

and confined to, and following a continuous conductor, of which the two metallic elements and the acid solution form a part, the whole comprising a complete electric circuit.

For the purpose of studying the generation and behavior of dynamic electricity the elements referred to may be formed into an electric generator or battery, and the magnetic needle and conducting wire may be combined to form an electrical indicator or galvanometer.

The engraving shows convenient apparatus for making the primary experiments in dynamic electricity. The glass tank or cell is built with special reference to projecting the visible manifestations of the phenomena exhibited in the cell, upon a screen, by means of the lantern, to enable a number of persons to observe simultaneously.

The cell consists of two plates of transparent glass 4 by 6 inches, separated by a half inch square strip of soft rubber, which is cemented to both glasses by means of a cement composed of equal parts of pitch and gutta percha. The cell is nearly filled with the exciting liquid, consisting of dilute sulphuric acid (acid 1 part, water 15 parts), in which are placed two plates, the positive plate consisting of a strip of zinc about one-sixteenth of an inch thick, the negative plate being a strip of copper.

As commercial zinc is so impure as to be violently attacked by the exciting liquid, it is well to dip the zinc strip into the solution, and then apply to it a drop or so of mercury, which amalgamates the surface of the zinc and prevents local action.

When these two plates are brought into contact with each other in the exciting liquid, hydrogen gas is given off copiously at the copper or negative plate, while the action at the zinc or positive plate is almost unnoticeable. If the plates are connected together by a conductor outside of the solution, the same phenomenon is observed.

The plane flat surfaces of the cell offer facilities for the examination of the plates by means of the microscope, and if so examined it will be found that so long as there is no metallic connection between the electrodes they will remain unaltered, and no action is discoverable; but when the circuit is completed, the first visible indication of action is the sudden whitening of the copper plate as if it were frost-covered; the next indication of action is the formation over the entire surface of the plate of myriads of minute silvery bubbles, which grow until they become detached, when they rise to the surface and escape into the air. These bubbles may be discharged into the mouth of a small test tube, and when a sufficient quantity of gas has accumulated it may be ignited, showing that it is hydrogen.

The appearance of the negative plate when the cell is in action is shown in Fig. 2 greatly magnified. The gas bubbles formed on the surface of the copper are at first very minute, but they rapidly increase in size and begin to merge one into another, taking an upward course. When a large bubble has absorbed a large number of the smaller bubbles and becomes sufficiently buoyant to overcome its adhesion to the plate it rises to the surface and is dissipated.

The accumulation of hydrogen on the negative plate seriously affects the strength of the current. To ascertain to what extent and at what time this happens, a

SIMPLE GALVANOMETER

like that shown in Fig. 1 will be required. This instrument consists of a common pocket compass, a wooden frame or spool, and about 20 feet of No. 32 silk covered copper wire. The wood spool (Fig. 3) has a recess cut in the top at either end to receive the compass, which is placed a short distance from the flat body of the spool, and the wire is wound evenly around the body back and forth until the spool is full. Then the terminals of the wire are connected with two spiral springs fastened to the ends of the spool and forming "binding posts" for receiving the wires from the battery.

In regard to the adjustment of the compass, it should be arranged with the line marked N S parallel with the wires of the coil, and the instrument should be turned until the N S line is exactly under the needle, then a weak current should be sent through the coil and the deflection noted. The current should then be sent in the opposite direction, when the needle will be deflected in the opposite direction. If the amount of deflection is the same in both cases the galvanometer is in condition for use; but if the deflections differ in degree, the compass must be turned in its socket until the proper adjustment is secured. The only precaution necessary in the construction of this instrument is to select a compass whose needle is delicately poised and vibrates freely.

By connecting the galvanometer with the cell as indicated in

the engraving it will be noticed that after a limited time the galvanometer needle begins to fall back toward 0°, a point which it ultimately reaches if the circuit is kept closed; a shorter the circuit the sooner the cessation of the current. This

ENFEEBLEMENT OF THE CURRENT

is principally due to three causes, one of which has already been noticed, that is, the accumulation of hydrogen on the negative plate. The film of hydrogen not only prevents contact between the exciting solution and the plate, but it actually renders the surface to a certain degree positive and consequently in nature, although not in degree, like the positive plate. Another cause of enfeeblement of the current is the reduction on the copper by the hydrogen of a portion of the sulphate of zinc accumulating in the liquid. This increases the similarity of the two plates, and consequently assists in diminishing the current. The reduction of the strength of the exciting liquid of the cell and the oxidation of the zinc contribute still further toward the diminution of the current. All this results in making the two plates similar in their action, and in a consequent weakening of the current; but this chemical action cannot be avoided, as to secure any action in a galvanic cell the exciting fluid must be capable of decomposition. The oxidation of the zinc, the accumulation of the hydrogen on the positive plate, and the weakening of the exciting solution are the three great causes of inconstancy in batteries. The first may be remedied in a great measure by amalgamation; the remedy for the last is obviously the strengthening of the solution; and the second, the accumulation of hydrogen on the positive plate or the polarization of the plate, can only be remedied by removing the plate from the exciting solution for an instant, or by brushing it while in the solution, or by violently agitating the exciting solution. The galvanometer needle faithfully indicates the result of either treatment. The polarization of the electrode may be strikingly exhibited by allowing the copper plate to become polarized and then replacing the zinc with a clean copper strip like the one already polarized. The galvanometer needle will be deflected in the opposite direction, showing that the polarized copper plate acts in the same manner as the zinc; that is, it is positive to the clean copper plate. Now by removing the polarized copper plate and wiping and replacing it, the deflection of the needle will be much less, and it will not fall back to 0°, until the very slight coating of zinc which has been deposited on the copper is removed from the polarized plate by means of emery paper or otherwise. Precisely the same effect is noticed when a newly amalgamated zinc plate is opposed to an oxidized zinc plate. The oxidized plate in this case will act as the negative.

This method of showing the effect of the polarization of the plate is much more conclusive and convincing than to employ a secondary battery, or to treat the element under examination as such by connecting it with another battery, as the phenomenon attributed to the polarized plate manifests itself in an unmistakable manner while the plate remains in position and under the conditions of actual use.

Although the zinc is called the positive plate of the battery, and the copper the negative plate, the positive electricity proceeds from the copper through the external portions of the circuit toward the positive or zinc plate, and the negative electricity proceeds from the positive or zinc plate toward the negative or copper plate.

This is extremely confusing to the student of electricity, but still there is reason for putting it in this way. The zinc plate in all batteries is the active element, and the platinum, copper, or carbon plate is the passive element. In the exciting fluid of the battery the current passes from the zinc or positive plate to the platinum, copper, or carbon, negative or receiving plate, thence outward by the conductor attached to the negative plate. This conductor, as it conveys away the positive electricity, has been called the positive electrode or conductor; and as negative electricity appears on the conductor connected with the positive or zinc plate, this conductor has been called the negative electrode or conductor. All that need be remembered is that on a conductor outside of the exciting solution, the positive electricity proceeds from the passive plate of the battery, and the negative electricity proceeds from the active plate of the battery, and the flow of the electric current outside of the exciting fluid is from the passive to the active plate.

Terms such as "electric current," "electric fluid," "flow of the current," are based on the assumption that the action of dynamic electricity is analogous to that of fluids; but as nothing is known of the form of electricity, these expressions are to be considered as purely conventional.