through a spring socket so as to lengthen or shorten the portion of the rod between the socket and the point. The ends of the wires are pointed, but the points are fitted to brass balls which may be screwed on or off.

Between the columns is a little stand, which may be altered in height by means of a set screw. Upon this stand, an object to be made the medium of a discharge may be placed; the ends of the wires being in due contact with it. To one of the eyes at the other ends of the rods, a wire or chains, communicating with a coating of the battery, may be affixed. By means of the common discharger (15) a communication being then made between the other rod, and the other coating of the battery, the circuit is completed, and the whole charge, of the battery, passes through the body upon the stand.

In some cases where pressure is required, the stand represented at E, is employed. Thus some gold leaf being compressed between two very small panes of glass, kept together by the screws with which this last mentioned stand is furnished, may be deflagrated and incorporated with the glass.

24. BATTERY DISCHARGER FOR DEFLAGRATING WIRES.

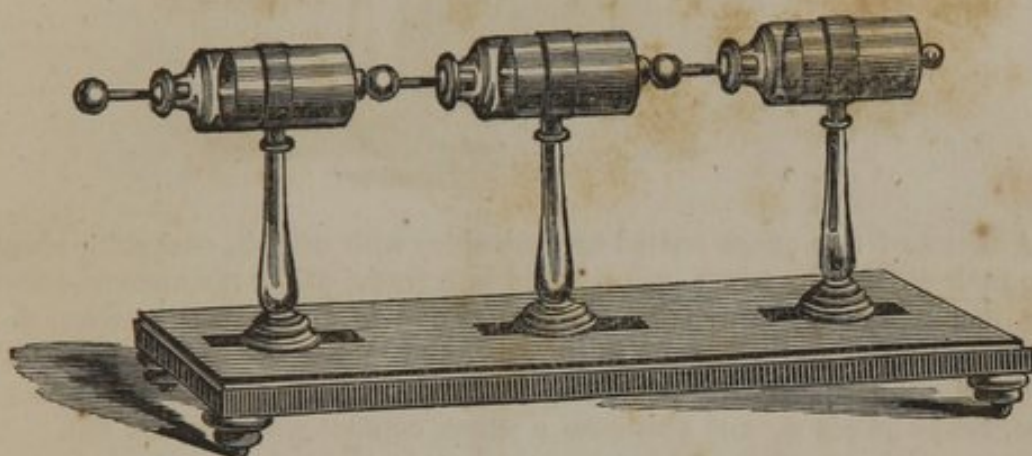


This apparatus is employed by me in lieu of Henley's universal discharger above described, being better adapted to my apparatus, and mode of operating. Two brass plates are secured to the pedestal, by a screw bolt, N, which passes through a hole made in each, near one extremity: the plates are thus allowed a circular motion about the bolt so as to be set in one straight line, or in any angle with each other. On one of the plates near the extremity not secured by the bolt, a brass socket is soldered, into which a glass column is cemented, surmounted by a forceps. At the corresponding end of the other plate, there is a brass rod, R, perpendicular to the plate, and parallel to the glass column. This rod, is also furnished with forceps. Between these forceps, and those at F, supported, and insulated by the glass column, C, a wire is stretched, which may be of various lengths, according to the angle which the plates, S, S, make with each other. The pedestal should be metallic, or have a metallic plate at bottom, in communication with the external coating of the battery. This being accomplished, it is only necessary to charge the battery, without subsequently breaking the communication between the inner coatings of the jars, and the prime conductor, by which the charge is conveyed. In that case touching the conductor, is equivalent to a contact with the inner coatings of the jars, so far as electrical results are concerned. Hence, by causing one of the knobs of the discharger, D, with glass handles, to be in contact with the insulated forceps, F, and then approximating the other knob to the prime conductor, B, the charge of the battery will pass through the wire, W, as it cannot descend by the glass column, nor reach the operator through the glass handles.

OF ELECTRICAL EXCITEMENT BY INDUCTION.

The simplest case of this kind, is that of the Leyden phial, or coated pane, already illustrated; where one surface, being in contact with an excited conductor, a tendency is *induced* in the electricity, on the other side of the electric, to leave it. This, probably, arises from that self-repellent power, between the particles of the electrical fluid, with which Franklin supposed them to be endowed.

25. APPARATUS FOR THE ILLUSTRATION OF ELECTRICAL INDUCTION.



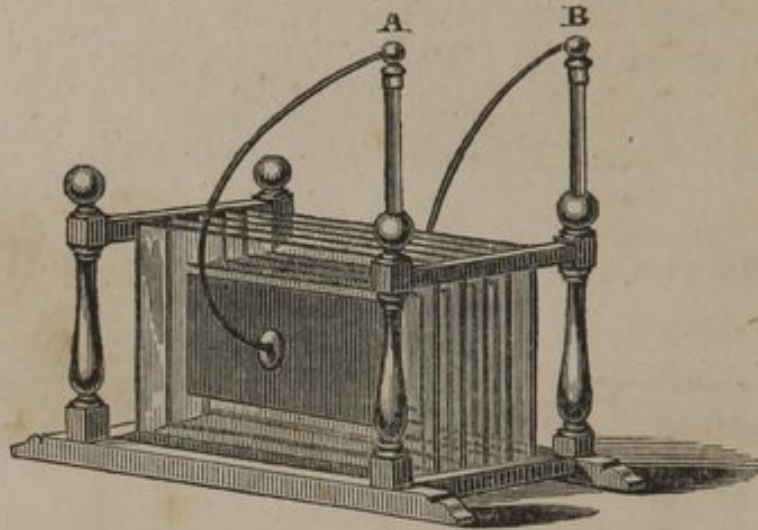
If the outer and inner coatings, of two or three insulated jars, be made to communicate; and the coatings of each extremity of the series, be brought into communication with the conductors of a machine in operation, as usual when one jar is to be charged; it will be found that a charge is received by all, and in discharging them, a spark may be perceived to pass between each jar, if a small interval be left. The effect of the discharge, is less than that which would be produced by means of one jar. In this case, the surfaces are said to be charged by *induction*.

The number of jars which can be thus affected, is greater, or less, according to the intensity of the electricity evolved by the machine, and the aggregate thickness of glass interposed.

26. A NEW APPARATUS FOR THE ILLUSTRATION OF ELECTRICAL INDUCTION.

As the prevailing theories of electricity cannot be understood without a correct idea of electrical induction, for the purpose of rendering it more intelligible, I have constructed the apparatus described in the following arti-

cle. The surfaces oppositely charged, being in the case of panes exactly alike, renders their commutable relation more easy to understand; and the process, as it proceeds in them, having a greater resemblance to that ascribed to voltaic series, may hereafter be more advantageously cited as a mean of illustration.



A series of five panes coated on both sides with tin foil, excepting about two inches from the edges, are situated in a frame at the distance of about two inches apart. A metallic communication is established between the inner coating of the first pane in the row, and that of the second pane immediately opposite, by means of a spiral spring of wire, which, by its pressure, keeps its place, and produces a close contact with the tin foil. A similar spring is interposed between each pair of coatings. Also the external coating of the first, and that of the last pane in the series, communicate severally by wires with metallic knobs, A, B, supported upon, and of course insulated by glass pillars. That is, the first pane communicates with the knob at A, the last with the knob at B.

This apparatus, like a Leyden jar, may be charged in either of three modes. That in which the positive pole alone is insulated from the earth, that in which only the negative pole is insulated; and that in which both poles are insulated.

When the operation is performed with the positive pole insulated, the negative pole communicating with the earth, the surcharge induced in the coated surface of the first pane, expels from the inner coated surface of that pane a portion of electricity, which is of course driven through the spiral into the nearest coated surface of the pane next in order. The surcharge induced thus in the nearer surface of the second pane, causes the other surface of this pane to give up electricity to the nearer surface of the third pane; so that, by a repetition of the process, every pane will be charged, if the electricity be sufficiently intense.

If, under these circumstances, one of the knobs of the insulated discharger be made to touch one of the insulated balls, while an approximation of the other knob to the other ball is effected; a spark will pass, arising from a discharge from the surface of the first pane, to that of the last, and at the same instant the equilibrium in all the surfaces will be restored.

During the entrance of the charge, the apparatus only receives an access of the fluid on the external coated surface of the first pane, and loses

a portion from that of the last pane. In the other surfaces the quantity is not altered, since whatever one loses, the other gains, and the quantities in the surfaces of each pane are equalized with the restoration of the equilibrium of the two external coated surfaces.

When the operation is performed with the negative pole in a state of insulation, it will be the converse of that above described. Electricity being abstracted from the external surface of the fifth pane, instead of being accumulated upon that of the first pane, the internal surface of the fifth pane becomes positively excited at the expense of the nearest surface of the fourth pane, which of course becomes negative on the surface thus robbed, and positive on the other side at the expense of the coated surface of the third pane. Thus by a successive inductive influence, transmitted from pane to pane, every other surface is negatively charged, causing those which alternate with them, to be charged in the opposite way.

When the knobs, A, and B, are acted upon by a machine with both poles insulated, the two processes above described co-operate simultaneously: since while electricity is abstracted from the external surface in direct communication with B, on the right, it is accumulated upon the external surface communicating with A, on the left; so that, by the inductive process, each pane becomes charged.

MEANS OF DETECTING OR MEASURING ELECTRICITY.

It has been seen, that the property which light bodies have of separating from, or approaching to, each other, when electrified, has been of use in showing the nature and extent of electrical excitement.

A ball of pith, supported by a radius, suspended from a pivot, so as to be capable of describing an arc of ninety degrees, over a corresponding curved scale, constitutes Henley's Quadrant Electrometer, employed in the experimental illustrations, 11.

Bennet's Electrometer has been described; in which, metallic leaves are suspended, within a glass cylinder, to a metallic cap. Slips of tin foil being pasted on the glass, opposite, and parallel to, the gold leaves.

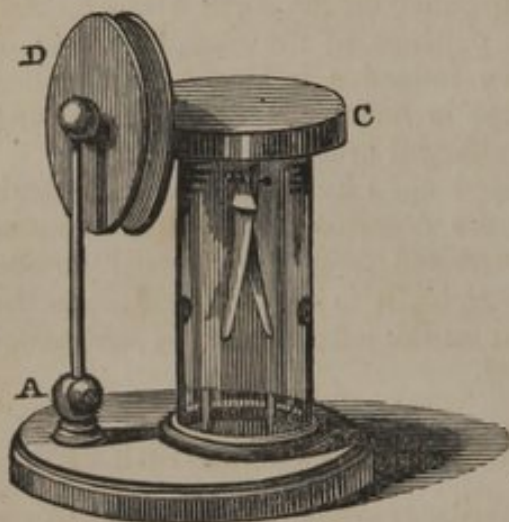
This last mentioned instrument, is sometimes, more properly, called an electroscope; as it is better calculated to discover electricity, than to measure it.

The efficacy of the gold leaf electroscope, is much increased by the addition of two metallic disks, one soldered to the cap, the other attached to the foot, by a hinge; so as that it may be placed parallel, and as near to the first mentioned disk as it can be, without touching. In this case, the capacity for electricity, of the disk, attached to the cap, is found to be increased, by *induction*; so that it will receive a surcharge. When the disks are separated, the excess of electricity received, while they

were near each other, is indicated by the divergence of the leaves.

The instrument thus constituted, is called the condensing electrometer, of which, an engraving and description is annexed.

27. DESCRIPTION OF THE CONDENSING ELECTROMETER.



The condensing electrometer, of which the annexed figure is a representation, differs from the ordinary instrument, in being furnished with two metallic disks, one attached to the canopy, C, the other upheld by a wire. The wire terminates in a hinge at A, by which the disk which it supports may be made to approach, or retire from the other disk. The metallic hinge communicates by a strip of tin foil, with other strips of the same material, which are pasted on the glass, as already described in the case of the gold leaf electrometer (10).

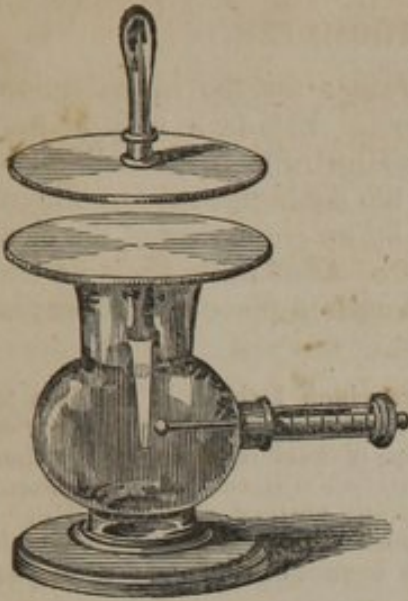
In order to put this instrument into operation, the disks must be quite parallel, and as near each other as possible without contact; then, on touching the cap with an electrified mass containing a charge of electricity, otherwise too low to affect the leaves, and afterward removing the disk, D, to the distance of two or three inches, the leaves diverge. A divergence of the leaves of the condensing electrometer may be produced by supporting a zinc disk of about six inches in diameter in the hand or otherwise, so as to have a communication, directly or indirectly, with the pedestal of the electrometer, and placing on it, from ten to twenty times, a disk of copper of the same size, held by a glass handle, and at each removal bringing the copper disk in contact with the cap of the electrometer. By these means a charge is imparted to the cap, which, when the outer disk is removed, is evinced by the divergency of the leaves. For our knowledge of the last mentioned method of producing electricity, by the contact of heterogeneous metals, we are indebted, I believe, to the celebrated Volta.

I have constructed an electroscope with a single leaf, to which a brass ball may be approximated by a micrometer screw. This is more sensitive, than any electrometer which I have seen on the usual plan. When furnished with a cap of zinc, if a plate of copper be placed on the cap, and then lifted, the leaf will strike the ball. This instrument acts both as an electroscope, and as an electrometer—as it detects and measures the minutest degree of excitement.

28. DESCRIPTION OF THE SINGLE LEAF ELECTROMETER.

By which the Electricity, excited by touch of heterogeneous metals, is rendered obvious, after a single contact.

A single gold leaf is suspended from a disk of zinc six inches in diameter, which constitutes the cap of the instrument. Opposite to this single leaf, a ball is supported which may be made to approach the leaf, or recede from it, by means of a



screw. Of the same size as the disk which forms the cap there is a copper disk with a glass handle, accompanying the instrument.*

The electricity produced by the contact of copper and zinc, is rendered sensible in the following manner. Place the disk of copper, on the disk of zinc, (which forms the cap of the Electrometer)—take the micrometer screw in one hand, touch the copper disk with the other, and then lift this disk from the zinc. Usually, as soon as the separation is effected, the gold leaf will strike the ball, if the one be not more than the twentieth of an inch apart from the other. Ten contacts of the same disks, of copper and zinc, will be found necessary to produce a sensible divergency in the leaves of the Condensing Electrometer. That the phenomenon arises from the dissimilarity of the metals, is easily shown, by repeating the experiment with a zinc disk, in lieu of a disk of copper. The separation of the homogeneous disks, will not be found to produce any contact, between the leaf and ball.

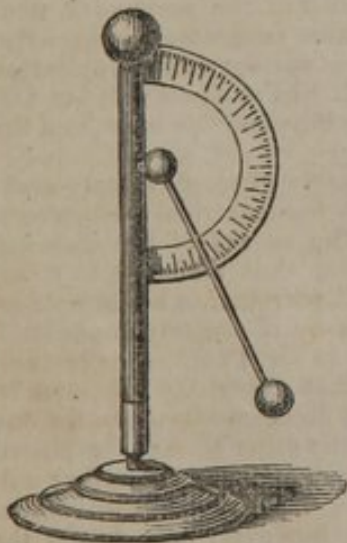
I believe this to be the only mode in which the electrical excitement, produced by the contact of heterogeneous metals, can be made evident without the aid of a condenser.

It is probable, that the sensibility of this instrument is dependent on that property of electricity, which causes any surcharge of it, which may be created in a conducting surface, to seek an exit at the most projecting termination, or point, connected with the surface. This disposition is no doubt rendered greater, by the proximity of the ball, which increases the capacity of the gold leaf to receive the surcharge, in the same manner, as the uninsulated disk of a condenser, 27, influences the electrical capacity of the insulated disk, in its neighbourhood.

It must not be expected, that the phenomenon above described, can be produced in weather unfavourable to electricity. Under favourable circumstances, I have produced it, by means of a smaller electrometer, of which the disks are only two and a half inches in diameter.†

The construction, as respects the leaf, and the ball, regulated by the micrometer screw, remaining the same—the cap of a condensing electrometer, and its disks, may be substituted for the zinc disk.

29. DESCRIPTION OF HENLEY'S QUADRANT ELECTROMETER.



Henley's Electrometer consists of a little wooden column, supporting a semicircle of ivory, or of wood covered with white paper; graduated near the periphery, into 180 degrees. At the centre of the semicircle, there is a pin, from which a moveable radius, terminated by a pith ball, is suspended. This radius is sufficiently long to allow the ball to reach to the base of the column, against which when left to itself it rests. But when the ball and column are electrified, the ball moves off from the column together with the radius to which it is affixed. But the radius being secured to the pivot at its upper end, the ball must describe a greater or less portion of a circle which is at the same time indicated and measured by the graduation.

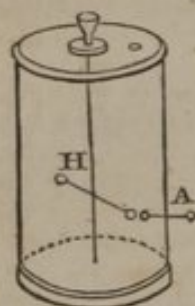
* For the experiment with this electrometer, a metallic handle would answer. Its being of glass, enabled me to compare the indication, thus obtained by my instrument, with that obtained by a condenser.

† I think I have seen an effect from a disk only an inch in diameter, or from a zinc disk, having a handle with a copper socket.

29½. OF COULOMB'S ELECTROMETER.

The electrometer of Coulomb is suitable rather for the investigation, than for the illustration of electrical phenomena. Yet as it may be proper to convey an idea of the principle of this instrument, I shall quote from the *Treatise on Heat and Electricity*, of the distinguished Dr. Thomson, of Glasgow, a description, accompanied by an engraving of the electrometer in question, in the most simple form. Alluding to the gold leaf electrometer, (10) or that in which straws are used in place of gold leaves, Dr. Thomson observes:—

“In these and many other common electrometers which I think it needless to describe, the instrument cannot be considered as a true measurer of the quantity of electricity, because as the two straws or the two slips of gold leaf separate farther and farther from each other, it is evident that gravitation will act more and more powerfully to bring them back again to their naturally vertical position. Hence the repulsive force of the straws, or leaf, is not proportional to the distance to which they separate from each other. These instruments cannot of course be employed to measure the energy of electricity.



“But the electrometer of Coulomb is free from this defect. It is represented in the margin. It consists of a glass vessel having a lid also of glass, in the centre of which a small hole is drilled. Through this hole passes an untwisted raw silk thread four inches long, and fixed at the top to a micrometer, by means of which it may be turned round any number of degrees at pleasure. To the silk thread is attached a very fine gum lac thread, H, having at each extremity a small knob. This lac needle with its knobs weighs only one-fourth of a grain. A small hole is drilled in the side of the vessel, at A, through which passes a fine wire terminated at both extremities by a knob. When an excited body is placed in contact with the knob at A, the knob at the other ex-

tremity will acquire the same electricity as the excited body. This electricity it will communicate to the knob of the lac needle suspended by the silk thread which was previously almost in contact, and the two knobs will repel each other. The moveable knob attached by the silk thread will separate from the other, and the quantity of electricity will be proportional to the distance to which it is driven off.

“Coulomb's electrical balance is an instrument intended to measure the quantity of electricity in bodies, and indispensable in accurate experiments.”

It should be understood that in this instrument, the knob of the suspended needle may be made to resist sufficiently its removal from that supported by the wire, by twisting the silk in fibre. Coulomb contrived a more perfect and complicated electrometer, upon the same principle as the one which I have described, but furnished with graduated circles for measuring the distance between the balls, and the extent of the torsion given to the suspending filament.*

By means of this apparatus, Coulomb confirmed an observation, previously made by the Earl of Stanhope, that the density of electricity in the electrical atmosphere, surrounding an excited body, diminishes inversely as the square of the distance from the charged body. Coulomb inferred, from the law thus assumed to exist, and from ingenious and accurate experiments tending to corroborate his inference, that the electricity accumulated about a conducting body is entirely superficial, none of it existing in the interior of the body. He also, as Dr. Thomson conceives, “proved by very simple but convincing experiments, that electricity deposits itself upon bodies according to their surfaces; that it has no more attraction for one body than for another: also, that if two bodies, having the same surface, be placed in contact, whatever their nature may be, any electrical surcharge in either will be divided equally between them.” Allowance is to be made for the obstruction arising from the diversity of conducting power, which, however, only delays the equalization, but does not prevent it from taking place.

* The description of this last mentioned instrument, with engravings, occupies three pages in the *Treatise* of Dr. Thomson, alluded to above; which is more space than I deem it expedient to devote to the same purpose.

OF THE EFFECTS OF ELECTRICITY.

The separation or approximation of electrified bodies, the extrication of light and heat, and the shock given to the animal frame, having been all, more or less, subjects of discussion, or adduced as the means of experimental illustration; it may now be proper to display a greater variety of electrical phenomena, and such as being more complicated require undivided attention in those who would comprehend them.

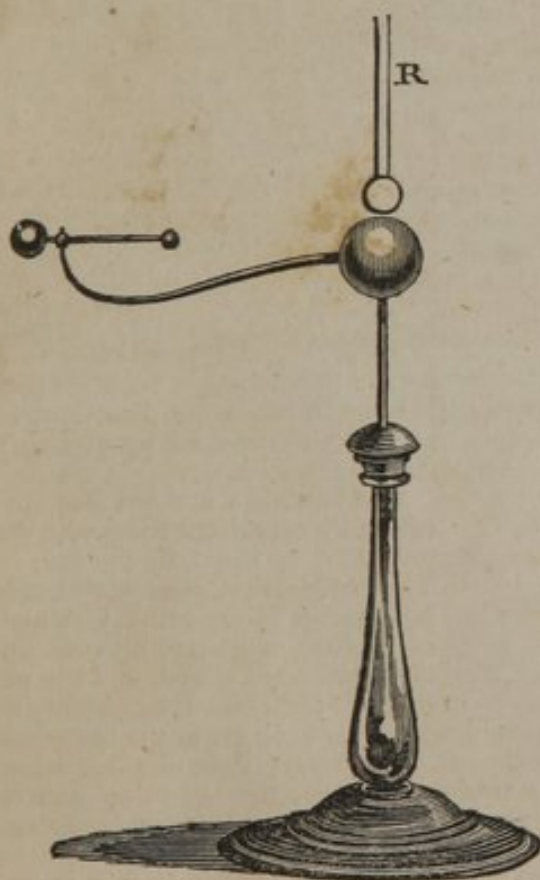
OF ELECTRICAL ATTRACTION.—OF ELECTRICAL LIGHT.—OF ELECTRICAL IGNITION.—OF THE ELECTRICAL SHOCK.

OF ELECTRICAL ATTRACTION.

Under this head are placed both the separation and approximation of light bodies, when electrified; since the former, though commonly ascribed to repulsion, is really, as I conceive, the effect of attraction.

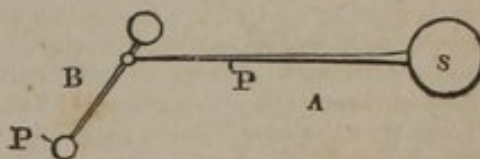
30. REVOLUTION OF A SUN, PLANET, AND SATELLITE.

Fig. 1.



A hollow brass globe, Fig. 1, is rendered much heavier on one side by running into it a quantity of molten lead, sufficient to occupy about one-third of the cavity. By these means when supported on a pivot it preserves a proper position although on the other side not furnished with lead, it is made to support an arm and two balls; one, larger, representing a planet, the other smaller, representing its satellite. These are carried upon the different ends of a wire passing through their axis, and balanced upon the point of the arm, so that the balls may counterpoise each other. From the larger arm, and from the smaller ball, points, P, P, project as represented in Fig. 2.

Fig. 2.



When the sliding rod of the conductor, R, is brought sufficiently near to the central globe of this apparatus, the machine being in operation, there ensues a complicated revolution. The planet and its satellite attached to the arm, B, are balanced upon a pivot, formed of the recurved and pointed termination of the larger arm, A; meanwhile the pivot revolving, as the

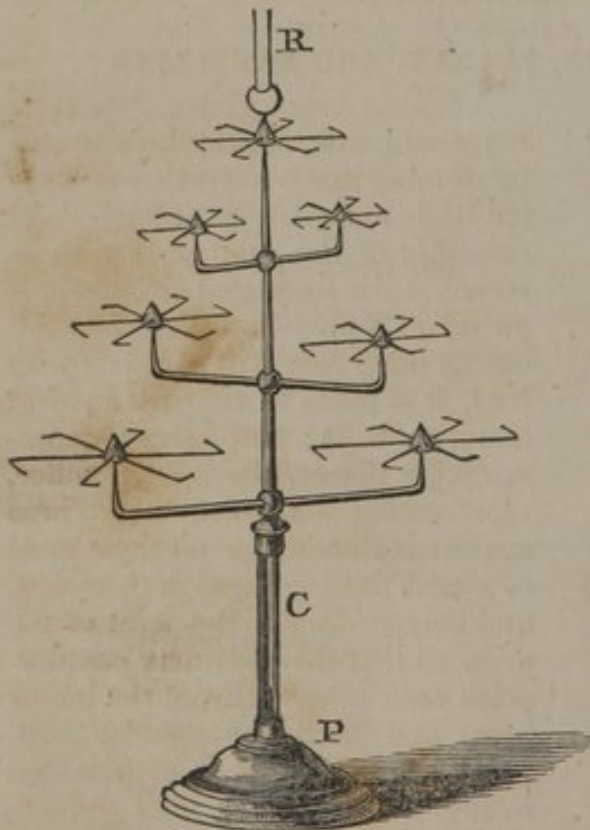
sun, S, turns upon its axis, carries the planet and satellite in their orbit, while they revolve about the pivot, as their common centre of gravity.

According to the Franklinian theory, the above described rotatory motions result from the attraction of the surrounding medium, operating successively at every part of the orbit, to separate the electrified air from the metallic points by which it is electrified.

It must be admitted that as these rotatory motions may be produced whether the excitement be negative or positive, the rationale is more difficult of conception, upon the theory of one fluid than upon that of two. It is necessary agreeably to the Franklinian doctrine, to ascribe all cases in which electrified masses separate from each other, to attraction between them, and the matter of the adjoining medium. This process becomes extremely difficult to follow in the "mind's eye," when the masses thus separated are undergoing a rapid change of position.

The explanation, supposing two fluids to exist, is, simply, that bodies similarly excited, repel each other; and consequently that repulsion arises between the points, and the air which they electrify, whether the excitement be vitreous or resinous.

31. ELECTRICAL TREE.



I believe that an apparatus resembling that of which this figure is an engraving, is named in Pixii's catalogue, "Arbre Electrique," a name which I have used for want of a better.

It consists of several sets of branches formed of wire. Each set is associated by a common hollow brass cone, into the apex of which, a recurved wire, forming a principal branch of the electrical tree, is so introduced as to form a support and a pivot, upon which, the cone and its branches may rotate. Each rotatory branch is recurved, and terminates in a point; the points in each set projecting in the same direction, so as to co-operate in producing a circular motion.

The branches are put into operation by communicating with the machine, as usual, by the rod, R. The excitement thus received, cannot pass off by the trunk, C, which is of glass, cemented into an upright brass rod above, and the pedestal, P, below. It can hardly be

necessary to add, that the rationale of the rapid rotation of each set of the branches, is analogous to that of the preceding experiment. In consequence of their being similarly surcharged with electricity, or similarly deficient, the adjoining neutral medium attracts the air, and the branches apart, with energy, and thus causes them to recede from each other as soon as they come into proximity.

To render the Franklinian rationale more intelligible, as applied to this experiment, and that of the miniature sun, earth, and moon, it may be observed, that the excitement of the machine being communicated by the sliding rod, R, to the central ball, and of course to all of the metallic wires therewith associated; it is diffused through the points to the air in their vicinity. Consequently the points, P, P, and the air electrified by them, being similarly surcharged, or similarly deficient, must be attracted by the adjoining neutral medium; and not attracting each other, they are made to separate rapidly, or to move in opposite directions. This process being reiterated with inconceivable speed, the revolutions proceed with proportionable velocity.

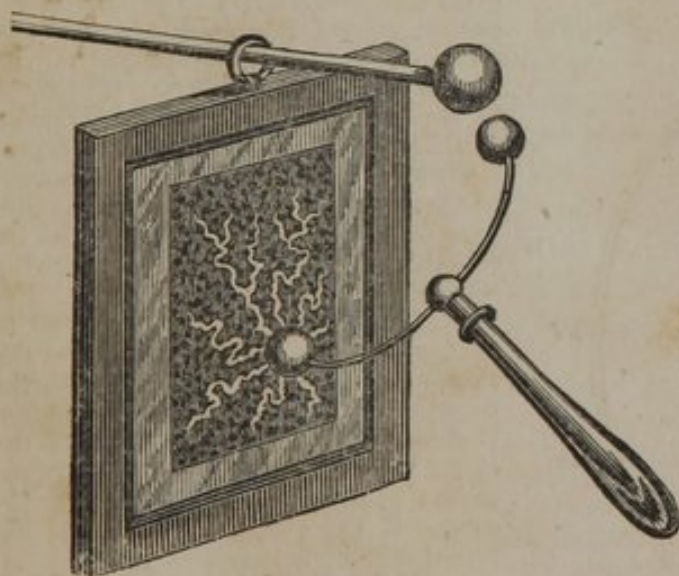
32. ELECTRICAL HAIL.



This experiment, which is in Pixii's Catalogue described as "Grêle Electrique," (electrical hail) affords another illustration of the movements which may be produced in light bodies by electrical attraction. A metallic rod supports one ball within the bell glass, another without, so as to be in contact with the knob of another rod, R, proceeding from the conductor of the large electrical machine in operation. The brass ball being by these means intensely electrified, attracts some of the pith balls which lie upon the metallic dish in which the bell is situated, and which should communicate with the cushions of the machine. As soon as the pith balls come into contact with the electrified ball, becoming similarly excited, agreeably to the general law, they recede from each other, and are attracted by the oppositely electrified dish. Reaching the dish they attain the same electrical state as at first, and of course are liable to be attracted again. Meanwhile other balls are undergoing the same routine, producing that contrariety of movements which characterizes the fall of hail.

ELECTRIC LIGHT ILLUSTRATED.

33. *Experimental Illustration of the egress and access of the electric fluid during the charging and discharging of coated surfaces, as rendered evident by means of a discontinuous coating of metallic filings.*



The charging and discharging of a coated pane, has already been illustrated and explained. The process is however rendered much more interesting, when, instead of a continuous coating of foil, a covering of metallic filings is applied, so as to leave a multitude of minute intervals between the particles of the metal. It is only necessary to have the discontinuity of covering on one of the surfaces; the other

may be coated with tin foil, as usual.

The tin foil coating should, by means of a strip of the same substance, communicate with the ring attached to the wooden frame in which the pane is secured. Let the pane, thus prepared, be suspended by the ring, as represented in the engraving, from a rod affixed to the conductor of a powerful electrical machine in operation. As represented in the figure, let a discharger be so held, in contact with the surface coated with filings,

as to carry off electricity from it, allowing the other surface of the pane to be proportionably surcharged. In the next place, let the discharger be so situated, as to complete the circuit between the surfaces, allowing the surcharge in the one, to rush to the other. By these means the efflux, and afflux of the electric matter, will be indicated by corruscations of electric light, with an indescribable splendour, which will appear so long as the surface coated with tin foil, remains in communication with a machine sufficiently active, and the situations of the discharger are alternated, as above described.

34. EXPERIMENTAL ILLUSTRATION.

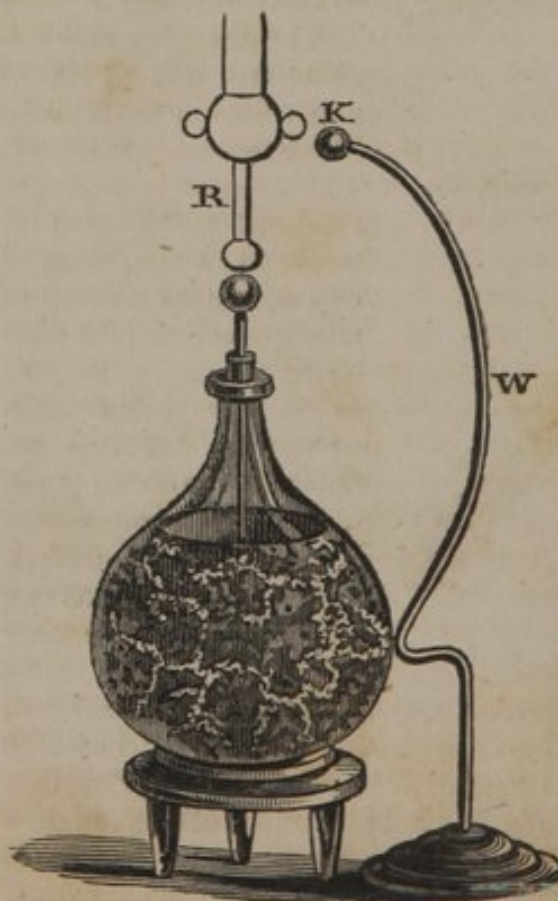


Analogous results may be obtained by means of a jar represented by the adjoining figure, which has a hook wherewith to suspend it; or still more advantageously by means of a large carboy, silvered by an appropriate amalgam within, and on the outside furnished with a discontinuous coating of filings.

If the discharger employed in this experiment have a glass handle, either the metallic socket, S, into which the handle is cemented, must be touched by one of the fingers, or a wire must be attached to it, making a communication with the negative conductor, directly or indi-

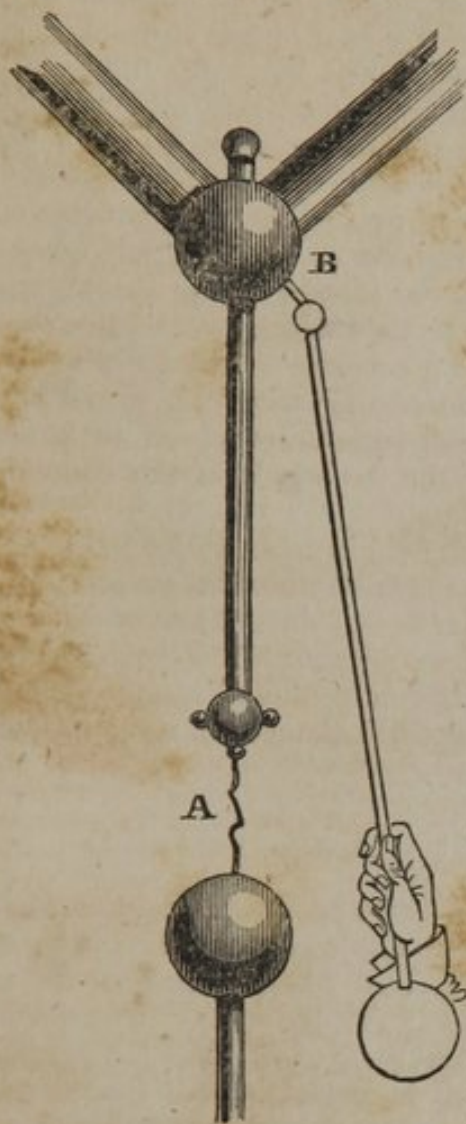
rectly. Otherwise, the external coating being insulated, electricity could not escape from it, and of course the inner surface could not be charged as already demonstrated.

35. EXPERIMENTAL ILLUSTRATION.



The adjoining cut represents a green glass carboy of about five gallons in capacity, coated internally by means of the amalgam usually employed for the purpose, externally by brass filings, as in the cases of the pane and phial above described. It is situated under the projecting ball, B, of the prime conductor, so that the knob at the top of the rod, proceeding through a cork from the internal coating, may be in contact with the sliding rod, R, of that conductor. The wire, W, is supported on a pedestal in contact with the external coating of the carboy, and in communication with the negative conductor of the machine. Hence, when by the operation of the electrical machine, the internal surface of the glass is becoming charged; the escape of the electricity from the external surface is indicated by corruscations of light, and snapping sounds, as in the preceding experiments; and at the instant when the charge acquires sufficient intensity to jump through the interval between the knob attached to the ball, B, and that supported by the wires, the deficit created in the external surface, being restored at once, the corruscations and sparkling are parti-

36. LONG ZIGZAG OR ERRATIC SPARK, CONTRASTED WITH THE SHORT STRAIGHT SPARK.



The object of the following engraving is to represent the different forms and lengths of the electric spark, which take place between a large and a small ball, accordingly as they are made negative or positive. The long and zigzag, or erratic, spark, A, takes place between a small ball attached to the positive pole, and a large one associated with the negative pole. The short straight spark, B, is elicited under circumstances the reverse of those just mentioned. They are represented as simultaneous, but with the same machine, can, of course, only be obtained in succession.

In no respect do the phenomena of mechanical electricity appear more favourable to the Franklinian theory, and more inexplicable, according to the doctrine of two fluids, than in the diversity of the electric spark in passing between a small and a large metallic ball, according to the manner in which the balls are associated with the positive or negative poles of the machine. When the small ball is attached to the positive pole the spark is long, comparatively narrow, and of a zigzag shape, such as lightning is often seen to assume; but when the situation of the balls is reversed, the spark is straight and thick, not one-third as long, and nothing of a zigzag shape can be observed in it.

According to the Franklinian theory, when any body is more highly charged with electricity than the adjoining bodies, the excess of the fluid is attracted by them, while it is inadequately repelled by the inferior quantity of the electric fluid, with which they are imbued. It follows that when a small globe is made positive in the neighbourhood of a large one, the excess of electric matter in the lesser, is attracted by all the negatively excited metal in the larger globe. When the small globe is made negative, the metal of which it consists attracts all the electric matter in the large globe. Hence there is this difference in the two cases; the smaller ball being positive, a comparatively small *moveable mass* of electric matter, is attracted by a large *immoveable mass* of metal: the small globe being made negative, a large *moveable mass* of electric matter is attracted by a small *immoveable mass* of metal. The charge being in both cases the effect of the same machine; the attractive power must be as great in one case, as in the other. The forces, by which the masses are actuated, being therefore equal, it is quite reasonable that the greatest projectile power should be attained, when the *moveable mass* is smaller. In that case it will require less air to be removed in order to effect a passage.

There is an analogy between the difference which I suppose to exist in the case under consideration, and that which exists between the penetrating power of an instrument which is blunt, and one which is pointed.

It remains to show why the large mass of electric matter attracted in a large globe by a small metallic globe negatively excited will be discharged in a spark when there is sufficient proximity, as at B, in the figure, although otherwise it will not pass. It must be evident that attraction increases, as the distance between the bodies which exercise it, lessens. Of course the attraction of the small globe must always act more powerfully on those portions of the electric fluid which occupy the nearest parts of the positively excited globe. But this difference of distance, and consequent diversity of attraction increases, as the smaller globe approaches the larger. Thus that portion of the electric fluid which sustains this pre-eminent attraction will be accumulated into a cone the acuteness of which and attraction causing the acuteness, increasing with the proximity, there will at last be sufficient projectile and penetrative power to break through the air, and thus open a passage for the whole of the quantity attracted by the negative ball.

When by the process last described, the fluid is made to leap through a comparatively small interval by the concentrated attraction exercised by a small negative ball upon the expanded surface of electric matter diffused through a large globe, the air does not become sufficiently condensed to resist it before it reaches its destination, and of course it cannot assume the erratic form which would arise from repeated changes in its course, as in the instance of the long spark.

37. OF THE ELECTRICAL BRUSH.



When the machine is in active operation, and the prime conductor insulated; from a small knob attached to it, as at B, in the figure, the electricity will be so sent off, as by the concomitant light to exhibit the form of a luminous brush as represented in this figure at B. For the production of this phenomenon it is necessary that the electric fluid shall be condensed into a small prominent mass, so as, agreeably to the preceding explanation, to have great penetrating power. This it cannot possess, when with the same intensity in the generating power, a large ball is positively electrified. In that case, the electric column presents a front too broad to procure a passage through the surrounding non-conducting air. A small ball, negatively electrified, can only be productive of a diffuse attraction for the electricity in the atmospheric medium around it; so that it has less ability to create any penetrating power, than when acting upon the electricity in a comparatively large globular conductor, as in the preceding illustration. Hence when the knob is on the negative pole, it may be productive of a luminous appearance in its immediate vicinity where the electric matter converging from the adjoining space becomes sufficiently intense to be productive of light; but it does not produce the striking appearance of the luminous brush.

As agreeably to Du Fay's theory, the knob, whether vitreously or resinously electrified, is surcharged with an electric fluid, the projectile power ought to be as great in the one case as in the other; and the long spark, and the brush, should be producible in either case.

38. GLOBE, ILLUMINATED PANES, AND TUBES.

No. 1.



No. 2.



Little disks of tin foil are so pasted in succession on a glass globe, pane, or tube, as to leave only a minute interval between them. In consequence of this arrangement when situated in the circuit between the poles of an electrical machine, the electric fluid availing itself of the conducting power of the metal, and leaping over each interval, produces as many sparks as there are intervals. At the same time, if these intervals fall within the lines of any drawing, the image representing the drawing will appear at each flash, and when, as in using a large machine, the flashes are incessant, remitting, without intermitting, the effect upon the eye is nearly as permanent, as if the illuminated spaces were inherently luminous.

In the case of the globe and tube, represented by fig. 1, and fig. 2, the disks are arranged in spirals winding about the globe or tube from one apex, or end, to the other. However intricate the route which ingenuity may, by means of the foil, prescribe, when the air and pane are dry, it will be pursued by the fluid with fidelity. Yet the sum of the intervals must not exceed the whole striking distance of the machine, or in other words, the greatest length of its spark.

This illustration may be varied by means of apparatus, of which engravings and descriptions will be found in the two following articles.

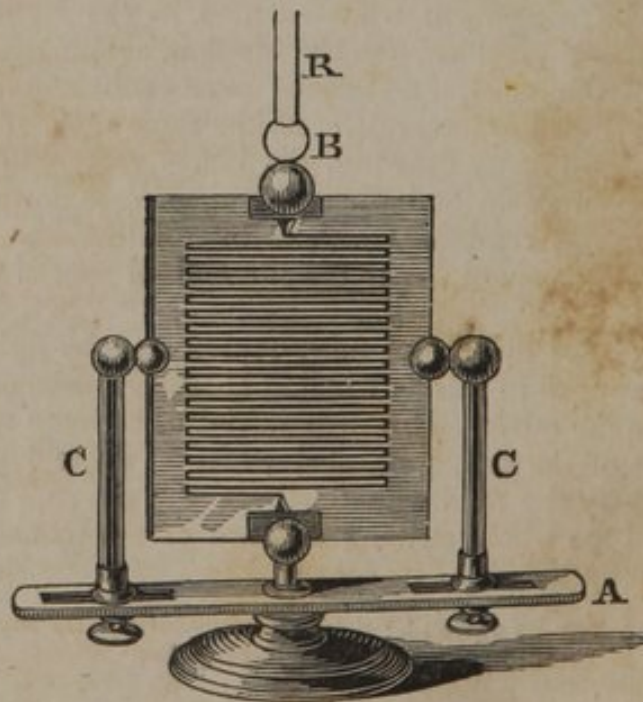
39. ILLUMINATED COLUMNS.



A swivel of wire, terminating in knobs, is so balanced upon a pivot, that, when charged, it revolves from the brass knob of the column to which it is nearest, to that of the next—and thus successively conveys to each, the sparks imparted to it by the machine.

40. CARREAUX ETINCELANTES.—SPARKLING PANES.

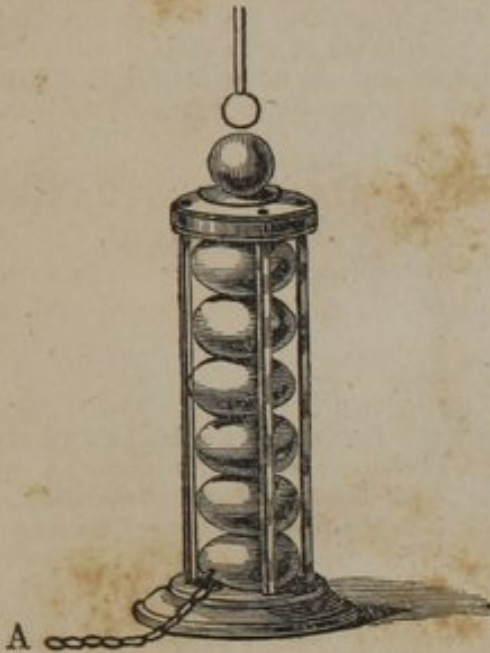
This appellation is given in Pixii's Catalogue to the apparatus described in this article.



This figure represents a pane, in which the discontinuities in the tin foil attached, as explained, (38) being made to occur along the lines of a drawing, an image is seen as often as the electric spark passes. The frame, A, having two glass columns surmounted by metallic clasps for securing the pane, is contrived to accommodate a succession of panes, all of one size exactly, on which different images are delineated, and which may be shown in succession. In operating, the upper ball, B, is situated so as to be in contact with the sliding rod, R, of the prime con-

ductor. At this point, the fluid enters, and coursing horizontally, first towards one side, and then towards the other, it finally escapes at the other ball, into the foot of the instrument, which should communicate with the cushions of the machine, directly or indirectly.

41. ILLUMINATED EGGS.



Between three glass columns a pile of eggs is supported in mutual contact. They are also in contact at top and at bottom with spiral wires, in the one case communicating with a chain, A, in the other, with a brass knob which surmounts the cap in which the columns terminate, and by which they are secured. The eggs thus situated, may be taken into the circuit between the conductors of the machine, or the coatings of a battery, and thus be illuminated by the passage of the electric fluid. The experiment is seen to the best advantage when a powerful machine is employed, as the effect is in that case durable; scarcely any intermission taking place in the flashes. The contents of the eggs appear to be exposed to the eye, as if divested of their shelly covering.

ELECTRIC LIGHT IN VACUO.

42. AURORA BOREALIS.



It appears from the experiments of Volta, that electrical excitement is consequent to the vaporization of water. In fact, to what other cause, than the successive formation and condensation of vapour, are we to ascribe the prodigious evolution of electricity, which accompanies thundergusts. Those portions of the earth which are within the arctic, or antarctic circles, must, in consequence of their frigidity, be incessantly receiving accessions of moisture from the atmosphere, which, as its capacity for moisture varies with the temperature, must, whenever it is carried by circulation to that icy region, part with a portion of the water which it absorbs in warmer latitudes. Indeed, independently of those aerial currents which would favour this result, the law of the diffusion of vapours, would cause it incessantly to extend itself from warmer latitudes, where it is supplied with the caloric requisite to its formation, towards those colder regions, in which it is

deprived of that repulsive principle, and thus converted into snow.

Here then is a great source for electrical excitement. Meanwhile the same frigidity which causes all vapour to condense, coats the whole surface of the earth in the vicinity with dry ice, which is well known to be an electric. How is the electric fluid thus accumulated to escape? It can have but one of two courses. Either it must strike through the dense air near the earth's surface horizontally, or penetrate through the rare medium above, where, as it proceeds, the resistance will les-

sen. The last mentioned course is obviously preferable, since, at a distance less than that of half a degree of latitude, it will find a medium as rare as that in the receiver of the finest air pump.

I infer that the corruscations of the aurora borealis, are produced by the efforts of electricity accumulated as above described, to seek that equilibrium to which it incessantly tends. I conceive myself fortified in this inference by a striking resemblance of the corruscations of that principle in passing through an exhausted receiver, as represented in the adjoining figure, to those of the aurora.

The figure represents only one of the appearances. At times the fluid will pass only on one side, and then successively shift to the opposite or intermediate paths.

ELECTRICAL IGNITION EXPERIMENTALLY ILLUSTRATED.

43. IGNITION OF COTTON BY THE ELECTRIC SPARK.



Let one of the knobs of a discharger be surrounded by a tuft of carded cotton, containing as much finely powdered rosin as it will retain; and while the other knob touches the outer coating of a Leyden jar properly charged, let the cotton be approximated to the knob of the jar proceeding from the inner coating, a spark will pass, and the cotton will be ignited.

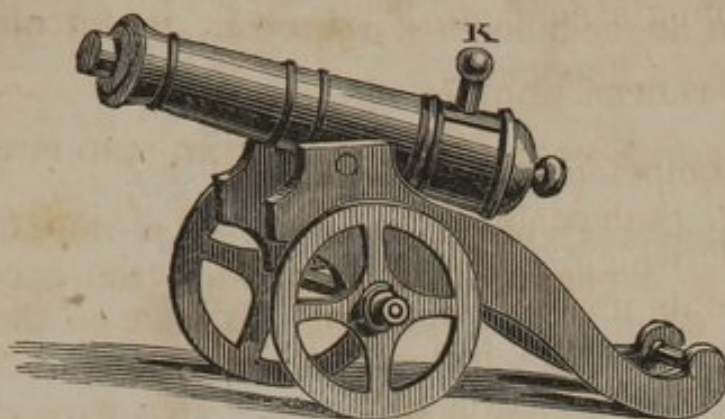
44. INFLAMMATION OF ETHER, BY THE ELECTRIC SPARK.



This object is conveniently effected by means of a wine glass with a perforated stem, through which, a wire passes from a dish of metal cemented to the foot. The wire rises about two thirds of the height of the glass, terminating in a knob. Up to the middle of the knob, the cavity of the wine glass may be filled with plaster of Paris, or other cement, so as to leave only a portion of the knob, bare. The ether should only form a thin stratum not entirely covering the apex of the knob.

In consequence of its ready vaporization and admixture with air in open vessels, ether is always surrounded by an explosive atmosphere which is readily inflamed by the passage through it of an electric spark, either from the conductor of a machine, or from a Leyden jar. The result is rendered more interesting, when accomplished by a discharge from surfaces electrified by means of water, as in the experiment described page 21.

45. IGNITION OF INFLAMMABLE MATTER BY THE ELECTRIC SPARK.—IGNITION OF HYDROGEN WITH OXYGEN.



By means of a wire, insulated by being enclosed in a glass tube cemented into a socket, which screws into the touch hole of the little cannon here represented, a spark from an excited conductor may be made to cross a small interval within the bore of the piece. Hence, if an explosive gaseous mixture, of hydrogen with oxygen, or atmospheric air, be made to occupy the cavity, and be secured by a cork, the mixture will explode on presenting the knob, K, of the insulated wire, to the prime conductor of the machine when in operation. It may be fired by the finger; or the nose of a person supported upon an insulated chair or stool, and communicating, at the same time, with the prime conductor sufficiently excited.

OF THE ELECTRIC SHOCK.

This effect of the electrical fluid is subsequently treated of, in illustrating the mode of electrifying a patient.

OF MITIGATING THE EFFECTS OF ELECTRICITY.

The same charge of electricity which would produce a shock, or deflagrate a wire, if received through a knob, may be insensibly received through a fine point. The power of an electrical machine, or that of a large battery, is thus easily paralysed. Hence the employment of pointed rods of metal, as a protection against lightning. Hence, also, it is necessary, in the construction of electrical apparatus, to avoid all edges or acute projections, unless where it is intended to facilitate the passage of the fluid.

RATIONALE.

When a knob is approached to an excited conductor—as soon as any portion of it is near enough to be struck, so much of the ball is at hand, as to allow the whole discharge to take place at once;—but, when the apex of a pointed wire is near enough to receive a portion of the fluid, the other parts are too remote to come into action; and whether the point advances to the electrified body, or the body approximates the point, the fluid is discharged before it is within striking distance of the thicker part of the wire.

In fact, the difference between a discharge by a point, and through a knob, resembles that which exists between making an auger-hole in a reservoir, to let out a fluid, and opening a floodgate.

OF THE PROPER MODE OF CONSTRUCTING, AND PUTTING UP,
LIGHTNING RODS.

The competency of pointed rods, to protect us against lightning, is dependent, not merely on the excellence of the point, which should be of platina, but on the mode in which joints in the conductor are made, and the nature of the soil in which it terminates. If a wire pointed at one end, be blunt at the other, and the nearest conductor to the blunt end be not pointed, the charge will not pass off gradually because received at a point. Moreover, the power of a conductor to receive the electric fluid, is compounded of its own conducting power, and that of the medium in which it terminates.

A metallic rod, terminating in a glass handle, in masses of sulphur, or resin, or dry sand, would not operate as a conductor. It cannot receive electricity, because it cannot deliver it.

Moist earth is but an imperfect conductor—since it owes its faculty of conducting to water, which according to Cavendish, conducts with 200,000 times less facility than iron.

Lightning rods should therefore be connected, by soldering, with an extensive metallic surface buried under the earth, as for instance, with sheets of lead, or copper.

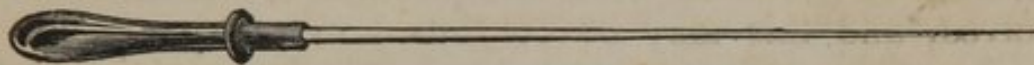
The cases, in which conductors have been found incompetent, are, I am satisfied, referrible to their inadequate communication with the earth.

Thus is an important lesson, given, with respect to the means of protection against lightning. In vain do we employ for this purpose a conductor, however perfect, if it have communication with the earth only through a limited contact with a soil, which, being at best an imperfect conductor, may become an electric by desiccation.

I have surmounted the lightning rod, by which my mansion is protected, by 17 copper wires pointed at one end, and at the other soldered into a hole drilled in the rod, which is constructed of iron. The juncture is surrounded by a globe of zinc of about two inches in diameter, above which the wires extend divergingly. The copper wires,

by their association with zinc, are protected from oxidation, while their greater fusibility, as compared with the platina point usually employed, is compensated by their number. The rod thus mounted rises about 10 feet above the apex of the roof, to the copper covering of which its lower end is soldered. The copper covering has an ample metallic connexion with the pipe for carrying off the rain, and this pipe with those of the public water works, all the joints being made with screws or solder. By these means a most ample communication with the earth is obtained. Analogous means should be employed in the case of all lightning rods, in situations where access can be had to a similar ramification of metallic pipes.

46. EXPERIMENTAL ILLUSTRATION.



Effect of a point shown, in drawing a charge from a battery, or conductor:—proved, also, that its power is weakened, or destroyed, by being associated with an electric, or imperfect conductor.

ADDITIONAL MEANS OF PRODUCING ELECTRICITY.

OF THE ELECTROPHORUS.—OF ELECTRICITY EVOLVED BY THE FRICTION OF CAOUTCHOUC, BY PRESSURE, BY CHEMICAL CHANGES, AND BY THE CONTACT OF HETEROGENEOUS METALS.

47. OF THE ELECTROPHORUS.



This is a peculiar instrument for the excitation of electricity, which we owe to the celebrated Volta. Electri-

cal induction has already been explained (see 25); likewise the susceptibility of resinous substances to be electrified negatively by friction, has been illustrated. The electrophorus is indebted for its efficiency to the co-operation of the effects of friction, with the inductive power. By rubbing the cake of resin, C, with the fur side of a dry cat skin, in a dry atmosphere, the resin is negatively electrified. If the metallic disk, D, be placed upon the resin while thus excited, it will acquire a greater capacity to receive electricity, in consequence of the proximity of the negatively excited surface of the resin, as has already been explained in the instance of the condensing electrometer. Hence, if placed upon the resin with the aid of the glass handle, K, on applying the knuckle to the knob, N, a spark will pass, and again when the disk is lifted about an inch or two from the resin, another spark will be received, and this may be continued in a dry air, for a longer time than any operator would have patience to repeat the operation. In dry weather, and in a dry apartment, an electrophorus will give sparks for many weeks, without being again excited by friction. It was through the aid of this property of his electrophorus, that Volta was enabled to contrive an apparatus for the production of instantaneous light, of which an engraving and description will be found in my Compendium.

EVOLUTION OF ELECTRICITY FROM CAOUTCHOUC BY FRICTION.

Dr. J. K. Mitchell has ascertained, that in the surface of a bag made of caoutchouc, or that of a thin sheet of the same material stretched on a frame, there is a surprising susceptibility of electric excitement. The attractive power, consequent to the excitation, appeared to me peculiarly powerful.

OF ELECTRICITY EVOLVED BY PRESSURE.

There are many substances, especially gum elastic or caoutchouc, which, if placed upon the disk of an electrometer, and pressed, will, on the cessation of the pressure, evolve enough electricity to be indicated by the gold leaf.

48. EVOLUTION OF ELECTRICITY FROM CAOUTCHOUC BY PRESSURE.



C, cap of electrometer; D, handle of metallic disk, between which, and the cap of the single leaf electrometer, may be seen a piece of caoutchouc subjected to pressure. The disk being suddenly removed, the leaf will strike the ball as when otherwise electrified.

THEORETIC EXPLANATION OF ELECTRICAL PHENOMENA.

It may be proper to give the rationale of the production, accumulation, and neutralization of electricity, agreeably to the doctrine of two fluids.

This doctrine has, within the last thirty years, been gaining in credit, especially on the continent of Europe.

OF THE THEORY OF TWO FLUIDS.

According to this hypothesis, when a body is electrically excited, a neutral compound, formed of two electrical fluids, is decomposed; one accumulates in the excited body, the other is evolved. That which accumulates in excited glass, is evolved by excited resin; and vice versa, that which accumulates in resin, is evolved by glass. Hence, according to this theory, the two electricities are always produced both by resin and glass; though the fluids accumulated in them respectively, being, in the first instance, separately recognised and associated with the substances in which they were observed, were named accordingly.

When, as in an electrical machine, a portion of a glass cylinder, or plate, is rubbed against a cushion, it gives off resinous, and receives vitreous, electricity. This surcharge of the vitreous fluid, is retained by the excited surface, until, in revolving, it comes opposite to the collector.

The change of capacity, which caused the glass to eject the resinous, and attract the vitreous fluid, ceasing with the friction to which it owes its existence, an equalization of the electricities, between the glass and the conductor, ensues; by which, the excitement is reduced, more or less, according to the extent of their respective surfaces. Returning to the cushion, the glass is re-excited, to the same extent, as at first; and, by a continuation of the process, gradually causes an exchange of vitreous for resinous electricity, between the conductors, until they are electrified, as oppositely as the performance of the machine will permit.

Under these circumstances, if a conducting communication be made, between the oppositely excited bodies, the electricities rush together, neutrality ensues, and a total cessation of electrical phenomena.

By some philosophers, the union of the two fluids is supposed to be productive of the evolution of heat and light. The inevitable consequence, that in separating they must absorb those elements, seems not to be sufficiently contemplated; nor indeed justified by any observed refrigeration between the surfaces of the cushion and electric, where the separation takes place.

In charging a Leyden jar, the two coatings become, for the time they are in communication with the conductors, respectively a part of them. That which touches the resinous, or negative conductor, therefore, gives up its vitreous electricity, and receives resinous; while an opposite exchange, of resinous for vitreous, takes place in the other coating. Meanwhile the opposite electricities are supposed to exercise a reciprocal attraction through the glass, and are thus retained upon the surfaces which they respectively occupy. Of course, a removal of the coatings, does not cause a removal of the charge.

When the positive and negative surfaces of a charged pane act simultaneously on a metallic arch made to complete the circuit between them, the resinous electricity is attracted out of the end of the arc, near the coating, vitreously charged, while the opposite effect takes place, at the other end. Thus, by a series of decompositions, and recompositions; or by currents, passing each other, the different surfaces are restored to their previous state.

The principle of induction is much resorted to, agreeably to the doctrine of two fluids, to explain the passage of a spark between a body either vitreously or resinously excited, and one which is neutral. It is supposed that the fluids attract each other in all proportions, and in a way to bring into equilibrio the self-repellent power of the homogeneous atoms tending to dissipate the aggregate fluid, and the attraction of the heterogeneous atoms tending towards its accumulation. Yet it is conceived that the equilibrium is liable to be destroyed by the presence of a body surcharged with either electricity. If it be vitreous, by induction it repels the vitreous fluid from any mass in its vicinity, and attracts the resinous; if the surcharge be resinous, it repels resinous electricity, and attracts vitreous. When this species of reaction reaches a certain degree of intensity, the surcharge, and the heterogeneous electric matter, which, by the inductive process, has been accumulated in the neighbouring conductor, rush together, producing an electric discharge, and under favourable circumstances, a spark or a shock.

Thus, the unknown electric compound, formed by the union of the two electricities, is considered as liable to be decomposed by the proximity of either of its constituents in excess.

When of two portions of the same matter, one is remote, the other actually combined with a common object of attraction, I cannot understand wherefore the one should be displaced by the other.

ADDITIONAL REMARKS, EXPLANATORY OF FRANKLIN'S HYPOTHESIS.

According to the theory of Franklin, the effect of an electrical machine, in drawing electricity from the cushion, and accumulating it in the prime conductor, has some analogy with that of a wheel, or pump, for raising water.

The increased capacity for the electric fluid, arising from friction in the glass, operates like a bucket on a wheel, to enable it to receive a portion of fluid; and the loss of this capacity, after the friction ceases, is analogous to that inversion of the buckets, which causes them to be emptied, at every semi-revolution.

When the liquid thus raised, is withdrawn from one reservoir to be thrown into another, so that the quantity in the former is diminished as much as it is increased in the latter, the effect is analogous to that of the cylinder or plate of an electrical machine in creating a surcharge in one of the surfaces of a pane, at the expense of the other. Should the reservoirs be allowed subsequently to communicate by a syphon or sluice, and in consequence being on the same level, a previous equilibrium of pressure be restored, the office performed by the syphon would be analogous to that of a metallic arc in restoring the electrical equilibrium of the charged surfaces of a coated pane; excepting that the velocity of the electric current is incomparably greater.

In explaining the operation of charging a coated pane by the theory of Franklin, the incessant agency of the attraction between the fluid and the glass, should be kept in mind. It is necessary to suppose an intense attraction to exist between the glass and the electrical particles; while between these particles there is an intense self-repulsion. When these forces are unimpeded, there can be no electric accumulation, because operating equally, they must produce an equal distribution of the electric fluid.

In a charged pane, this tendency to an equilibrium is counteracted by the impermeability of the glass, so that when by the operation of the machine, the fluid is abstracted from one side of the pane to be piled upon the other, the same attraction of the glass which resists the withdrawal of the fluid from the negative surface, retains it upon the positive surface as soon as it reaches it; while the surcharge thus retained, prevents any accession to the negative surface, of electricity from other bodies. Thus an electrical surcharge in a coated jar, or pane, is dependent on its attraction for the negative surface, and the repulsion between it, and the electric matter, in other bodies.

RATIONALE OF ELECTRIC LIGHT AND IGNITION.

It appears evident, that there is a re-action between heat, light, and electricity.

It is not surprising, therefore, that the presence of one, should cause the appearance of either of the others; since they all, evidently, pervade nature. It may be conjectured, that the electric fluid is luminous when projected with intensity, into the air, in consequence of its carrying, along with it, the light encountered in its progress through ponderable matter. In like manner it may cause the extrication of caloric, by displacing it, when latent; or by adding temporarily to its repellent power, it may enable it to overcome attraction of cohesion; in which case, a metal, no doubt, contains caloric enough to produce a violent, or even explosive, separation of the metallic particles.*

49. MEANS OF ELECTRIFYING PATIENTS WITH SPARKS.



* See Lectures on Caloric and Light in my Compendium.

A person, seated on an insulated chair, is made to communicate with one of the conductors. Being thus negatively or positively electrified, sparks may be taken from any part of the body, by a metallic knob, or point. If the knob be too severe, the point may be used; and if this be too powerful, it may be covered by a wooden cone, C.

50. APPARATUS FOR ELECTRIFYING A PATIENT, BY SHOCKS.

In order to subject a person to shocks, a coated jar is used, with two knobs; one in communication with the inside coating through the rod, R, which supports it, the other supported on an insulated wire, W, so that it



may be made to approach, or recede from, the knob which communicates with the inner coating. To the outer coating, and the insulated knob, chains are attached, each terminating at one end in a knob of metal with an insulating handle. The handles are held by the operator, and

the knobs applied to the patient, so as to leave between them, the part to be electrified. The coatings of the jar being severally connected with the different conductors, of an electrical machine, the charge increases in the jar, until it become strong enough to strike through the interval between the knob connected with the inner coating, and that insulated in its vicinity. Of course, the height of the charge, depends upon the interval thus left; according to the operator's discretion, or the feelings of the patient.

SOME ENCOMIUMS

UPON THE

EXCELLENT TREATISE OF CHEMISTRY, BY BERZELIUS;

ALSO

*Objections to his Nomenclature, and Suggestions respecting a Substitute,
deemed preferable,*

IN A LETTER TO PROFESSOR SILLIMAN.

BY ROBERT HARE, M.D.

Professor of Chemistry in the University of Pennsylvania.



Philadelphia, June, 1834.

MY DEAR SILLIMAN,

I have already apprized you, that last year I had the honour to receive from the celebrated Berzelius, six volumes of his admirable treatise of Chemistry; to which, during the last summer, I gave much time, in order to avail myself of the vast fund of useful practical knowledge which it contains. I am of opinion that to adepts in the science, this treatise is the most interesting and instructive compilation of chemical knowledge which has ever issued from the press. It comprises much matter for which Chemistry is indebted entirely to the genius, skill, and industry of the author, while scarcely any subject in it is so treated, as not to create a renovated interest in the reader, however previously familiar with the science.

Sweden may with reason be proud of her Scheele, her Bergman, and her Berzelius. The last, but not the least, of these great chemists, aided by an Herculean intellect, and commencing at the point at which his predecessors terminated their glorious career, may be considered as possessing attainments which have never been excelled. Yet the sun is not without spots, nor is Berzelius without errors; unless indeed, those which I have ascribed to him, are phantoms of my own intellectual vision.

I concur with those chemists who consider the relation ascertained by Berzelius, between the quantities of oxygen in oxybases, and in oxacids, as a necessary consequence of the laws of combination, on which the Daltonian theory has been founded. I conceive also that the interesting facts which demonstrate the existence of the relation alluded to, would be more easily understood and remembered, if referred to the theory of atoms, than when made the basis of his doctrine of capacities for saturation, and of the numbers by which those capacities are expressed.

Moreover, I do not approve of his nomenclature. This is a subject highly interesting to me at this time. The last edition of my text book is exhausted, and in publishing a new edition I shall be obliged either to adopt the nomenclature of Berzelius, or to adhere

to that now generally used, with such improvements as may seem to me consistent with its principles.

I will proceed to state my objections to the Berzelian nomenclature, and to suggest the language which I would prefer. I should be glad if the promulgation of my opinions should call forth remarks, which may enable me to correct, in due season, any errors into which I may have fallen. I regret the necessity of making a final election, before submitting my objections to Berzelius himself, whose disapprobation it would grieve me much to incur.

My apology will be found in the adage—"Amicus Plato, sed magis amica veritas." Besides, if my opinions are incorrect, they will only react upon their author. The productions of Berzelius stand deservedly too high in public favour to be reached by ill founded criticism.

The most striking feature in the nomenclature of Berzelius, is the formation of two classes of bodies; one class called "*halogene*," or salt producing, because they are conceived to produce salts directly; the other called "*amphigene*," or both producing, being productive both of acids and bases, and of course indirectly of salts. To render this division eligible, it appears to me that the terms acid, base, and salt, should, in the first place, be strictly defined. Unfortunately there are no terms in use, more broad, vague, and unsettled in their meaning. Agreeably to the common acceptance, chloride of sodium is pre-eminently entitled to be called a salt; since in common parlance, when no distinguishing term is annexed, salt is the name of that chloride. This is quite reasonable, as it is well known that it was from this compound, that the genus received its name. Other substances, having in their obvious qualities some analogy with chloride of sodium, were, at an early period, readily admitted to be species of the same genus; as, for instance, Glauber's salt, Epsom salt, sal ammoniac. Yet founding their pretensions upon similitude in obvious qualities, few of the substances called salts, in the broader sense of the name, could have been admitted into the class. *Insoluble* chlorides have evidently, on the score of properties, as little claim to be considered as salts, as *insoluble* oxides. Luna cornea, plumbum corneum, butter of antimony, and the fuming liquor of Libavius, are the appellations given respectively to chlorides of silver, lead, antimony, and tin, which are quite as deficient of the saline character as the corresponding compounds of the same metal with oxygen. Fluoride of calcium (fluor spar) is as unlike a salt as lime, the oxide of the same metal. No saline quality can be perceived in the soluble "*haloid salts*," so called by Berzelius, while free from water; and when a compound of this kind is moistened, even by contact with the tongue, it may be considered as a salt formed of an hydracid and an oxybase, produced by a union of the hydrogen of the water with the halogene element, and of the oxygen with the radical. It is admitted by Berzelius, vol. 3, page 330, that it cannot be demonstrated that the elements of the water, and those of an haloid salt, dissolved in that liquid, do not exist in the state

of an hydracid and an oxybase, forming a salt by their obvious union.

On the other hand, if, instead of qualities, we resort to composition as the criterion of a salt; if, as in some of the most respectable chemical treatises, we assume that the word salt is to be employed only to designate compounds consisting of a base united with an acid, we exclude from the class chloride of sodium, and all other "haloid salts," and thus overset the basis of the distinction between "*halogene*" and "*amphigene*" elements.

Moreover, while thus excluding from the class of salts, substances which the mass of mankind will still consider as belonging to it, we assemble under one name combinations opposite in their properties, and destitute of the qualities usually deemed indispensable to the class. Thus under the definition that every compound of an acid and a base, is a salt, we must attach this name to marble, gypsum, felspar, glass, and porcelain, in common with Epsom salt, Glauber's salt, vitriolated tartar, pearlash, &c. But admitting that these objections are not sufficient to demonstrate the absurdity of defining a salt, as a compound of an acid and a base, of what use could such a definition be, when, as I have premised, it is quite uncertain what is an acid, or what is a base. To the word acid, different meanings have been attached at different periods. The original characteristic sourness, is no longer deemed essential! Nor is the effect upon vegetable colours treated as an indispensable characteristic. And as respects obvious properties, can there be a greater discordancy, than that which exist between sulphuric acid, and rock crystal; between vinegar, and tannin; or between the volatile, odoriferous, liquid, poison, which we call prussic acid, and the inodorous, inert, concrete, material for candles called margaric acid?

While an acid is defined to be a compound capable of forming a salt with a base, a base is defined to be a compound, that will form a salt with an acid. Yet a salt is to be recognised as such, by being a compound of the acid and base, of which, as I have stated, it is made an essential mean of recognition.

An attempt to reconcile the definitions of acidity given by Berzelius, with the sense in which he uses the word acid, will in my apprehension, increase the perplexity.

It is alleged in his Treatise, p. 1, Vol. II, "*that the name of acid is given to silica, and other feeble acids, because they are susceptible of combining with the oxides of the electropositive metals, that is to say, with salifiable bases, and thus to produce salts, which is precisely the principal character of acids.*" Again, Vol. I, page 308, speaking of the *halogene* elements, he declares that "their combinations with hydrogen, are not only acids, but belong to a series the most puissant that we can employ in Chemistry; and in this respect they rank as equals with the strongest of the acids, into which oxygen enters as a constituent principle." And again, Vol. II, page 162, when treating of hydracids formed with the halogene class, he alleges "*The former are very power-*

ful acids, truly acids, and perfectly like the oxacids; but they do not combine with salifiable bases; on the contrary, they decompose them, and produce haloid salts."

In this paragraph, the acids in question are represented as pre-eminently endowed with the attributes of acidity, while at the same time they are alleged to be destitute of his "*principal character of acids*," the property of combining with salifiable bases.

In page 41, (same volume) treating of the acid consisting of two volumes of oxygen and one of nitrogen, considered by chemists generally as a distinct acid, Berzelius uses the following language. "If I have not coincided in their view, it is because, judging by what we know at present, the acid in question cannot combine with any base, either directly or indirectly, that consequently it does not give salts, and that salifiable bases decompose it always into nitrous acid,* and nitric oxide gas. It is not then a distinct acid, and as such, ought not to be admitted in the nomenclature." Viewing these passages with all that deference which I feel for the productions of the author, I am unable to understand upon what principle the exclusion of nitrous acid from the class of acids, can be rendered consistent with the retention, in that class, of the compounds formed by hydrogen with "*halogene*" elements.

Having thus endeavoured to show that the words acid, salt, and base, have not been so defined as to justify their employment as a basis of the Berzelian nomenclature, I will with great deference proceed to state my objections to the superstructure, erected upon this questionable foundation. Consistently with the French nomenclature, the combinations formed by electronegative principles, with other elements, have been distinguished as *acids*, or characterized by a termination in "*ide*," or in "*ure*," which last monosyllable, when there has been no intention of altering the meaning, has, by the British chemists, been translated into *uret*. The termination in *ide*, which is common to both languages, is, by Thenard, and other eminent French authors, restricted to the binary compounds of oxygen, which are not acid. Analogous compounds formed with the "*halogene*" elements, chlorine, bromine, fluorine, iodine, cyanogen, &c., have by the same writer been designated by the termination in *ure*. Thus we have in his work, chlorures, bromures, fluorures, iodures, cyanures. Some of the most eminent chemists in Great Britain, have distinguished the elements called halogene, by Berzelius, together with oxygen, as supporters of combustion; and have designated the binary compounds made with them, when not acid, by the same termination as the analogous compounds of oxygen. Accordingly in their writings, instead of the names above mentioned, we have chlorides, bromides, fluorides, iodides. In Henry's Chemistry, cyanure is represented by cyanide; in Thomson's, by cyanodide, and in Brande's and Turner's, by cyanuret.

The term *uret*, equivalent as above mentioned to the French

* Hyponitrous acid of other chemists.

ure, is restricted by the English chemists to the compounds formed by non-metallic combustibles, either with each other, or with metals. Hence we have in English, sulphurets, phosphurets, carburets, borurets, for sulphures, phosphures, carbures, borures, in French.

Berzelius classes as electronegative, all those substances which go to the positive pole when isolated, or *when in union with oxygen*, while all substances are by him treated as electropositive which go to the negative pole, either when isolated, or when in union with oxygen.* (See Vol. 1st, page 201.)

According to his nomenclature, when both the ingredients in a binary compound belong to the class of bodies, by him designated as electronegative, the termination in ide, is to be applied to the more electronegative ingredient; but where one of the ingredients belongs to his list of electropositive bodies, the termination in ure, (uret, in English) is to be applied to the electronegative ingredient. As, agreeably to the prevailing nomenclature, which in this respect, the great Swedish chemist has not deemed it expedient to change, the electropositive compounds of oxygen with radicals, forming electropositive bases, have each a termination in ide, it seems that consistency requires us, conformably with the English practice, to designate in like manner analogous electropositive compounds of the electronegative elements called by him "*halogene*." But especially it would be inconsistent not to put the same mark upon the compounds of substances which from their analogy with oxygen are placed in the same "*amphigene*" class. If there were insuperable reasons for retaining the term oxide, as a generic name for the electropositive compounds of oxygen, it seems to me inexpedient not to employ the words sulphide, selenide, and telluride, to designate the electropositive compounds of sulphur, selenium, and tellurium. And since the three last mentioned elements when united with hydrogen, form electronegative compounds which act as acids, why not treat them as such, under appellations corresponding with those heretofore used for that purpose?

I conceive the following definitions to be justified by the practice of modern chemists in general, as established in the case of oxacids and oxibases. *When two compounds capable of combining with each other to form a tertium quid, have an ingredient common to both, and one of the compounds prefers the positive, the other the negative pole of the voltaic series, we must deem the*

* The term isolated, is employed to convey an idea of the state in which the elements of water are, when after having been separated by the voltaic wires, they are severally on their way to their appropriate poles, that is, the oxygen proceeding to the positive pole, and the hydrogen to the negative pole. Each element is in that case isolated, and obedient to the attractive influence of one of the poles. When a salt containing an oxacid and an oxybase, is decomposed, the acid will go to the positive, and the base to the negative pole. The radical of the acid, in consequence of its not counteracting the propensity of the oxygen for the positive pole, is deemed electronegative; while the radical of the base overcoming that propensity, is deemed electropositive.

former an acid, the latter a base. And again, all compounds having a sour taste, or which redden litmus, should be deemed acids in obedience to usage.

I should think it preferable, if in adopting these definitions, the termination in *ide* was considered as applicable to all compounds of electronegative principles with other substances, whether producing electronegative or electropositive combinations, and that the terms acid, and base, should be considered as severally indicating the subordinate electronegative, and electropositive compounds. In that case oxybase, chloribase, fluobase, bromibase, iodobase, cyanobase, sulphobase, telluribase, selenibase, would stand in opposition to oxacid, chloracid, fluacid, bromacid, iodacid, cyanacid, sulphacid, selenacid, telluracid; yet for convenience, the generic termination *ide* might be used without any misunderstanding; and so far, the prevailing practice might remain unchanged. Resort to either appellation would not, agreeably to custom, be necessary in speaking of salts or other compounds analogous to them; since it is deemed sufficient to mention the radical as if it existed in the compound in its metallic state. Ordinarily we say, sulphate of lead, not sulphate of the oxide of lead. This last mentioned expression is resorted to, only where great precision is desirable. In such cases, it might be better to say sulphate of the oxybase of lead. So long however as the electronegative combinations of oxygen are designated as oxacids, and the electropositive as oxides, it seems to be incorrect, not to use analogical terms in the case of analogous compounds, formed by the other pre-eminently electronegative principles; and assuming the definition above stated, to be justified by modern practice, it follows, that in order to entitle the electronegative and electropositive ingredients of the double salts of Berzelius, to be classed, the latter as bases, and the former as acids, it is not necessary to appeal to the highly interesting and important experiments of Bonsdorf, confirmed in some instances by the testimony of Berzelius himself, proving that the attributes of acidity (as heretofore defined) exist in the one case, and those of alkalinity in the other. My definition is founded upon the conviction that these characteristics have not latterly been deemed necessary to acids, and that in bases, they never were required; having, as respects them, only served as a means of subdivision, between alkaline oxides and other bases.

Chemistry owes to Berzelius much valuable information respecting the compounds formed by the substances which he calls "*halogene*;" especially respecting the combinations formed by fluorine, with boron, and silicon, and the "*double salts*," as he considers them, formed by the union of two "*halogene salts*," &c. While in the highest degree interested in the facts which he has ascertained, it will be inferred from the premises, that I do not perceive that any adequate line of distinction can be drawn in this respect between the simple salts formed by oxacids and oxybases; and the *double* salts formed by his "*halogene*" elements.—Agreeably to the definition which I have ventured to propose, in a combination of this

kind, the electronegative salt would play the part of an acid, while the electropositive salt would perform that of a base.

In common with other eminent chemists, he has distinguished acids in which oxygen is the electronegative principle, as *oxacids*, and those in which hydrogen is a prominent ingredient as *hydracids*. If we look for the word radical, in the table of contents of his invaluable Treatise, we are referred to p. 218, vol. 1st., where we find the following definition, "*the combustible body contained in an acid, or in a salifiable base, is called the radical of the acid, or of the base.*"—In the second vol. page 163, he defines hydracids to be "those acids, which contain an electronegative body, combined with hydrogen;" and in the next page it is stated, that "hydracids are divided into those which have a simple radical, and those which have a compound radical. The second only comprises those formed with cyanogen and sulphocyanogen." Again, in the next paragraph, "no radical is known that gives more than one acid with hydrogen, although sulphur and iodine, are capable of combining with it in many proportions. If at any future day more numerous degrees of acidification with hydrogen, should be discovered, their denomination might be founded on the same principles as those of oxacids." Consistently with these quotations, all the electronegative elements forming acids with hydrogen, are radicals, and of course by his own definition, combustibles; while hydrogen is made to rank with oxygen as an acidifying principle, and consequently is neither a radical nor a combustible. Yet page 189, vol. 2d, in explaining the reaction of fluoboric acid with water, in which case, fluorine unites both with hydrogen and boron, it is mentioned as one instance among others in which fluorine combines with *two combustibles*.

I am of opinion that the employment of the word hydracid, as co-ordinate with oxacid, must tend to convey that erroneous idea, with which, in opposition to his own definition, the author seems to have been imbued, that hydrogen in the one class, plays the same part as oxygen in the other. But in reality, the former is eminently a combustible, and of course the radical, by his own definition.

Dr. Thomson, in his system, does not recognise any class of acids, under the appellation of hydracids; but with greater propriety, as I conceive, places them under names indicating their electronegative principles. Thus he arranges them as oxygen acids, chlorine acids, bromine acids, iodine acids, fluorine acids, cyanogen acids, sulphur acids, selenium acids, and tellurium acids.* Those appellations might, I think, be advantageously abbreviated into oxacids, chloracids, fluacids, bromacids, iodacids, cyanacids, sulphacids, selenacids, telluracids.

As respects the acids individually, I conceive that it would be preferable, if the syllable indicating the more electronegative ele-

* I had formed my opinions on this subject, before I was aware that Dr. Thomson had resorted to this classification.

ment had precedence in all, as it has in some cases. The word hydrofluoric does not harmonize with fluoboric, fluosilicic, fluochromic, fluomolybdic, &c. Fluorine being in each compound the electronegative principle, the syllables indicating its presence, should in each name occupy the same station. These remarks will apply, in the case of acids formed with hydrogen, by all principles which are more electronegative. Hence we should use the terms chlorohydric, fluohydric, bromohydric, iodohydric, cyanhydric, instead of hydrochloric, hydrofluoric, hydrobromic, hydriodic, hydrocyanic.

These opinions, conceived last summer, were published by me in the *Journal of Pharmacy* for October last. Since then, I find that in the late edition of his *Traité*, Thenard has actually employed the appellations above recommended.

As by the British chemists the objectionable words have not been definitively adopted; the appellations muriatic and prussic, being still much employed, it may not be inconvenient to them to introduce those which are recommended by consistency. In accordance with the premises, the acids formed with hydrogen by sulphur, selenium, and tellurium, would be called severally sulphydric, selenhydric, and telluhydric acid. Compounds formed by the union of the acids thus designated, with the bases severally generated by the same electronegative principles, would be called sulphhydrates, selenhydrates, and telluhydrates, which are the names given to these compounds in the Berzelian nomenclature. Influenced by the analogy, a student would expect the electronegative ingredient of a sulphhydrate to be sulphydric acid, not a sulphide. The terminating syllable of this word, by its associations, can only convey the conception of an electropositive compound.

By adhering to the plan of designating each acid by its most electronegative ingredient, the compounds of hydrogen and silicon, or of hydrogen and boron with fluorine, would appear in a much more consistent dress. In the compound named hydrofluoboric acid, and that named hydrofluosilicic acid by Berzelius, fluorine is represented as acting as a radical with hydrogen, while with boron and silicon it acts as the electronegative principle. It has been shown that hydrogen, no less than boron and silicon, must be considered as a combustible, and of course a radical. This being admitted, if the compounds in question are really entitled to be considered as distinct acids, their names should respectively be fluohydroboric, or fluohydrosilicic acid. But as I have elsewhere observed an incapacity to combine with bases, or to react with them without decomposition, is made by Berzelius an adequate reason for expunging the compound formed by one atom of nitrogen with four atoms of oxygen from the list of the acids of nitrogen. I do not, therefore, understand how the compounds referred to, while equally incapable of combination, can be considered by him as acids. At first it struck me that the liquids consisting of fluohydric acid, either with fluoboric acid, or with fluosilicic acid, might be considered as merely united by their common attraction to

water, since they separate when this liquid is abstracted by evaporation. Upon reflection, however, I retract that opinion, since it appears to me that if the compounds in question are to be considered as acids, they may be viewed satisfactorily as fluacids with a double radical; but I deem it more consistent to suppose that a fluobase of hydrogen in the one case unites with fluoboric acid, in the other, with fluosilicic acid; so that fluohydroboric acid might be called fluoborate of the fluobase of hydrogen, or more briefly fluoborate of hydrogen; and in like manner fluohydrosilicic acid would be called fluosilicate of the fluobase of hydrogen, or briefly fluosilicate of hydrogen.

There are instances in which compounds, usually called bases, act as acids. Of course it is consistent that compounds, usually called acids, should in some instances act as bases. In this respect a striking analogy may be observed between the union of the oxide of hydrogen (water) with the oxacids and oxybases; and that of fluoride of hydrogen with fluacids and fluobases. According to Berzelius, water, in the first case, acts as a base, in the second as an acid. So I conceive the fluoride of hydrogen acts as a base in the cases above noticed, while it acts as an acid in the compound of hydrogen, fluorine, and potassium, called by Berzelius "*fluorure potassique acide*." This compound I would call a fluohydrate of the fluobase of potassium, or more briefly fluohydrate of potassium, as we say sulphate of copper, instead of the sulphate of the oxide (or oxybase) of copper. It appears from the inquiries of the author of the nomenclature under consideration, that each of the three acids abovementioned as formed by fluorine, with the three different radicals, hydrogen, boron, and silicon, is capable, with electropositive metallic fluorides, of forming the compounds treated of by him as double salts. These compounds, to which I have already alluded, might be called fluohydrates, fluoborates, or fluosilicates of the metallic ingredient. As for instance, the compound into which potassium enters, named by him "*fluorure borico potassique*," I would designate as a fluoborate of the fluoride (or fluobase) of potassium, or for the sake of brevity, fluoborate of potassium. "*Fluorure silico potassique*," would by the same rule, be called fluosilicate of potassium.

The illustration thus given in the instance of potassium, renders it unnecessary to furnish other examples, as it would only require that the name of any other metal should be substituted for that of potassium, in order to modify these appellations, so as to suit every case.

Pursuant to my fundamental definition, ferropotassium cyanide, cyanure ferroso potassique in the Berzelian nomenclature, should be considered as a compound of cyanoferric acid, and a cyanide or cyanobase of potassium, and would of consequence be a cyanoferrate of potassium. Or if the iron be in two different degrees united with cyanogen, as the names cyanure ferroso potassique, and cyanure ferrico potassique indicate, we should have both a cyanoferrite and a cyanoferrate of potassium; and of course cyano-

ferrous and cyanoferric acid for their respective electronegative ingredients. "Cyanure ferrique acide" would be exchanged for cyanoferrate of hydrogen, being a case analogous to that of the "fluorure potassique acide" above considered and provided for.

If I am justified in my impression above stated, water, and the compound formed by fluorine with hydrogen ("hydrofluoric acid" or fluohydric acid as I prefer to call it) should be severally designated as acids when they act as acids; as bases, when they act as bases. In other cases the one might be designated as an oxide, the other as a fluoride, of hydrogen. In the case of a compound so well known as water, I would adhere to the common name, resorting to the scientific names only as definitions. Thus water would be defined as an oxide of hydrogen, which in some combinations, acts as an oxybase of hydrogen, in others as hydric acid, or the oxacid of hydrogen.*

After designating as metalloids all non-metallic bodies, Berzelius alleges (page 203, vol. 1st,) that they are divided into oxygen, and bodies which are *combustible*, or *susceptible of combining with oxygen*; in which process the greater part display the ordinary phenomena of combustion, or, in other words, of fire. Agreeably to this classification, susceptibility of union with oxygen and combustibility are confounded; to which I object, because oxidizement frequently ensues without combustion, and combustion occurs often without oxidizement.

Speaking of chlorine, (Treatise, p. 276, vol. I.) it is alleged that it supports the combustion of a great number of bodies, of which a majority ignite in it at ordinary temperatures. If oxidizement be identical with combustion, how can this word be employed with propriety in the case thus quoted, where oxygen is not present? If combustion in the case of chlorine is applied only to those instances in which reaction with other bodies is attended by the phenomena of fire, why is not the term equally restricted in its application in the case of oxygen?

Oxygen differs so far from the substances usually called combustibles, that they will produce fire with oxygen, and with but few, if any other substances; while oxygen will produce fire with many substances. But this characteristic of producing fire with many substances, applies to chlorine, and as chlorine does not produce fire with oxygen, it is devoid of the only characteristic which should entitle it to be treated as a combustible, if combustibility and susceptibility of union with oxygen be identical.

Hence, if it be deemed proper in the case of oxygen to place the bodies with which it enters into combustion in one class, designated as combustibles, while oxygen is distinguished as the common "*comburant*" of them all, there is equal reason for placing

* The use which I have made of the terminations in *ide*, in fluoride of hydrogen, or oxide of hydrogen, to signify a compound of hydrogen with fluorine, or oxygen generally, without conveying the idea of its being either a base or an acid, illustrates the advantage which would result from the use of that termination in that broad sense.

chlorine in a like predicament. The impropriety of designating the substances comprised in his halogene and amphigene classes, with the exception of oxygen as combustibles, upon the basis of their susceptibility of oxidizement, must be evident from the fact, that fluorine is not oxidizeable, while it is so perfectly analogous to the others, especially chlorine, in its properties, that it would be disadvantageous to class it apart.

Berzelius objects to the use of the word "*comburant*," (equivalent to the English word supporter) upon the ground that the same substance may alternately be a supporter and a combustible. I should, however, go farther, and likewise object to the use of both words, as tending to convey the erroneous impression, that in combustion, one of the ponderable agents concerned, performs a part more active than the other; whereas, in all such cases, the reaction must evidently be reciprocal and equal. I have repeatedly shown to my pupils, that a jet of oxygen burns in an atmosphere of hydrogen, as well as a jet of hydrogen similarly situated in oxygen.

I would recommend that all the bodies comprised in the halogene and amphigene classes of Berzelius, should be placed under one head, to be called the basacigen class; indicating their common and distinguishing quality agreeably to the premises, of producing both acids and bases. The electronegative compounds of these substances to be called acids, their electropositive compounds, bases, as already suggested.*

* Since the preceding letter was ready for the press, the following remark of Berzelius attracted my attention, as sanctioning indirectly the definition which I have proposed, page 5.

Treatise, Vol. 3, page 323, he alleges—"It follows from this that the property of playing the part of an acid, is attached neither to the substance, nor to the manner in which the combination takes place. *It only indicates a state contrary to the property of being a base.*"

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