Perkins & Heath. Patent Hardened Steel Plate.

PINNOCK'S
Catechism
OF
ELECTRICITY
Being an easy Introduction to that
Science

LONDON;

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A

CATECHISM

OF

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BEING A

Short Introduction to that Science;

WRITTEN

IN EASY AND FAMILIAR LANGUAGE.

Intended for the Use of Young People.

THIRD EDITION.

LONDON:

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CATECHISM OF ELECTRICITY.

CHAPTER I.

History of Electricity.

Question. What is Electricity?

Answer. Electricity treats of the *phenomena* exhibited by the operations of a very *subtile* fluid, which is one of the principal agents in nature.

Q. Whence is the term Electricity derived?

A. It is derived from the Greek word *electron*, or amber.

Q. Why was it so termed?

A. Because the attractive power which electric bodies acquire by *friction*, was first observed in amber.

Q. Was electricity known to the ancients?

A. The ancients were certainly acquainted with that attractive power which amber acquired by friction, but they do not appear to have followed up this discovery, nor to have entertained any idea of those electric properties, which the persevering inquiries of the moderns have brought to light.

Phenom'ena, *s.* extraordinary appearances.
Sub'tile, *a.* fine, delicate, insinuating.
Fric'tion, *s.* rubbing.

Q. Who among the moderns have been most celebrated for discoveries in this science?

A. It would be tedious to enumerate all who have become celebrated as electricians; the principal among our own countrymen were, Mr. Boyle, Mr. Hawksbee, Mr. Grey, and Dr. Priestley*.

Q. For what discoveries in Electricity was Mr. Boyle celebrated?

A. Mr. Boyle was the first who observed that diamonds after having been rubbed, afforded light in the dark; this he discovered to be the electric light.

Q. What were the principal discoveries of Mr. Hawksbee?

A. Mr. Hawksbee first discovered the great electric power of glass; and likewise the power which electric bodies possessed, when excited by friction, of communicating an unpleasant sensation to the hand that touched them.

Q. What discoveries rendered Mr. Grey celebrated as an electrician?

A. Mr. Grey discovered, that glass, when excited, possessed the property of communicating its power of attraction to other substances, and that this power could be conveyed in any direction. He likewise was the first to discover that some bodies possessed the power of *transmitting* the electric fluid, while others did not; the former

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Transmit'ting, *part.* sending forward.

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* To these may be added Dr. Franklin, who, though a resident in America, was, for some time, a British subject, and the author of many valuable discoveries in this science.

therefore he named conductors, the latter non-conductors.

Q. What has rendered Dr. Priestley celebrated in this science?

A. Dr. Priestley has contributed greatly to the improvement of electrical apparatus, and pointed out a variety of ways in which the electric fluid may be employed as a powerful agent, both in the chemical and medical departments.

Q. Have there been no eminent electricians since Dr. Priestley?

A. Too many to be here enumerated; some of their most important discoveries will however be mentioned in the course of this Catechism.

Q Have not the English philosophers been greatly assisted by the learned in foreign countries, in bringing this science to the perfection that it has now attained?

A. Yes.

Q. Who among them were the most celebrated?

A. Otto Guericke, of Magdebourg; Du Fay, Nollet*, and Volta, in France; Beccaria and Galvani, in Italy; M. Von Kleist, the inventor of the Leyden Phial, in Germany, and many others.

CHAP. II.

Of the General Principles of Electricity.

Q. WHAT is the Electric Power?

A. The Electric Power is the effect of some

* Pronounced *Nollé.*

matter in an active state, either within or round the electrified body.

Q. How is this ascertained?

A. If we place our hands or face before an excited tube of glass, or before an *insulated* conductor when electrified, we shall distinctly feel *emanations* and hear a weak noise; in the dark we shall perceive sparks of bright light, streaks of rays, or small flashes.

Q. What may we infer from these phenomena?

A. As it is certain that these impressions upon our senses can be made only by matter, we may conclude, that every electrified body is surrounded by some matter in motion, which is the immediate cause of all the electric phenomena, and is what we call the electric fluid.

Q. What are the origin and nature of the Electric Fluid?

A. The origin and nature of the Electric Fluid have never been with certainty ascertained. It is, however, generally agreed, that it has a strong *analogy* with the matter of heat and light, and that fire, light, and electricity, are only three different effects from the same essence.

Q. What reasonings may be used in support of this idea?

A. 1. Both heat and electricity are best excited by friction. 2. That the same substances which are good conductors of heat, as metals, &c. are good conductors of electricity also. 3. The pulse and perspiration of animals are increased

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In'sulated, *a.* cut off from all communication with other substances, as will be explained hereafter.

Emana'tion, *s.* something that flows from a substance.

Anal'ogy, *s.* a similarity or likeness.

by electricity, as well as by heat. 4. Combustible substances may be set on fire by the electric spark; and metals can be melted by it. 5. The light emitted by the electrical apparatus, has all the properties of that transmitted from the sun. 6. Light moves with almost infinite swiftness, and so does the electric fluid.

Q. Are there not some objections to the *theory*, that heat and electricity are the same?

A. Yes; 1. The electric fluid may be perceived by the smell, which heat cannot. 2. Electricity will not melt congealed bodies, as ice, &c. 3. Electricity will not pass through certain bodies, which are therefore called non-conductors, but heat will. 4. Electricity does not warm the body electrified.

Q. What may we *deduce* from these facts?

A. That if the basis of the electric matter be radically the same as the matter of light and heat, it retains some other matter in combination with it, with which we are unacquainted.

Q. How are electrical phenomena produced?

A. Electrical phenomena are produced by friction and by communication.

Q. How may Electricity be excited by Friction?

A. If a dry glass tube be rubbed with a piece of dry silk, and a downy feather, or a ball made of the pith of elder, be presented to it, it will be first attracted, and then repelled: sealing-wax rubbed with new and soft flannel, will produce the same effect.

The'ory, *s.* doctrine.
Dedu'ce, *v.* to draw, to infer.

Q. How is this produced by friction?

A. By friction the electrical fluid, a certain quantity of which is supposed to exist in all bodies, is put in action, and becomes perceptible by our senses.

Q. How is it produced by Communication?

A. By presenting the body to which the electricity is to be communicated, to the excited tube; if the electricity remain near the end or part presented, the body is called a non-conductor, or electric; if the electricity be communicated to every part, it is called a conductor, or non-electric.

Q. When is a body said to be Insulated?

A. A body is said to be Insulated when it communicates with nothing but electric, as when it is placed upon glass pillars, on wax, or resin, or any other non-conducting substance.

Q. Can a conductor be electrified while it communicates with the earth?

A. No; for while the conductor communicates with the earth, either by immediately touching it, or by the interposition of other conductors, the electricity is conveyed from it to the earth, as fast as it is excited.

Q. What substances are the best conductors?

A. The following is a list of the best conductors, beginning with those that are least so, and going on progressively to the best of their class.

Smoke; steam; earthy substances; most *saline* substances; ice and snow; water, and all other fluids except oil; blood, milk, and other fluids of

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Sal'ine, *a.* of the nature of salt.

the animal body; charcoal; metallic ores; the semi-metals; all the metals in the following order: lead, quicksilver, tin, iron, brass, platina, silver, gold; thus the worst conductor in this list is smoke, and the best gold.

Q. What are the best Electrics, or Non-Conductors?

A. The best Electrics, or Non-Conductors, are most hard stones; ashes of animal and vegetable substances; oils and metallic oxides; dry air; loaf sugar; paper; feathers; wool; hair; &c.; silk and cotton; wax; all resinous substances; sulphur; amber; precious stones; glass: thus hard stones are the worst electrics, and glass the best.

Q. Do not circumstances sometimes change a conductor to a non-conductor, and the contrary?

A. Yes; a piece of green wood is a conductor; when baked it is a non-conductor; formed into charcoal it is again a conductor, but when reduced to ashes, the electric fluid cannot pass through it.

CHAP. III.

Of the Electrical Apparatus.

Q. Of what does the Electrical Apparatus principally consist?

A. The Electrical Apparatus principally consists of an electrical machine, conductors, Leyden phial, a discharging rod, a battery; an elec-

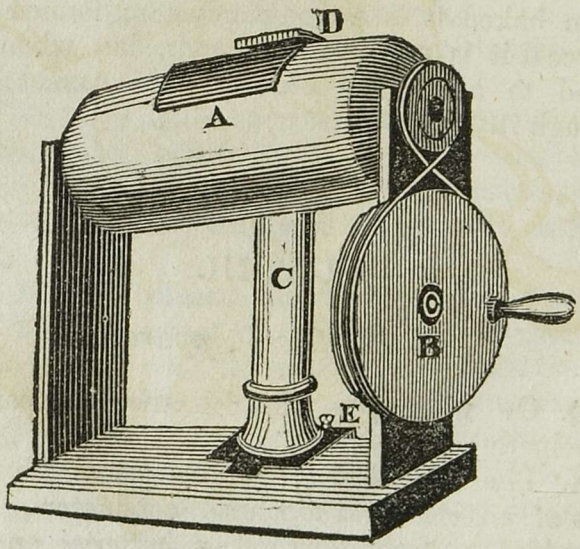
trometer; a universal discharger; and many other instruments for the purpose of making particular experiments.

Q. What is the Electrical Machine?

A. Electrical Machines are of two sorts; the cylindrical and the plate machine.

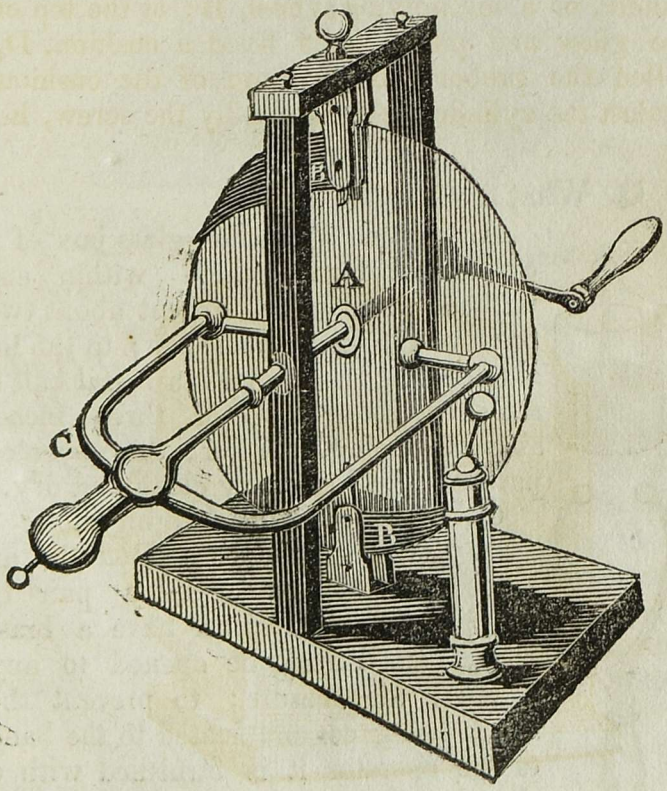
Q. Describe the Cylindrical Machine.

A. The Cylindrical Machine consists of a cylinder of glass from 8 to 16 inches in diameter, and from 12 to 24 inches long, A, turning between two upright supports, either with a simple handle, or a multiplying wheel, B; at the top of the glass and pillar, C, is fixed a cushion, D, called the rubber; the pressure of the cushion against the cylinder is regulated by the screw, E.



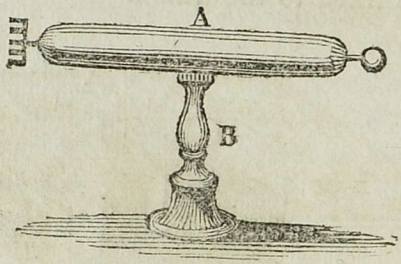
Q. Describe the Plate Machine.

A The Plate Machine consists of a circular plate of glass, A, turning on an axis that passes through its centre; it is rubbed by two pairs of cushions, B B, at the top and bottom of the frame, which are made to press the glass plate between them with any degree of force, by means of regulating screws; a brass conductor, C, supported by glass, is fixed to the frame.

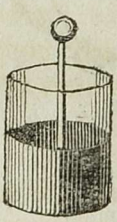


Q. Describe the Conductor.

A. The Prime Conductor, or as it is sometimes called, the Positive Conductor, A, is made of metal, and supported by a glass pillar, B; at one extremity it is furnished with pointed wires, for the purpose of receiving the electric fluid from the cylinder, and at the other with a knobbed wire to communicate it.



Q. What are Leyden Phials?



A. Leyden Phials are glass jars of a cylindrical form, coated within and without with tinfoil, except about two or three inches from the top; to the inside coating a wire with a metal ball is attached, rising two or three inches above the top of the jar; the uncoated part must be kept very clean and dry.

Q. What is the discharging Rod?

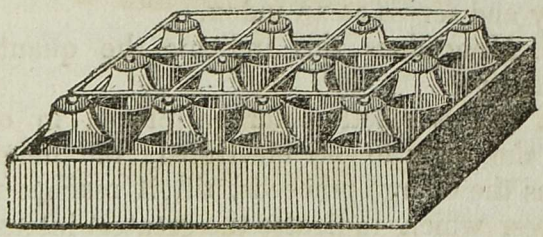
A. The Discharging Rod is an instrument of brass, like a pair of forceps; the extremities have a brass knob, and it may be opened to any distance at pleasure; to prevent the shock being communicated to the hand of the operator it is furnished with a glass handle.

Q. What is a Battery?

A. A Battery is a number of Leyden phials connected together in a box, to increase the force of the electric explosion.

Q. Describe its construction.

A. The figure below represents a battery of twelve jars, connected by means of brass rods; the bottom of the box that contains these jars is lined with tin-foil.



Q. What is an Electrometer?

A. An Electrometer is an instrument for ascertaining the presence of electricity in any body, and the quantity of that fluid with which it is charged.

Q. Describe an Electrometer.

A. The simplest kind of Electrometer is made by suspending two small balls of cork or the pith of elder, by silk threads; these, when touched by an electrified body, will *diverge*, according to the degree of which, a judgment is formed of the quantity of electricity contained in the electrified body.

Q. Is there not an instrument for determining exactly the quantity of electricity with which any substance is charged?

A. Yes; the quadrant electrometer is used for this purpose.

Diver'ge, *v.* to separate in opposite directions.

Q. Describe it.

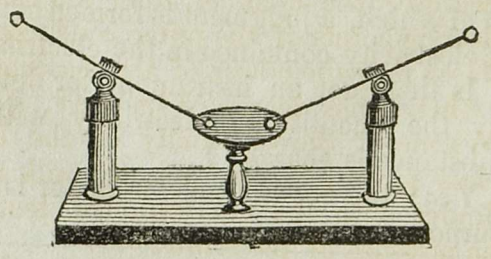
A. It consists of a smooth round stem about seven inches long, with a ball on its top; immediately under this ball is a semicircle of ivory, the lower half of which is divided into ninety degrees; in the centre of the semicircle a pin is fixed, on which a thin piece of cane, four inches long, with a ball at its lower end, turns freely and serves as an index.

Q. How does this indicate the quantum of electricity?

A. If this electrometer be placed in contact with the body to be electrified, the index will rise as the charge proceeds, till it reaches ninety degrees, which indicates the greatest intensity of electricity.

Q. What is the Universal Discharger?

A. The Universal Discharger consists of a mahogany board, fourteen inches long, and four wide, with a small table standing on a glass leg in its centre; two wires, sliding in spring tubes, and mounted on universal joints, are fixed at the top of two glass pillars, cemented to the board at equal distances from the centre.



CHAP. IV.

On the manner of Using the Electrical Apparatus.

Q. How is the electrical machine to be excited?

A. To excite an electrical machine effectually, it is necessary first to discover those parts of the cushion which press against the glass cylinder, and apply to them an amalgam composed of quicksilver, five parts, and zinc, one part, melted together with bees wax; the silk must be greased before the amalgam is applied.

Q. How may the parts of the cushion which press the cylinder be discovered?

A. Draw a line, with whiting dissolved in spirit of wine, on the cylinder; on turning it the whiting is deposited on the cushion, and marks those parts which rub against the cylinder; on those parts only the amalgam is to be applied.

Q. What other preparations are necessary?

A. As air not only resists the emission of the electric fluid, but also dissipates that which is collected, a piece of black or oiled silk should be placed over the cylinder, from the cushion to the collecting points of the prime conductor.

Q. How may the power of the machine be renewed when it has decreased by use?

A. Whenever the electricity of the cylinder grows less powerful, turn back the silk and rub the cylinder with the amalgamated leather, or alter the pressure of the screw.

Q. How may the electric power of the cylinder be increased?

A. Rub the cylinder with a coarse cloth a little greased, and wipe it with a clean cloth; or place a little tallow over the amalgam.

Q. How is the Prime Conductor used?

A. The Prime Conductor is used to collect the electric fluid from the cylinder, and communicate it to other bodies; for this purpose the end which has the pointed wires is placed near the cylinder; and to the other chains, wires, and other articles of apparatus are sometimes attached.

Q. How is the Leyden Phial used?

A. Place the jar on a table, or any other non-electric that communicates with the earth, and the knob on the top one-eighth of an inch from the ball of the conductor: on turning the machine, sparks will pass from the conductor to the jar; when no more sparks pass, the jar is charged: it may then be discharged by the discharging rod.

Q. How is the discharging rod used?

A. Open the forceps and apply one knob to the outside coating, and the other to the ball of the jar; an explosion will instantly ensue, with a force proportioned to the quantity of electricity with which the jar was charged.

Q. How is the Battery used?

A. A Battery serves merely to increase the power of the electric shock, by discharging at the same moment a number of jars connected together; it is done in the same manner as the single jars.

Q. Are not some precautions necessary in using a battery?

A. Yes; in charging a battery an explosion sometimes takes place *spontaneously* before any considerable charge can be given; to prevent this, a slip of writing paper, an inch wide, should be pasted round the inside of each jar immediately above the coating; an electrometer should be placed on every battery while charging to indicate the progress of the operation.

Q. How is the Universal Discharger used?

A. The body, through which the operation is intended to be passed, is placed on the table; the sliding wires are then brought in *contact* with its opposite sides, and one of them being connected with the outside of a jar, or battery, and the other with the discharging rod, the charge is sent through it with great accuracy.

CHAP. V.

Of Positive and Negative Electricity.

Q. Does the electric fluid always produce the same effects?

A. It was early observed that the electricity excited by the friction of glass, and that produced by the rubbing of wax, appeared different, and mutually destroyed each other; the former

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Sponta'neously, *ad.* of its own accord.
Con'tact, *s.* touch.

therefore was called the *vitreous*, the latter, the *resinous* electricity.

Q. How may this difference be proved?

A. Bring excited glass in contact with the electrometer made by pith balls suspended by silken strings, and they will immediately diverge; but on the application of excited wax they will instantly close again: the same phenomena will appear if the experiment be reversed, by applying the wax first; if the glass and wax, when excited, be applied together, no effect will be produced.

Q. Are there really two kinds of electricity?

A. No: these appearances are produced in consequence of some bodies possessing a *superfluous* quantity of the electric fluid, while others have less than their proper share; the former is therefore said to be in a positive state, or charged with positive electricity; the latter to be in a negative state, or charged with negative electricity.

Q. How may this be proved?

A. Place a Leyden jar, as before directed, on some conducting substance communicating with the earth, and charge it; the inner coating, by being insulated, will have received a great increase of electricity; but the fluid will pass from the outer coating to the earth, and leave it in the negative state; as soon as the communication is

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Vit'reous, *a.* belonging to glass.

Res'inous, *a.* of the nature of resin, of which sealing-wax is partly composed.

Super'fluous, *a.* more than is natural or necessary.

formed by the discharging rod, an explosion takes place by the sudden passage of the superfluous fluid from the inside coating, to that of the outside, by which the *equilibrium* is restored.

Q. What further experiment may be made in support of this doctrine?

A. Place the jar on an insulated stand (suppose a stand with glass legs, or a cake of wax) bring the coating in contact with the conductor, and turn the machine: on applying the discharging rod no explosion will ensue, as none of the electric fluid could pass off from the outside coating, and consequently an equilibrium will be maintained.

Q. Is the result of these experiments invariable?

A. No; trifling differences in the conditions of these experiments will occasion varieties in the result; thus a tube of rough glass will, by friction, excite negative electricity, while a smooth one produces positive; on the contrary, positive electricity is excited in a stick of sealing-wax, whose surface is scratched, while a smooth one produces negative.

The following is M. Cavelli's table of the effects produced by the friction of various substances:

	Is rendered	*By friction with*
The back of a cat	Positive	Every substance with which it has been hitherto tried.
Smooth Glass	Positive	Every substance hitherto tried except the back of a cat.

Equilib'rium, *s.* an equality of weight or measure.

	Is rendered	*By friction with*
Rough Glass .	Positive	Dry oiled silk, sulphur, metals.
	Negative	Woollen cloth, quills, wood, paper, sealing-wax, white-wax, the human hand.
Tourmalin . .	Positive	Amber, blast of air from bellows.
	Negative	Diamonds; the human hand.
Hare's Skin .	Positive	Metal, silk, loadstone, leather, hand, paper, baked wood.
	Negative	Other finer furs.
White silk . .	Positive	Black silk, metals, black cloth.
	Negative	Paper, hand, weasel's skin.
Black Silk . .	Positive	Sealing wax.
	Negative	Hare's, weasel's, and ferret's skin; loadstone, brass, silver, iron, hand, white silk.
Sealing wax .	Positive	Some metals.
	Negative	Hare's, weasel's, and ferret's skin; hand, leather, woollen cloth, paper, some metals.
Baked wood . .	Positive	Silk.
	Negative	Flannel.

Q. What may we infer from the foregoing observations?

A. From the foregoing observations we learn that positive and negative electricity are both produced in all cases of electrical excitement; and that these phenomena are not peculiar to any distinct class of bodies, but may be produced indifferently or *alternately*, by changing the materials or method of friction.

Alter'nately, *ad.* by turns.

CHAP. VI.

Of the Phenomena of Electricity.

Q. How may the Phenomena of Electricity be divided?

A. The Phenomena of Electricity may be divided into four classes: 1. The experiments which serve to illustrate electrical attraction and repulsion; 2. Those produced by the stream of electricity: 3. Those accompanied with luminous appearances; 4. The effects arising from concentrated electricity, in experiments with the Leyden phial, battery, &c.

Q. What occasions electrical attraction and repulsion?

A. The motion of light bodies, produced by electricity, and usually called attraction and repulsion, is occasioned by the mutual attraction existing between the electric fluid and common matter.

Q. Prove this by experiment.

A. Take a small downy feather, or pith ball, suspended by a metal thread, such as is used for gold lace, and holding the thread, bring the ball near an electrified conductor, either positive or negative, the object will be attracted by and adhere to the electrified conductor until its electricity is destoyed.

Q. How is it that the same effect is produced by the positive and negative conductor?

A. Because such bodies as are positively electrified, endeavour to impart their superabundant fluid to surrounding substances; while those that

are negatively electrified endeavour to acquire electric fluid; as soon as an equilibrium is obtained, attraction ceases.

Q. What experiment exhibits repulsion as well as attraction?

A. Let the ball, or feather, be supported by a silk thread; the light body will first be attracted to the electrified conductor, and will then recede from it; nor can it again be attracted until it has touched some insulated conducting substance.

Q. How may this be accounted for?

A. The light body being insulated by the non-conducting property of the silk, receives by contact with the electrified surface a similar electric state, it then recedes from that surface, and, if any uninsulated conductor be near, it is attracted by it, discharges its electricity, and is again attracted to the electrified surface as before: this will continue till the whole of the electricity is destroyed.

Q. Will the light body recede if no uninsulated conductor be near?

A. Yes; as it is attracted by the surrounding air.

Q. What inferences may we draw from these phenomena?

A. We may infer, 1. That bodies positively electrified in the same degree will recede from each other; their surplus electric fluid being attracted by the *ambient* air which is in its natural state.

2. Bodies negatively electrified in the same

Am'bient, *a.* surrounding.

degree will recede from each other, having an attraction for the natural electricity of the surrounding medium.

3. Bodies electrified either positively or negatively in different degrees, will be mutually attracted until their relative proportions of the electric fluid are equal, when they will recede from each other.

4. Positive and negative bodies will reciprocally attract each other, and if of equal intensity, be unelectrified by the contact.

Q. What farther experiments may be made on these principles?

A. 1. Suspend a brass plate from the conductor of an electrical machine, and a similar one at the distance of three or four inches beneath it, connected with the ground: on this put some figures of men or animals, cut in paper; as soon as the upper plate is electrified the figure will rise up and dance.

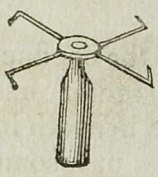
2. Place a pointed wire on the machine, electrify the inside of a dry glass tumbler by holding it over the wire and turning the machine; place some pith balls on the table, cover them with the glass, and they will be alternately attracted by the glass and the table, and continue their motion for some time.

3. Insulate two small bells on separate glass pillars at three-quarters of an inch distance from each other; suspend a clapper by a silk thread, midway between them; connect one of the bells with the conductor of the machine, and the other with the ground; the clapper will vibrate from one to the other, while the machine is in motion, producing an electric chime.

Q. How is the Stream of electricity produced?

A. What is usually called the Stream of electricity, is, in reality, a current of air produced in the following manner: if an electrified conductor having points on its surface, the air opposite those points is soon similarly electrified, recedes from them, and is replaced by other unelectrified particles, which also become electrical and recede; so that a current of air is constantly produced by an electrified point, and seems to issue from it.

Q. What experiment proves this?



A. This figure represents a cross made of wire, whose pointed extremities are bent in one direction; when this is balanced by its centre on a point, it turns swiftly round like the fly of a roasting jack.

Q. May not various machines be set in motion by the electric stream?

A. Yes; light models of wind and water-mills; an orrery, showing the revolutions of the planets with their satellites round the sun, may be set in motion by the current from a pointed conductor.

Q. From what general principles do these phenomena of motion result?

A. They uniformly result from the following simple principles; the attraction of the electric fluid from common matter; its tendency to equal diffusion, and the occasional interruption of these properties by the interposition of non-conductors.

CHAP. VII.

Of the Phenomena of Electricity, (continued.)

Q. Is light constantly attendant on electricity?

A. No; light is not constantly attendant on the excitation of electricity, but appears when that process is vigorously performed, and is then brilliant in proportion to its *intensity*.*

Q. In what form does electrical light usually appear?

A. Electrical light usually appears in the form of sparks or pencils of rays; but these appearances may be varied almost infinitely, and many amusing experiments performed.

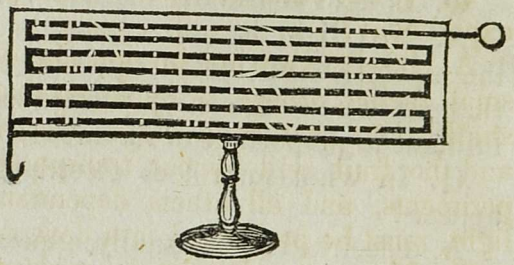
Q. Describe some of these experiments?

A. Take a tube of glass and pass a narrow strip of tin-foil round it in a spiral direction, as in the figure; then with a penknife cut small pieces from the foil at equal distances; hold one end of the tube in the hand, and present the other to an electrified conductor; a brilliant line of light will then surround the tube, called by some the diamond necklace.

A similar effect may be produced by a jar in which the coating of tin-foil is separated so as to

* The intensity of electricity signifies the quantity of electricity which a body contains beyond its natural standard.

form regular intervals; the electric fluid in passing from one piece of foil to another will exhibit a very beautiful luminous appearance: a word in luminous characters may likewise be formed by the same method.



A pleasing effect is produced from electrical light, by what is called the diadem of *beatification*. Bind the head of the person who exhibits this phenomena with a band of silvered leather, and let him place himself on a stool with glass legs, holding the chain connected with the conductor in his hand: while the machine is turned let another person pass his knuckle or finger near the band and it will appear beautifully illuminated, and vivid flashes of light will play about the person's head.

Q. May not *opaque* substances be rendered transparent by electricity?

A. Yes; place two wires in a straight line, with their ends about three-fourths of an inch from each other; over the interval lay a thick piece of pipe-clay or of pumice stone; on passing the charge from one wire to the other, these opaque substances will appear perfectly transparent.

Beatifica'tion, *s.* the state of the blessed in heaven.
Opa'que, *a.* dark, not to be seen through.

Q. May not this experiment be varied?

A. Yes, greatly; place five or six eggs in a straight line, touching each other; pass a small shock through them and they will appear pleasingly illuminated.

Q. What other substances are proper for this experiment?

A. Insert two wires in opposite directions in a small melon, orange, or apple, so that their points shall come near each other; electrify the wires and the fruit will appear transparent: these experiments, and all others dependant on electric light, must be performed in a dark room.

Q. May not inflammable substances be fired by the electric spark?

A. Yes; put a small quantity of rectified spirit of wine into a ladle or spoon, and let the person who holds it stand on the insulated stool, having his other hand on the conductor; if then another person approach the spoon with his finger, or a metal rod, the spark will set the spirit in a flame.

Q. May not the effects of the electric fluid be greatly heightened by *concentrating** it?

A. Yes; by means of the Leyden jar, the battery, or several batteries connected by a conductor, the most astonishing effects are produced.

Q. What experiments may be made with the Leyden jar?

A. They may be almost infinitely varied; if a card be held close to the coating of a charged jar, and one knob of the discharging-rod appplied to

* By concentrating, here is meant bringing a large quantity of this fluid into one common receptacle.

it, and the other to the knob of the jar, an *explosion* will ensue, and the electric fluid, in passing through the card, will *perforate* it.

2. Draw a line with a pen dipped in water, on the surface of a strip of glass; place one end of the line in contact with the coating of a Leyden jar, and at six inches distance upon the line, place one knob of the discharging-rod when the jar is charged, bring the other knob of the rod to the ball of the jar, and the discharge will take place *luminously* over the water.

3. Charge a very large jar; connect its outside coating with one that is ten or twelve times smaller; make a communication between their inner coatings with the discharging-rod, and the small jar will be broken, the quantity of electricity transferred to it being beyond its capacity.

4. Charge a large jar and place a shilling or other piece of coin between the knob of the discharger and its outer coating; when the discharge is made, the coin will be slightly fastened to the tin-foil by the melting of the latter at the point of contact.

Q. Is it possible to render the direction of the electric fluid visible?

A. Yes; charge a Leyden jar that has been rendered slightly damp by breathing on it, in a darkened room: when the jar is fully charged, if the turning of the machine be continued, the electric fluid will be seen to pass from the inner to the outer coating over the uncoated interval, in luminous streams.

Explo'sion, *v.* a report like that of a gun or pistol.
Per'forate, *v.* to pierce through.
Lu'minously, *ad.* with a bright light.

2. Let a small jar be charged and placed under the receiver of an air-pump; on *exhausting* the air, brushes of light will pass from the knob of the jar to its coating.

3. Lay a small chain upon a piece of white paper, in a darkened room; send the shock of a Leyden phial through it, and the chain will appear beautifully illuminated, with a kind of radiation at every joint; on examining the paper, it will appear stained with a blackish tinge at every joint of the chain.

Q. What experiments may be made with the concentrated electricity of a battery, or of several batteries?

A. The limits of a short treatise will not permit the mention of more than two or three:

1. Place a quire of stout paper against the coating of a jar in a battery, and send the discharge through it, as directed in experiment 1, with the Leyden phial, and every sheet will appear perforated.

2. Take two slips of window-glass, one inch broad, and three or four inches long; let a narrow slip of leaf-gold be placed between the glasses, with about an inch extending beyond them at each end; press them closely together; apply one end of the gold leaf to the outer coating of a phial in a charged battery; and one knob of the discharging-rod must touch the other end of the leaf; on sending the charge through it, the gold will be melted and actually *incorporated*

Exhaust'ing, *part.* drawing out.
Incor'porated, *part.* mixed, blended.

with the glass, which must itself have undergone a partial *fusion*.

2. Place a strip of silver or gold leaf on white paper, and pass a strong charge through it; the metal will disappear with a bright flash, and the paper will be stained with a purple or grey colour.

3. Take a piece of the finest flatted steel wire, called by watchmakers pendulum wire; send a powerful electric charge through it, and it will become red hot, or dispersed in red hot balls.

4. Place a steel wire three or four inches long, and the fortieth or fiftieth of an inch diameter, exactly balanced on a point, in the direction from north to south; send a moderately strong charge of a battery through it, and it will become magnetic, the end that lay southward being the south pole: a strong charge passed through a natural magnet destroys its power.

Q. Will the charge of a battery destroy animal and vegetable life?

A. By a smart shock from a battery, a plant, and even a small animal, may be killed; but no battery has yet been constructed sufficiently powerful to kill an animal larger than a sheep or dog.

Q. What is the immediate cause of the death of animals by electricity?

A. The immediate cause of the death of animals by electricity has not yet been ascertained; on *dissection* no injury of the vessels or intestines appears.

Fu'sion, *s.* a melting.

Dissec'tion, *s.* cutting open a dead body for the purpose of examination.

CHAP. VIII.

Of the Identity of the Electric Fluid, and Lightning.

Q. By whom was the Identity of Electricity and Lightning first discovered?

A. By Dr. Benjamin Franklin, a celebrated philosopher of Philadelphia, in the United States of America.

Q. By what arguments has he established the fact?

A. The most conclusive are,

1. The zig-zag form of lightning corresponds exactly in appearance with a powerful electric spark that passes through the air.

2. Lightning strikes bodies that are good conductors of electricity, and avoids those that are non-conductors.

3. Lightning inflames combustible bodies; so does electricity.

4. Metals are frequently melted by lightning; so are they by a strong charge of electricity.

5. The magnetic needle is affected in the same manner by lightning and by electricity; and iron may be rendered magnetic by both.

Q. How may these assertions be proved?

A. By experiment; let a pointed metal rod be elevated in the *atmosphere* and insulated; if lightning be caused by the electricity of the

---

Iden'tity, *s.* sameness.
At'mosphere, *s.* the air.

clouds, such an insulated rod will be electrified whenever a thunder cloud passes over it, and this electricity may then be compared with that obtained in our experiments.

Q. Where and by whom was this experiment tried?

A. It was first tried in the gardens of Marli, near Paris, on the 10th of May, 1752, by some members of the academy of France, with a rod forty feet high; it became electrified during the passage of a stormy cloud over it, afforded sparks, charged phials, and served for many other experiments.

Q. Did not Dr. Franklin adopt a different method?

A. Yes; it occurred to him that a kite would obtain more ready access to a thunder-cloud than the loftiest metallic rod; he accordingly framed one by means of a silk handkerchief stretched over two light strips of wood placed cross-wise; to the top of the kite he attached a pointed wire.

Q. How was this apparatus used?

A. Having launched his kite, he fastened a key to the end of the hempen cord, and to this he tied a silk string, which served to insulate the whole apparatus.

Q. What phenomena ensued?

A. The first sign of electricity he perceived was, the separation of the loose fibres of the hempen cord; some rain soon after falling, the string of the kite became wet, and the electric fluid was then collected by it more copiously.

Q. How was this ascertained?

A. On presenting his knuckle to the key, a stream of acute and brilliant sparks was ob-

tained: with these sparks spirits were fired, phials charged, and the usual electrical experiments performed.

Q. What other apparatus did Dr. Franklin construct?

A. Dr. Franklin afterwards constructed an apparatus for perpetual observations: it consisted of an insulated rod placed on the top of his house, and connected with two bells and a pendulum, which were so arranged as to ring when electrified, and thus give notice of the approach of a charged cloud.

Q. Are these experiments attended with danger?

A. Yes, very great, unless performed with the utmost caution: Professor Richman, of Petersburgh*, had constructed an apparatus for observations on atmospherical electricity, which had no contrivance for discharging the *superfluous* fluid.

Q. What was the consequence?

A. On the 6th of August, 1753, he was examining the electricity of this apparatus, in company with a friend, when his head accidentally coming too near the insulated rod, a flash of electric fluid immediately passed from it, and killed him on the spot.

Q. What marks of violence appeared?

A. A red spot was left on his forehead; his shoe was torn, and his waistcoat singed; his

---

Super'fluous, *a.* more than enough.

* The modern capital of Russia: Moscow is the ancient.

companion was struck senseless, but recovered; the door-case of the room was split, and the door torn off its hinges.

Q. How is this danger now *obviated?*

A. A metal rod, connected with the ground, or with the nearest water, is placed at a small distance from the insulated rod; with this arrangement, when the electricity becomes too powerful, it passes the interval between the rods, and is conducted safely away.

CHAP. IX.

On the Application of these Principles to the Safety of Persons and Buildings.

Q. WHAT beneficial consequences have followed the discovery that electricity and lightning are the same?

A. It suggested the application of the metallic conductors mentioned in the *preceding* chapter, to the sides of buildings, thus securing them from this formidable enemy.

Q. How is this *effected?*

A. Metal being a better conductor than the materials of which buildings are composed, the

---

Ob'viated, *part.* removed, prevented.
Prece'ding, *part.* going before.
Effect'ed, *part.* done, brought to pass.

lightning is attracted by the rod, follows its course, and is conveyed into the earth.

Q. What experiment proves this?

A. The effects of the electric fluid when it strikes a building, and the method of preventing these effects are exemplified by an instrument called the thunder house, as in the following figures:

Fig. 1.

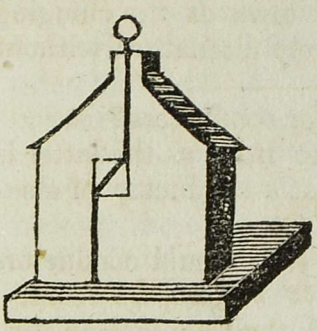


Fig. 2.

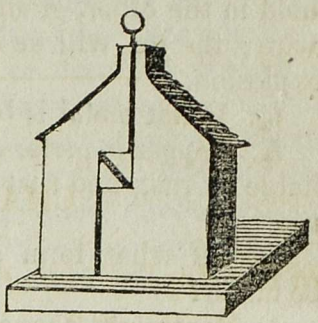


Fig. 1. is the representation of the side of a house, to which a metal conductor is affixed; about the middle of the building a square hole is made, into which a piece of wood is loosely fitted, having a wire let into it *diagonally;* if this piece of wood be put in so that the wire shall form a communication with the other parts of the conductor, on sending an electric shock through the conductor an explosion is heard, but no other consequence follows; but if, on the contrary, the piece of wood be put in, as in fig. 2, so that the communication of the parts of the conductor is

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Diag'onally, *ad.* from corner to corner.

cut off, the piece of wood will be driven out with considerable force.

Q. Are conductors with a ball at the top preferable to pointed ones?

A. By no means, as the former occasion an explosion, while the latter carry off the electric fluid silently.

Q. How is this proved?

A. Charge a very large jar; touch the outer coating with one hand, and bring a sharp needle held in the other, gradually towards the charging wire; the jar will be entirely discharged without explosion.

Q. What metal is best for conductors?

A. Copper is preferable to iron, as the latter is liable to rust, and rust is not a conductor of electricity.

Q. Of what form and size should conductors be made?

A. A straight copper rod, half an inch in diameter, rising several feet above the highest part of the building, should be acutely pointed at its upper extremity, while the lower part should be buried considerably below the foundation, in a *stratum* of moist earth, or in a large body of water.

Q. What inferences may be drawn from these experiments?

A. We may infer from these experiments, that it is dangerous during a thunder-storm to approach the fire-place, in a room, bell-wires, gilt furniture, or any other extensive surfaces of metal.

Stra'tum, *s.* a bed.

Q. What is the most secure situation?

A. The most secure situation is the middle of the room; and this security is increased by standing on a glass-legged stool, a hair mattrass, or a thick woollen hearth-rug: a hammock suspended by silk cords would be still better.

Q. What precautions should be taken in the open air?

A. During a thunder-storm, persons in the open air should not take shelter under a tree or building, as these elevated bodies are most likely to receive the electric matter; nor near any considerable mass of water, or even the streamlets occasioned by the rain, as these are excellent conductors, and the height of a human being, when connected with them, is very likely to determine the course of an electrical discharge.

Q. Is there any means of determining the distance of a thunder-cloud, and thereby estimating the degree of danger?

A. Yes; for as the motion of light is instantaneous, and that of sound only 1142 feet in a second, it is easy, by observing how many seconds elapse after seeing the flash before we hear the thunder, to calculate the distance exactly.

Q. Give an instance?

A. Suppose the flash to be seen ten seconds before the thunder is heard; 1142 multiplied by 10 gives 11,420 feet, or 2 miles 860 feet.

Q. Why are thunder-storms most frequent in summer?

A. Because the operation of the sun's rays has then accumulated a great quantity of vapour.

Q. In what parts of the world are thunder-storms most tremendous?

A. These natural electrical phenomena called thunder-storms, being most frequent and most tremendous where the heat is greatest, they are consequently experienced in all their terrific majesty in and near the torrid zone.

Q. Are there not other natural electrical phenomena?

A. Yes; the Aurora Borealis or northern lights, and shooting stars are considered as electrical emanations.

Q. What is the Aurora Borealis?

A. The Aurora Borealis, is a luminous appearance in the heavens, seldom seen in this country, but frequent in more northerly regions, where it serves to compensate in some measure for the temporary absence of the sun.

Q. What form does it assume?

A. Its appearance is different in different countries; but it most frequently assumes every possible variety of form and shade of colour, diffusing a light equal to that of the full moon: this is particularly the case in the latitude of Hudson's Bay.

Q. Is it attended with any explosion?

A. Not with an explosion, but with a loud hissing or crackling noise, which to a person unaccustomed to it is extremely terrific.

Q. Why are Shooting Stars supposed to be electrical phenomena?

A. Because the light of Shooting Stars is similar to the electric spark, and because the

appearance of these meteors can be exactly imitated by electricity.

Q. How may this imitation be effected?

A. If electricity be passed gradually through the receiver of an air-pump, when partly exhausted of its air, it assumes the appearance of the Aurora Borealis; but if a considerable charge be suddenly transmitted, it will pass through the receiver in the form of a shooting star.

Q. What occasions the different appearance of these meteors as they proceed from the same cause?

A. The Aurora occurs in the highest regions of the atmosphere, where, in consequence of the extreme *rarity* of the air, the electric fluid meets with but little resistance in its passage: shooting stars occur much lower, where the air has more *density* and opposes greater resistance.

CHAP. X.

Of Chemical and Medical Electricity.

Q. HAS Electricity ever been applied to useful purposes?

A. Yes; many curious and valuable experiments both in chemistry and medicine have been made by the assistance of the electric fluid.

Ra'rity, *s.* thinness. Den'sity, *s.* thickness.

Q. What are the principal experiments in chemistry made by electricity?

A. By electricity *combustion* may be induced; metals *fused* and *oxidated;* water *decomposed,* and many other chemical processes performed; but as they are in general tedious and difficult, it will not be necessary to describe them here.

Q. Has electricity been applied to medical purposes?

A. Yes; and many surprisingly beneficial effects were said to have resulted from it: but as most of these were found, on strict investigation, to be imaginary, medical electricity has fallen into disrepute, and it is not allowed to possess those salutary powers which it may justly claim.

Q. What imaginary powers were attributed to electricity?

A. It was asserted, that by electricity, the virtues of a drug held in the hand of the patient could be transmitted to the internal parts of the body; and that an atmosphere charged with electricity was an infallible restorer of health and strength.

Q. What powerful recommendations has medical electricity to boast?

A. Medical Electricity, when judiciously used, is an innocent and by no means painful remedy, and may be applied immediately to the affected part, without interfering with any other: even

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Combus'tion, *s.* burning.

Fu'sed, *v.* melted.

Ox'idated, *v.* changed into an earthy substance, called an oxide.

Decompo'sed, *v.* reduced to its component parts.

where a cure has not been obtained, it has frequently afforded great relief.

Q. What diseases are most likely to obtain relief from electricity?

A. Electricity has been found greatly serviceable in contractions and *rigidity* of the nerves; sprains, deafness, dimness of sight, swellings of the knee, rheumatism, &c.

Q. What part of the body is most affected by electricity?

A. The nerves appear to be most powerfully affected by electricity; if the charge be passed through the spine, such a weakness of the lower extremities is for the moment induced, that the person sometimes falls prostrate on the floor.

Q. On what part of the body may experiments be made with the greatest safety?

A. No ill effects are likely to ensue in passing the charge through the arms, but great caution is required in the indiscriminate application of the shock.

Q. What additional apparatus is necessary for medical purposes?

A. The additional apparatus is very simple: 1. a jar fitted up with Lane's electrometer, by which shocks may be given of any required force. 2. A pair of directors, each consisting of a glass handle, surmounted with a brass cap with a wire two or three inches long, having a ball screwed on its extremity.

Q. How are these used?

A. The directors must be applied to the op-

Rigid'ity, *s.* stiffness.

posite extremities of the part to be electrified, and being respectively connected by conducting wires, the one with the outside of the jar, and the other with the receiving ball of the electrometer, the jar must be set to the machine, and the required number of shocks given.

Q. Is not a single director sometimes employed?

A. Yes; the insulated director being held by its glass handle, and its ball previously connected with the conductor by a flexible wire, is brought near the patient, and thus sparks are communicated.

Q. Is no other apparatus necessary?

A. Yes; a stool with glass legs, called an insulated stool, is essentially necessary; it should be large enough to receive a chair upon it, with room in front for the feet.

Q. What is the use of this stool?

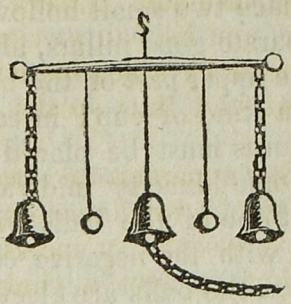
A. The patient being placed on this insulated stool, and connected with the conductor of the machine by a chain or wire, becomes a part of it, and sparks may be drawn from any part of the body, by a person who stands on the ground and presents a brass ball to it.

CHAP. XI.

Miscellaneous Experiments.

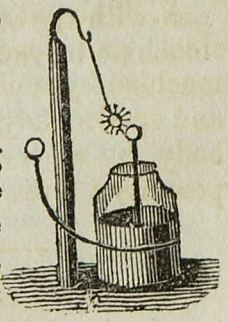
Q. By what means may we ascertain when an electrical cloud is passing?

A. *Suspend* three small bells from a narrow plate of metal; the two outermost by chains, and that in the middle by a silken string; from the middle bell let a chain pass to the floor; between each bell let a small knob of brass be hung by a silk string to serve as a clapper; join this apparatus to a conducting-rod, and the bells will ring when the conductor is electrified.



Q. How is the artificial spider constructed?

A. Take a small piece of burnt cork and fasten to it some short pieces of linen thread, so as to resemble the legs of a spider; suspend this by a silken string between two brass balls, the one connected with the inside, the other with the outside of a charged Leyden jar, the spider will move from the one to the other and soon discharge it.



Q. On what principle is this effected?

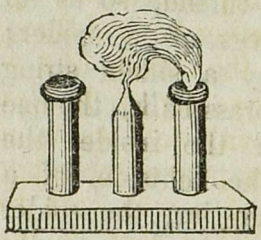
A. The spider is attracted by the positive

Suspend', *v.* to hang.

knob of the jar, where it acquires a surplus of the electric fluid; it is then attracted by the negative knob, to which it communicates it; and this is continued alternately till the equilibrium is restored, and consequently all attraction destroyed.

Q. May not a pleasing experiment be made with phosphorus?

A. Yes; place two small hollow metal balls on the top of separate glass pillars, about two inches apart; let the upper part of the balls be indented so as to form a kind of cup; in each cup a small bit of phosphorus must be placed; let the flame of a candle come exactly midway between the balls; connect one of the balls with the positive, and the other with the negative conductor of the machine; when the balls are electrified the flame will be directed towards the negative cup, and the phosphorus will be fired: the same will happen with the other cup, if the connection with the machine be reversed.



Q. What experiment may be performed with gold leaf?

A. Place a leaf of gold or silver in the palm of the hand, and bring it within a short distance of an electrified conductor; it will be attracted and continue to move from the hand to the conductor,

and from the conductor to the hand alternately, as long as the former is electrified.

Q. What experiments may be made with threads?

A. Take twelve or fourteen threads, and tie them together at top and bottom; annex them by one of the knots to the electrified conductor; the threads will separate from each other and assume a *spheroidal* figure.

Q. By what means may the electric fluid be made to assume the zigzag form?

A. Annex a ball of an inch and a half or two inches diameter to the conductor, so as to project three or four inches from it; present a larger ball to this, and long sparks of a zigzag form will be obtained.

Q. How may this be prevented?

A. Whilst a current of sparks is passing between the conductor and the large ball, if a sharp point be presented at twice the distance, the sparks will immediately cease, the electric fluid being imperceptibly transmitted by the point.

Q. May not æther be fired through water?

A. Yes; dry the outside of a wine glass, that its stem may serve for an insulating stand; fill the glass nearly with cold water, and on the surface of the water pour some æther; connect the water by means of a wire with the conductor of the machine; when that is turned, present a knuckle to the surface of the æther, and a spark will pass from the water to the knuckle, which will fire the æther.

Spheroi'dal, *a.* resembling a cask, thus 

Q. To what distance may the electric matter be conveyed?

A. It is impossible to say; a shock has been given and spirits inflamed by electric matter conveyed through the river Thames. In another experiment, the electric fluid was made to pass through a circuit of two miles, across the New River twice, over several gravel-pits and a large field, and afterwards a circuit of four miles.

Q. Is the progress of the electric fluid swift?

A. The progress of the electric fluid is inconceivably swift: an observer in the middle of a circuit of two miles, felt the shock at the instant that he saw the phial discharged.

Q. May not experiments for amusement only, be made by electricity?

A. Small boats or swans, made of light wood or cork, may be attracted and made to swim in any direction by presenting the finger to them, or they may be fitted up with sails, and made to scud briskly before an electrical gale from a wire held in the hand of the operator.

Q. What appearance does electricity assume in *vacuo?*

A. If a wire with a round end be included in an exhausted receiver of an air-pump, and presented to a conductor of an electrical machine, every spark will pass through the vacuum in a broad stream of light, moving with regularity, and then dividing itself into a number of beautiful rivulets. If the receiver be not completely exhausted, the effect will be more brilliant.

Vacuo, *s.* the ablative of vacuum; a space empty of air.

Q. What is the electrical pistol?

A. The electrical pistol is a tube of metal close at one end, and the other stopped by a cork: if this tube be filled with hydrogen gas, procured by mixing steel filings with sulphuric acid, and an electric spark sent through it, the gas will explode and the cork fly out with violence.

CHAP. XII.

Of the Connexion of Electricity with Natural History.

Q. Has electricity any influence in promoting vegetation and animal life?

A. Many experiments have been made to ascertain whether it has or not; but the results have never been sufficiently uniform to justify any conclusion on the subject: further investigation may perhaps lead to some degree of certainty.*

Q. Are there not animals which possess the power of transmitting the electric shock?

A. Three species of fish; the torpedo, the gymnotus, and the silurus electricus, have the power, while living, of communicating shocks, very much resembling those of artificial electricity.

Q. Describe the Torpedo.

* Since the above was written, the Editor has met with some very sensible remarks on the influence of the electric power on the animal economy, in Mr. G. Gurney's "Lectures on Chemical Science," from which work he has, at the end of the Catechism, made a brief extract or two.

A. The Torpedo is a flat fish, seldom exceeding eighteen inches in length, and weighing but a few pounds when full grown: it is not very rare.

Q. In what manner is the shock communicated?

A. If the torpedo, whilst in the water or out of the water, be touched with one hand, it generally communicates a trembling motion, or slight shock to the fingers of that hand only.

Q. How is a stronger shock communicated?

A. If the torpedo be touched with both hands at the same time, one being applied to the under and the other to the upper surface of the fish, a shock will be received, exactly like that occasioned by the Leyden phial.

Q. What circumstances occasion the strongest possible shock from the torpedo?

A. To obtain the strongest possible shock, the torpedo must be removed from the water, the thumb applied to its upper surface, and the middle finger of the same hand to the opposite surface.

A. Does the torpedo communicate only one, or a succession of shocks?

A. Sometimes it communicates one single determinate shock only; sometimes the shocks succeed each other so rapidly, that scarcely two seconds elapse between them.

Q. How does the power of the torpedo resemble artificial electricity?

A. The power of the torpedo is conducted by the same substances which conduct artificial electricity, and is intercepted by the same sub-

stances which are non-conductors of electricity: hence, if the animal, instead of being touched immediately by the hand, is touched by non-electrics, as wires, wet cord, &c. held in the hand, the shock will be experienced.

Q. Can more than one person be electrified by this fish at the same time?

A. Yes; a circuit being formed by several persons joining hands, the shock will be felt by them all at the same time.

Q. What is peculiar to the electric action of the torpedo?

A. The shock of the torpedo cannot pass through the least interval; thus, it will not be conducted by a chain, nor pass from one conductor to another, if held at not more than the two-hundredth part of an inch from each other.

Q. Can the torpedo impart electricity, or not, at will?

A. It is uncertain; but as each effort is accompanied with a depression of the eyes, it is supposed that it can impart a shock, or not, at pleasure.

Q. What is the Gymnotus Electricus?

A. The Gymnotus Electricus, or Electrical Eel, is usually about three feet long, (though some have been taken of ten and even twenty feet) and from ten to fourteen inches in circumference.

Q. Where is it usually found?

A. It is usually found in the river Senegal, in Africa, and in the rivers of Surinam, in South America: from its abounding in this latter country, it is frequently called the Surinam eel.

Q. Is the electric power of this fish considerable?

A. The gymnotus possesses all the electric properties of the torpedo, but in a superior degree: the strongest shock is received when, the animal being out of the water, you apply one hand towards the head and the other towards the tail.

Q. Does this power depend on the will of the fish?

A. Yes: for it sometimes gives strong shocks, and sometimes weak ones: it gives the strongest shocks when provoked by being frequently and roughly touched.

Q. Could an electric spark be obtained from the gymnotus?

A. Yes: a bit of tinfoil being pasted on glass, and a narrow interval made with a penknife, the shock in passing through that interruption, shewed a small but vivid spark, plainly visible in a dark room.

Q. What use is the fish supposed to make of this power?

A. It is supposed to use this power for the purpose of securing its prey, or of defending itself against its enemies; for small fishes, when put into the water with it, were either killed or completely stunned, so as to be incapable of motion.

Q. What is the Siluris Electricus?

A. The Siluris Electricus is a fish of an oblong shape, smooth, and without scales; its colour is greyish, with dark spots near the tail; its length is about twenty inches, and it has the power of giving electrical shocks like the torpedo: few particulars, however, are known concerning it.

CHAP. XIII.

Of Galvanism.

Q. What is Galvanism?

A. Galvanism, in its most restricted sense, signifies merely the influence of metals by mere external contact with the animal body. In a more extended sense it denotes that electricity which is excited by the combination of a series of metals and some conductor *interposed.*

Q. From whence is the term Galvanism derived?

A. From Dr. Galvani, of Bologna, the first discoverer of this species of electricity.

Q. What led to this discovery?

A. He first observed that a frog, dead and skinned, is capable of having his muscles brought into action by means of electricity.

Q. What further discovery ensued?

A. He further observed, that the same motions may be produced in the dead animal, or even in a *detached* limb, merely by making a communication between the nerves and muscles, with substances that are conductors of electricity: with glass, sealing-wax, and other non-conductors, no motion could be produced.

Q. What kind of motion is produced in dead animals by this species of electricity?

Interpo'sed, *part.* put between.
Detach'ed, *part.* separated from the body.

A. This species of electricity occasions a *tremulous* motion of the muscles in animals recently dead, and sometimes an extension of the limbs.

Q. How must the animal be prepared for this experiment?

A. Galvani used to skin the legs of a frog, and to leave them attached to a small part of the spine, but separated from the rest of the body; the limb must then be deprived of its *integuments*, and the nerve which belongs to it partly laid bare.

Q. What follows?

A. If the limbs thus prepared, be slightly electrified, they will be instantly affected by a kind of spasmodic contraction, sometimes so strong as to occasion it to jump a considerable way.

Q. What part of the body is most sensibly affected by electricity?

A. The movements are much stronger when the electricity is made to pass through a nerve to the muscles, than through any other part.

Q. How long after death will this sensibility last?

A. In cold-blooded animals, as frogs, &c. this sensibility will be retained for several hours, though gradually diminishing: with other animals the sensibility does not last long, sometimes only a few minutes.

Q. Is apparent electricity *essential* to these movements?

Trem'ulous, *a.* shaking, trembling.
Integ'uments, *s.* covering, as skin, &c.
Essen'tial, *a.* absolutely necessary.

A. No; the like movements may be produced in the prepared animal, without the aid of any apparent electricity.

Q. How may this be done?

A. In an animal *recently* dead, detach one end of a nerve from the surrounding parts, remove the integuments from over the muscles which depend on that nerve, take a piece of wire and touch the nerve with one extremity, and the muscles with its other extremity; the prepared limbs will move in the same manner as when a slight degree of electricity is passed through them.

Q. Will any substances answer this purpose as well as wires, &c.?

A. No; if the communication between the nerve and the muscle be formed by non-conductors of electricity, such as glass, sealing-wax, &c. no movements will take place.

Q. Is a simple wire the best medium of communication between the nerve and muscles?

A. By no means; conductors composed of different bodies connected together, are much preferable; but they must be placed in perfect contact with each other to produce the desired effect.

Q. What substances are most proper for this purpose?

A. The most effectual way of producing those movements in prepared animal parts, is by the application of two metals, as silver and zinc, silver and tin, or copper and zinc.

Q. How is this done?

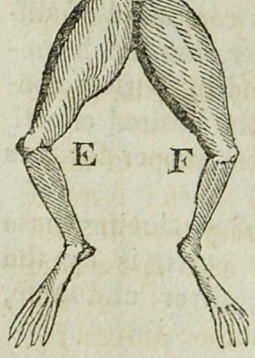
A. If part of the nerve proceeding from a pre-

Re'cently, *ad.* newly, lately.

pared limb, be wrapped in a piece of tin-foil, or only laid upon zinc, and a piece of silver laid with one end on the bare muscle, and with the other upon the tin or zinc, the motion of the limb will be very vigorous.

Q. How is the frog to be prepared for this experiment?

A Separate the head and upper extremities of a frog from its body; open the belly and remove the entrails, by which means you will lay bare the *crural* nerves; then pass one blade of the scissors under the nerve, and cut off the *spine* with the flesh close to the thighs, so that the legs may remain attached to the spine by the nerves only; cut off the spine, except a small bit attached to the nerves, and wrap some tin-foil round that portion; flay the legs, and the preparation is complete.



A B—The spine covered or armed with tin-foil.
C D—The crural nerves.
E F—The flayed legs.

Cru'ral. *a.* belonging to the legs.
Spine, *s.* the back-bone.

Q. What further experiments may be performed with this?

A. Hold the preparation by the extremity of one leg, the other leg hanging down, with the nerves and spine lying upon it; in this situation let a piece of silver, as a half-crown, touch the thigh with one edge, and the tinfoil on the spine with the other; the leg that is at liberty will then vibrate so powerfully, as sometimes to strike against the hand that holds the other leg.

Q. Cannot this experiment be performed another way?

A. Yes; place two wine-glasses, filled with water, near but not touching each other; put the legs and thighs of the preparation in the water of one glass, and the spine with its tin-foil in the other, the nerves forming the communication; if you now put the fingers of one hand into the water of the glass that contains the legs, and holding a piece of silver in the other, you touch the tin-foil with it, the prepared legs will move so powerfully, as sometimes even to jump out of the glass.

Q. Cannot experiments of this kind be made on living subjects without cruelty?

A. Yes; place a living frog on a piece of zinc, with some tin-foil pasted on its back; form a communication between the zinc and tin-foil with a piece of silver or other wire, and spasmodic convulsions will ensue.

Q. Will this happen with any other animal?

A. Yes; place a living flounder, after wiping it, upon a pewter-plate or piece of tin-foil, and lay a piece of silver on its back; form a communication between the metal under the fish and that

on its back by means of a wire, and the animal will be convulsed.

Q. Are human beings affected by these combinations?

A. Yes; very sensibly: men have been convulsed by the application of metallic substances while undergoing surgical operations.

Q. Cannot experiments be made without injury?

A. Yes; in various ways: place a piece of metal, as zinc or tin, upon the tongue, and a silver coin or spoon under the tongue; upon these metals coming in contact a pungent taste will be perceived.

Q. Is taste the only sense affected?

A. No; in a dark room put a slip of tin-foil on the bulb of one of the eyes, and a silver-spoon in the mouth; on completing the communication between the spoon and the tin-foil, a faint flash of white light will appear before the eyes.

Q. Does this light continue during the contact of the metals?

A. No; it appears only at the moment of contact, and may be repeated at pleasure.

Q. Do these phenomena proceed from some electrical property peculiar to the animal parts, or from the metals?

A. For some time this was doubtful; but the discoveries of Professor Volta have proved, that electricity may be excited by the mere contact, not only of metallic substances, but likewise of other bodies, and that it may be increased to a most extraordinary degree.

Q. What substances are most proper for this purpose?

A. The substances generally used for exciting electricity are silver, zinc, and water; these must be in contact with each other to produce the effect.

Q. How may this effect be increased?

A. This effect may be increased at pleasure by a regular series of these combinations; for if a combination of silver, zinc, and water, produce a certain effect, a second combination added to the first will increase the effect; a third still more, and so on.

Q. How are these combinations formed?

A. To construct an apparatus of this kind, procure a number of plates of zinc and silver, or zinc and copper, of any shape, and of the same size, and an equal number of pieces of cloth, pasteboard, or leather of the same form, but rather smaller; soak these last in salt water thoroughly; place a plate of silver or copper on the table, on that put a plate of zinc, and on the zinc, one of the moistened discs; repeat this combination until a series of fifty or sixty repetitions has been placed one upon the other; the column thus formed is called the Voltaic pile.

Q. Is not this pile in danger of being thrown down?

A. To prevent its falling, it is usual to build up the pieces between three pillars of varnished glass, placed in the form of a triangle, and cemented into a piece of wood which serves as a base for the pile.

Q. What experiment may be performed with this pile?

A. The Voltaic pile being thus constructed, moisten both hands with brine, and take a silver

spoon in each; if the top of the pile be then touched with one spoon and the bottom with the other, a slight shock will be felt, as often as the contact is repeated.

Q. Is any luminous appearance produced?

A. If a spoon be held in the mouth, and the contact made as before, a vivid flash of light will be perceived, whether the eyes be open or shut.

Q. How may the power of the Voltaic pile be increased?

A. Its power may be greatly increased by forming several piles and connecting them at the top by means of a piece of metal.

Q. What inconveniences attend the use of the Voltaic pile?

A. The power of the Voltaic pile gradually diminishes as the zinc surfaces become oxidated by the action of the moisture; it therefore requires to be taken to pieces and cleaned, an operation that is very troublesome when the number of pieces is considerable.

Q. How has this defect been remedied?

A. By the invention of the Voltaic trough, or battery, the construction and use of which will be explained in the next chapter.

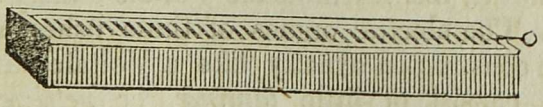
CHAP. XIV.

Of Galvanism (continued).

Q. WHAT is the Voltaic Battery?

A. The Voltaic Battery is composed of pairs or plates of different metals, usually zinc and

copper *cemented* in regular order into a mahogany trough, so as to form cells between each pair capable of holding water.



Q. What is the use of these cells?

A. These cells are intended to contain water or any fluid that is a conductor, as a substitute for the moistened discs used in the pile.

Q. What advantages result from this arrangement?

A. There is a vast deal less trouble in pouring out and renewing the fluid from these cells, and in cleaning the plates, than in the Voltaic pile; the effect likewise is not subject to be diminished by the drying up of the moisture.

Q. How are these plates prepared?

A. The zinc plates are made by casting that metal in an iron or brass mould; they may be about an eighth of an inch thick; the copper plates may be cut from a sheet of metal of a moderate thickness; the zinc and copper must be *soldered* together at the top, the other edges being secured by the cement in the trough.

Q. What are the usual number and size of the plates?

A. The most usual number is fifty pair; and in that case, they may be three inches square,

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Cement'ed, *v.* fastened with a cement.
Sol'dered, *v.* fastened together with solder.

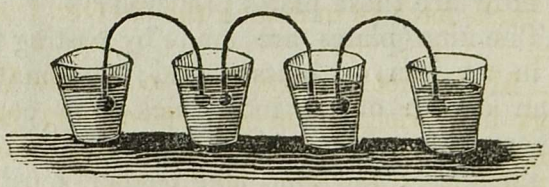
each pair not more than half an inch distant from each other.

Q. Do not the electric organs of the torpedo, gymnosus, &c. resemble the Voltaic battery?

A. The electric organs of those fishes appear to be constructed exactly like a Voltaic battery: they consist of little *laminæ*, or *pellicles*, arranged in columns, and separated by a fluid.

Q. Has not Volta invented another kind of battery?

A. Yes; it consists of a row of glasses, or cups, containing salt and water, or any *saline* fluid; into each of these a bent wire is plunged, having at one head a plate of zinc, and at the other a plate of copper; by this means a communication is formed from glass to glass; and each glass except the first and last, has in it a plate of copper and a plate of zinc.



Q. What is the power of a Voltaic battery?

A. The power of a small Voltaic battery to produce muscular motion in either a living or dead animal is very great.

Q. Give an example?

Lam'inæ, *s.* thin plates or scales.
Pel'licle, *s.* a thin skin.
Sali'ne, *a.* of the nature of salt.

A. Place two wires in the ears of an ox, sheep, or other animal, soon after its death: let one of the wires be connected with one end of a battery of one hundred plates, and the other wire be occasionally made to touch the other end; very strong muscular action will be excited; the eyes may be made to move; and the apparent process of smelling, chewing, &c. may be induced.

Q. What effect would this battery have on a prepared frog?

A. The legs of a frog may be made to move very powerfully, and sometimes leap to a very considerable distance, and that too an hour after death.

Q. What remarkable instance of the power of a Voltaic battery is on record?

A. The tongue of an ox was secured to a table by an iron skewer; when the power of a Voltaic battery was applied, the tongue was drawn in with such force as to detach the skewer from the table.

Q. Might not the application of the Voltaic battery be serviceable in the recovery of persons apparently dead from suffocation, by drowning, &c.?

A. No advantage has yet been derived from it; trials have been actually made on criminals a short time after their execution; very violent muscular action was produced, but no appearance of returning life.

Q. How may the electric energy be restored when diminished?

A. The fluid must be changed, and the metallic pieces cleaned by removing the oxydated

surface; this may be done either by filing, by rubbing them with sand, or by immersing them in *diluted* muriatic acid, and then wiping them with a coarse cloth.

Q. How are the effects of a Voltaic battery *identified* with electricity?

A. It gives the shock—shews a luminous spark accompanied with an *audible* report—it burns metallic and other combustible bodies—and continues in action for a long time.

Q. How may the shock be communicated?

A. As the dry skin of the human body is a bad conductor, immerse a wire, that proceeds from one extremity of the battery, in a basin of water, wherein you may plunge one of your hands: then grasping with your other hand, well moistened, a silver spoon or other large piece of metal, touch the other end of the battery with it, and a smart shock will be felt.

Q. Will the shock affect more than one person?

A. Yes; several persons may join hands, after moistening them well with water; and on completing the circuit, they will all feel the shock at the same instant, but its effects will be weaker.

Q. Cannot an electric battery be charged by it?

A. Yes; if a wire proceeding from a strong Voltaic battery be made to communicate with the inside coating; and another wire which proceeds from the other extremity of the battery, be

---

Dilu'ted, *a.* made weak by being mixed with water.
Iden'tified, *v.* proved to be the same.
Aud'ible, *a.* that may be heard.

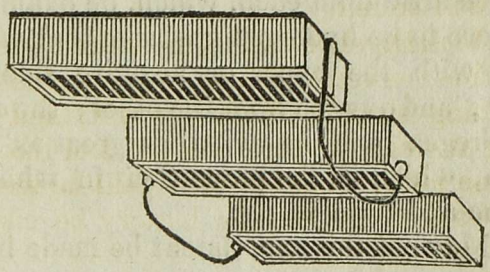
made to communicate with the outside coating of a common electrical battery, the latter will become instantaneously but weakly charged.

Q. How may metals be consumed by a Voltaic battery ?

A. Let the wires from the two extremities of the battery pass through glass tubes, that in handling them the operator may not receive the shock; bring the points of the wires near the gold or silver leaf, at opposite sides, and the spark will fire the metal, and consume or melt it.

Q. How may the power of the Voltaic battery be increased ?

A. The power of the Voltaic battery may be wonderfully increased by joining several together with metal cramps, &c. (thus)



CHAP. XV.

Of the Chemical Effects of Galvanism.

Q. May Chemical phenomena be produced by the Voltaic battery ?

A. The Chemical phenomena produced by Voltaic electricity are much more remarkable and extensive than those which result from the action of the ordinary electrical apparatus.

Q. Are the chemical processes performed with accuracy?

A. Yes; the *decompositions* produced by the Voltaic apparatus are effected with remarkable precision; the *component* parts of the bodies subjected to its action are separated at some distance from each other, and no observable change occurs in the intermediate space.

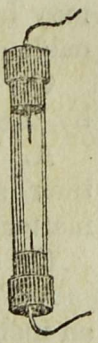
Q. How may this be proved?

A. Connect two wires of gold or platina with the opposite extremities of a Voltaic battery, and plunge them in a vessel of water, without permitting them to touch each other; bubbles of air will soon arise from each, which, on examination, will prove to be hydrogen gas from that wire connected with the upper or negative side of the battery; and oxygen from the other; the quantity of hydrogen will be twice as great as that of oxygen, which is the proportion in which they combine and form water.

Q. May not this experiment be made in a different manner?

Decomposi''tion, *s.* the act of separating a body into its original component parts; this is called chemical analysis.

Compo'nent, *a.* those simple substances of which a body is composed.



A. Yes; take a glass tube filled with distilled water and closed by a cork at each end; insert a brass or copper wire connected with one extremity of a Voltaic battery through one cork, so that it may project within the tube, and a similar wire from the other extremity, through the other cork.

Q. What effects will follow?

A. From the wire connected with the negative extremity of the battery, a constant stream of hydrogen gas will ascend and *accumulate* at the top of the tube, while the other wire will deposit a stream of oxide in the form of a cloud, which accumulates in a greenish form in the water or on the sides of the tube, and is a perfect oxide of brass: the wire at the same time is discoloured and *corroded.*

Q. Cannot this experiment be reversed?

A. Yes; by altering the communication with the battery; for if the negative extremity be connected with the upper wire, and the positive with the lower, the upper will then *evolve* hydrogen gas, and the lower will be oxidated.

Q. Does not this experiment afford a measure of the power of Voltaic batteries?

A. Yes; a measure of the intensity of the power of Voltaic batteries producing chemical changes,

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Accu'mulate, *v.* to gather together.
Corro'ded, *part.* its surface rendered rough.
Evol've, *v.* to unfold.

may be derived from the quantity of gas it is capable of evolving from water in a given time.

Q. May not metals held in solution be revived by the Voltaic battery ?

A. Yes ; not only may metals be revived from their solution in acids, but alkaline and acid matter may be separated from neutral fluids. *

Q. How may metals be revived ?

A. Take a glass tube, four inches long and half an inch in diameter, fill it with a *dilute* acetate of lead, and insert a cork at each end with a wire, the points of which shall reach within an inch of each other; place these wires in contact with the extremities of a Voltaic battery, and the negative wire will soon be covered with a beautiful vegetation of thin laminæ of lead.

Q. How may an acid and an alkali be separated from a neutral fluid ?

A. *Mince* some leaves of red cabbage, and infuse them for a short time in warm distilled water; strain off the blue liquid that will result from it; take a small glass tube bent thus, and introduce a platina wire into each of the legs through the cork; fill this tube with the infusion ; connect one of the wires with the positive and the other with

Dilu'te, *a* mixed with water, made weak.
Mince, *v.* to cut small.

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* For an explanation of these, and other chemical terms, consult the Catechism of Chemistry, published by Messrs. Whittaker, Ave-Maria-Lane.

the negative side of a battery; in a short time the liquor in the positive leg will become red, and that in the other green.

Q. How is this a proof of the separation of an acid and an alkali?

A. Because it is the property of an acid to change blue vegetable colours, red; and of an alkali to turn them green.

Q. Will not the Voltaic electricity prevent the solutions of metals in acids?

A. Yes; introduce a platina wire connected with the positive side of a Voltaic battery, into a glass filled with dilute *nitric acid*, and likewise a copper wire connected with the negative side, the copper will be but little affected; but if it be separated from that connection, it will be rapidly dissolved.

Q. May not one metal be coated with another by means of the Voltaic power?

A. Yes; fill a glass with a solution of sulphate of copper, and connect it with the positive end of the battery; *immerse* a slip of silver into this solution, and suffer it to remain a long time; no alteration will take place; but if the silver be connected with the negative end of the battery, in a few minutes it will be coated with copper.

Nitric acid, *s.* aqua-fortis.
Immer'se, *v.* to plunge.

CHAP. XVI.

Galvanism (continued).

Q. May not chemical effects result from the action of Voltaic electricity on solid bodies?

A. Yes; when the wires connected with the extremities of a powerful Voltaic battery are brought into contact, a distinct spark is obtained: if one of the wires be terminated at the end by a piece of well-burnt charcoal, the spark is much more lively; but if each wire be armed with charcoal points, the light evolved when these points touch each other, is very brilliant and intense.

Q. Is this light *transient* or lasting?

A. When the battery is powerful, the emission of light may be kept up for a considerable time: it is so dazzling as to be insupportable to the eye, except for a momentary glance; and when it ceases, the most brilliantly illuminated room will appear comparatively dark.

Q. How is the charcoal, employed in these experiments, prepared?

A. Cut box-wood into peices of about an inch long, and three-eighths of an inch thick; put them into a *crucible*, cover them with sand, and place the vessel in a fire, where it is to be kept

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Tran'sient, *a.* passing quickly away.

Cru'cible, *s.* an earthen vessel, calculated to endure intense heat.

red-hot for an hour; or plunge the pieces of wood into red-hot lead.

Q. To what distance will the Voltaic spark pass?

A. To a very small one: with a powerful battery, charcoal points were brought within the thirtieth or fortieth of an inch before any light was evolved; but afterwards a stream of light continued to play between them, when they were gradually withdrawn to the distance of near four inches.

Q. Was heat evolved as well as light?

A. The light was accompanied with so intense a heat that it immediately fired any substance that was introduced into it; not only did thick platina wires melt rapidly and fall in large globules, but many other substances were completely *fused.*

Q. Does a vacuum assist the transmission of this fluid?

A. In a receiver partly exhausted, the stream of light may be made to pass through an interval of six or seven inches.

Q. What effect has the Voltaic battery on inflammable fluids?

A. As the charcoal points usually take fire from a battery of moderate power, almost any combustible substance may be inflamed if placed between them: oils, alcohol, æther, and naphtha, are decomposed when the points are plunged into

---

Fu'sed, *part.* melted.

them; but they will be inflamed when the points are brought near each other on the surface.

Q. Does the Voltaic battery affect metals?

A. Yes; if these substances in thin leaves be placed in contact with the wires of a powerful battery, they inflame and burn with great brilliancy.

Q. With what appearance do they burn?

A. Gold burns with a vivid, white light, tinged with blue; silver emits a bright emerald green; copper a bluish white light, attended with sparks; tin the same; lead burns with a beautiful purple light, and zinc with a bluish white light, fringed with red.

Q. What effect is produced by quicksilver?

A. If a fine iron wire be connected with one extremity of a powerful battery, and its end be brought to touch the surface of some quicksilver, connected with the other extremity, both the wire and the quicksilver will be consumed, and a very brilliant effect produced.

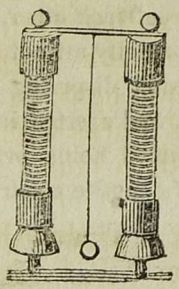
Q. What is the Electric Column?

A. The Electrical Column is formed by laying a small round plate of flatted zinc, on this a disc of silver-paper, with the silver next to the zinc, and on the silver-paper a disc of common writing-paper; this is repeated to perhaps a thousand series; by these, an apparatus is formed capable of separating the pure electrical effects of the Voltaic battery from its chemical power.

Q. What curious machine has been formed on this principle?

A. A series of 1,200 groups has been placed in two columns of equal length, the positive end

of one and the negative of the other being placed lowest, the whole properly insulated; both the upper extremities being connected with a wire, and the lower with little bells, a small brass ball is suspended between the latter by a fine thread of raw silk; the ball will alternately vibrate from one to the other, and continue to do so for an indefinite time.



NOTE.—Having in the foregoing pages treated of the connexion that subsists between Electricity and Chemistry, we cannot more appropriately conclude, than by making a few short extracts, in further illustration of the subject, from "*Gurney's Lectures on Chemical Science,*" a work recently published.

Speaking of Electricity, Mr. Gurney says: "If we should ever arrive at an adequate and satisfactory knowledge of the nature of this most extraordinary and giant-like power, it will be through the agency of the Chemist that we shall reach that knowledge. It would appear from observation, that not a single chemical change takes place among the ultimate particles of matter but what is effected by electricity, under some one or other of its forms and modifications. It is said to be the proximate cause of all attraction, whether of affinity, of cohesion, or of gravitation; and

equally the cause of all repulsion: whether of that repulsion which acts at insensible distances between the ultimate atoms of matter, or that which obtains between visible bodies, whether compound or simple."

* * * * * *

"The first important fact in connection with Chemical science is the following: namely, that all bodies in a similar state of electricity repel each other, and that all bodies in opposite states of electricity attract each other; and in this law we find the grand disposing cause of all chemical changes, of all kinds, and exerted in whatever degree; the degree of change effected being probably in proportion to the relative degree of opposite electricity that is excited."

* * * * * * *

"I cannot avoid coming to the conclusion, in my own mind, that the regularity, the beauty, and the harmony of all the changes which take place in the material world will, one day or other, be found to depend on the one grand disposing cause of electricity; and, above all, in the animal economy, where these changes are so vitally important, that it seems peculiarly desirable to ascertain in what manner, and to what extent, the foregoing may be safely and judiciously applied!" Vide Lecture VI.

FINIS.

Shackell and Arrowsmith, Johnson's Court, Fleet-street.