CHAPTER IX.

DYNAMICAL ELECTRICITY.

I.—FUNDAMENTAL PRINCIPLES.

Galvani's Experiment.

409. It has been observed that chemical combinations are sources of electricity. The form of electricity thus developed is different, but its nature is the same as that produced by friction. The name of GALVANISM has been given to electricity developed by certain chemical combinations, in honor of GALVANI, who first discovered this new way of generating it.

In 1790, GALVANI observed that the body of a frog recently killed, when placed near an electrical machine, manifested signs of excitation whenever sparks were drawn from it. The cause of action was, in fact, the return shock, as has been explained; but GALVANI, ignorant of this fact, began to seek for an explanation of the phenomena. One day he saw a dead frog suspended from a copper hook in a window, and noticed a muscular contraction whenever the wind blew the lower extremities against the iron bars of the window. Here was a case of electrical manifestation which was entirely independent of any electrical machine, and it furnished a clew to one of the most important discoveries in modern science.

This discovery led to an experiment which may be repeated as follows: Having killed a frog and cut off the hinder half of the body, we suspend it by a copper hook, *c*, passed between the back

(**409.**) What is Galvanism? Why so called? *Explain the method of its discovery. How may* GALVANI'S *experiment be repeated?*

bone and the nerves which run on each side of it, as shown in Fig. 283; then holding a small plate of zinc, *z*, in the hand, we bring one end of it in contact with the copper stem that holds the hook, and then touch the legs of the frog with the other end. At every contact the muscles contract, reproducing all the motions of life.

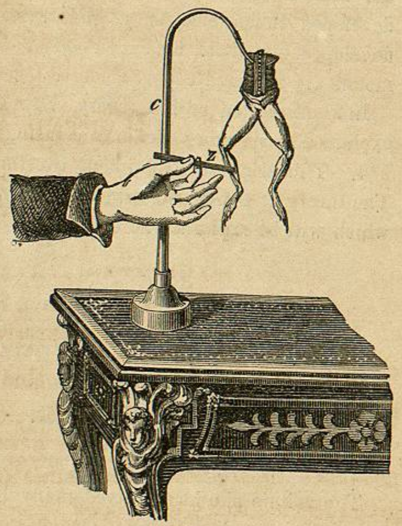

Fig. 283.

GALVANI attributed the phenomena observed, to the electricity existing in animal tissues, which, passing from the nerves to the muscles, through the metals, produced the muscular contractions.

Volta's Theory of Contact.

410. VOLTA repeated the experiment of GALVANI, and after much study, advanced the theory of contact. According to this theory, when two metals or other dissimilar substances are simply brought in contact, there is always a decomposition of the natural electricity of both bodies, the positive fluid going to one and the negative fluid to the other.

In the case of the frog, the electricity was supposed to be developed by the contact of the copper hook and zinc plate, the nerves and muscles serving simply as conductors.

VOLTA called the force which separates the two electricities in cases of contact, the *electro-motive force*, which he supposed to act

To what did GALVANI *attribute the phenomena observed?* (**410.**) What was VOLTA'S theory? *What is the electro-motive force?*

like the *coercive force* in magnetism, to prevent a recombination of the separated fluids. He called those bodies which by contact developed much electricity, *good electro-motors*, and those which developed but little, he called *bad electro-motors*. The best electro-motors are zinc and copper soldered together.

In confirmation of his theory, VOLTA performed the experiment explained in speaking of the condensing electrometer, Figs. 273 and 274. This decisive experiment overthrew the theory of GALVANI. The theory of contact has since given way to the chemical theory, which will be explained hereafter.

The Voltaic Pile.

411. In the year 1800, VOLTA invented an apparatus by which he could multiply the number of contacts, and thus produce a more powerful effect. This apparatus is called the *voltaic pile*.

The voltaic pile has received many different forms, but the same principle is applied in all. One of these is shown in Fig. 284. It consists of an assemblage of *couples*, each consisting of a disk of copper and a disk of zinc in contact, and each couple being separated from the next by a layer of cloth moistened with dilute sulphuric acid. The couples are all disposed in the same order, the zinc of each couple being always on the same side of the corresponding disk of copper. When the pile is completed, there will be a disk of zinc at one end and a disk of copper at the other. A connection is made between them by means of the wires, *a* and *b*, one being attached to each of the extreme plates.

In the pile shown in Fig. 284, there are twenty couples, the zinc disk being at the bottom of each couple, and the copper one at the top. The pile is supported by a suitable frame-work.

This apparatus has been much modified, but the name *pile* has been retained for all apparatus of the same kind, and the electricity generated in this way is called *voltaic*, or *galvanic electricity*.

What are good and bad electro-motors? (**411.**) What is the voltaic pile? *Describe the pile figured in the text. What name is given to the electricity of the pile?*

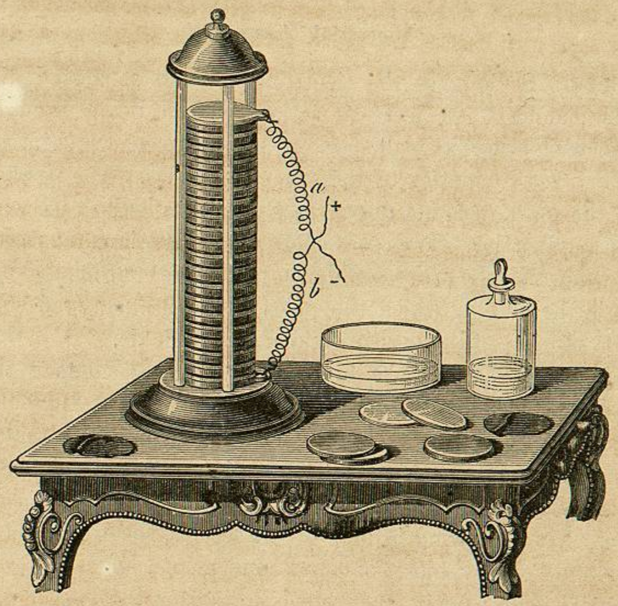

Fig. 284.

Electrical Tension in the Pile.—Poles.—Electrodes.

412. In a pile which is insulated, one half is found to be electrified positively and the other half negatively, the middle being neutral. In the zinc and copper pile, that end towards which the zinc plate in each couple is turned, is positive, the other end being negative, as indicated by the signs + and −, in Fig. 284.

The tension of the electricity in either end increases with the number of couples in the pile, but is independent of their size. The tension is greatest at the two extremities; hence these extremities are named *poles;* the one towards the zinc end is the *positive pole*, the one towards the copper end is the *negative pole*.

The wires, *a* and *b* (Fig. 284), which are attached at the two poles for the purpose of completing the circuit, are called *electrodes*.

(**412.**) *How does the tension vary in the pile? Where is it greatest in any pile? What are the poles? How named? What are the electrodes?*

Electrical Currents.

413. So long as the electrodes remain separated, the pile manifests no electrical action, but on being brought near each other, a small spark is seen to pass, which arises from a recombination of the two electricities. The passage of the spark does not discharge the pile, as is the case with the Leyden jar. We see a continual succession of sparks, showing that the process of decomposition is continually kept up in the pile, by which the poles are continually fed with new supplies of the positive and negative fluids.

If the two wires are brought into actual contact, the sparks cease, but the flow of the fluids continues as before, decomposition going on in the pile, and recomposition taking place through the electrodes. This continuous flow of electricity is called *the electric current.* There are, in fact, two currents flowing in opposite directions, according to the two fluid theory, but it is found convenient to consider only one of them, namely, that which flows from the positive to the negative pole. In the figures, hereafter, the direction of this current will be indicated by an arrow, as in Fig. 292.

Chemical Theory of the Pile.

414 FABRONI first suggested that the phenomena of the pile were due to chemical action. In the pile described, the dilute acid in the cloths between the couples, acting upon the zinc, was supposed to be the cause of the development of electricity. This view was adopted by DAVY and WOLLASTON, who made many experiments calculated to sustain it. Finally, DE LA RIVE and BECQUEREL succeeded in demonstrating most conclusively that in every chemical action electricity is developed. They also showed that

(413.) What phenomenon is observed when the circuit is completed? What is the electric current? Which way do we suppose the current to flow? (414.) What was FABRONI's theory?

whenever a metal is attacked by an acid, the former is positively and the latter negatively electrified.

According to this view, which is now universally adopted, the acidulated cloths, that VOLTA regarded as simply conductors, are in fact the principal cause of the development of electricity.

The Carbon Pile.

415. The CARBON PILE was invented by BUNSEN, about twenty years ago, and is often called the *Bunsen Pile.*

Each *couple* of BUNSEN's pile consists of four pieces, which are shown both separately and united in Fig. 285. These

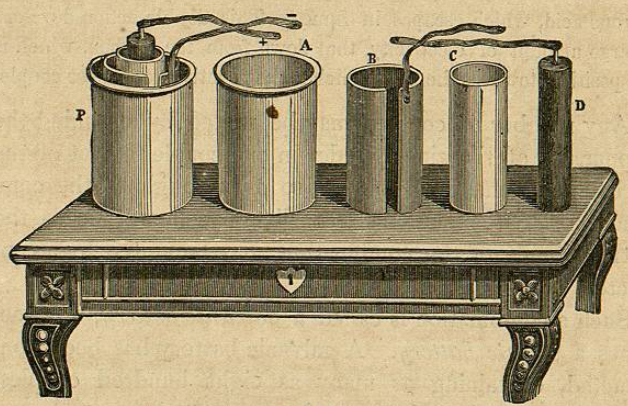

Fig. 285.

parts are: 1. An earthen vessel, *A*, containing dilute sulphuric acid; 2. a zinc cylinder, *B*, open at one side and having a strip of copper soldered to its upper extremity; 3. a vessel, *C*, of porous earthen-ware, containing nitric acid; 4. a cylinder of carbon or coke, which is well calcined, and a good conductor of electricity. At the top of this

How is the action of the pile explained according to this theory? (415.) Who invented the Carbon Pile? When? Describe one of the couples of BUNSEN's pile, in detail.

cylinder a stem of copper is inserted, to which is soldered a thin strip of the same metal.

The completed couple, represented at *P*, is formed by putting the cylinder *B* into *A*, then putting *C* into *B*, and finally, introducing the cylinder *D* into the cylinder *C*. On bringing the slips of copper in contact, a current of electricity is developed, flowing from the carbon to the zinc.

In this case there is a double chemical action. Water is decomposed in the vessel *A*, giving its oxygen to the zinc, forming oxyde of zinc, which is taken up by the sulphuric acid, producing sulphate of zinc. This remains in solution. The hydrogen of the water passes through the porous cell, *C*, and uniting with a part of the oxygen of the nitric acid, decomposes it, reproducing water, and also forming nitrous acid, which escapes in fumes. This double action develops a large amount of electricity, that flows from the carbon, which is the positive, towards the zinc, which is the negative pole of the couple.

Any number of couples may be united by attaching the copper slip of the zinc cylinder in one couple to that of the carbon in the next couple, and so on throughout the combination. The remaining two slips, which will be at the extreme ends of the combination, may be united by a conductor.

Such a combination is called a *galvanic battery*, or sometimes a *voltaic battery*. A galvanic battery has been constructed, containing as many as eight hundred couples. Fig. 286 represents a battery of twenty couples.

II.—APPLICATIONS OF GALVANIC ELECTRICITY.

Effects of the Galvanic Battery.

416. The Effects of the Galvanic Battery may, for convenience of study, be divided into *physiological*, *heat-*

Explain the action of a couple of Bunsen's *pile.* How are the couples connected? What is such a combination called? (**416.**) What are the principal effects of the galvanic battery?

ing, *illuminating*, *chemical*, and *magnetic*. They are all due to the recombination of the two electricities, as in machine electricity, but they are more remarkable and more energetic, because of their continuous action.

Physiological Effects.

417. The Physiological Effects of galvanic electricity are a succession of shocks producing violent muscular contractions, not only in living, but in dead animals, as shown in the case of Galvani's frog.

When we touch but one of the poles of a galvanic battery, no shock is felt, but if we take both electrodes in our hands, as in Fig. 286, we feel a sensation similar to a shock from a Leyden jar, with

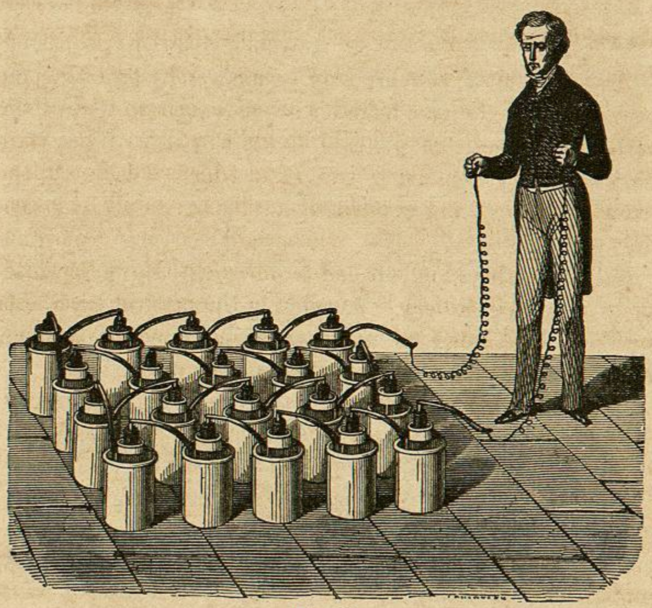

Fig. 286.

To what are they due? (**417.**) What are the physiological effects? *How may a shock be obtained from a battery?*

this difference, the latter is instantaneous, whilst that from the galvanic battery is continuous. The action of the battery keeps up a continuous supply of the two fluids, which supplies the place of that lost by recombination in passing through the body of the experimenter.

The effect of galvanic electricity upon the bodies of dead animals is peculiarly striking. It produces violent contractions of the muscles, causing motions similar to those of the living being. On the occasion of performing some experiments upon the body of a criminal who had been executed, in England, a violent and convulsive respiration was produced, the eyes opened, the lips moved, and the face, no longer under the control of the will, assumed expressions so strange and horrifying that one of the assistants fainted from terror, and only recovered his natural state of mind after several days.

Heating Effects.

418. When a current of galvanic electricity is passed through a conductor, it becomes heated, and often to such a degree as to produce fusion or even vaporization. When a powerful current is passed through a wire, it soon becomes incandescent, and then melts or is dispersed in vapor. Small wires burn with splendid brilliancy. Silver burns with a greenish light, and much smoke arising from the vaporization of the metal. Gold burns with a bluish white light. Platinum, which is infusible in the most intense heat of our furnaces, melts into spherical globules with a dazzling light.

With a battery of 600 couples, DESPRETZ fused nearly half a pound of platinum in a few minutes. Carbon is the only body which has not been fused by galvanic electricity. DESPRETZ, however, by passing a current through small rods of pure carbon, succeeded in softening them so much that they could be bent and made to adhere, which indicates an approach to fusion.

What effect has galvanic electricity on dead animals? (**418.**) Describe the heating effects of the battery. DESPRETZ' experiments.

Illuminating Effects.

419. The heating effects just described are accompanied with a disengagement of more or less light, but to obtain the most brilliant electrical light possible, calcined carbon points are employed. They are at first placed in contact, one being connected with the positive, and the other with the negative pole of a powerful galvanic battery, as shown in Fig. 287. The points immediately become incandescent,

Fig. 287.

(**419.**) Describe the illuminating effects.