he gave utterance to a blast which startled his audience from their seats, and shook the dishes upon the grocery shelves. When the surcharged atmosphere had cleared a space, the Colonel sat calmly majestic in his chair, while I observed that every eye had become fastened upon me, the writhing object of his disdain.

"So they've got it incopperated as a city, eh?" continued Colonel Snore. "Have they nommernated a Mayor yet, I wonder? For everdently, gentlemen," said Colonel Snore, with the last severe thrust which his merciless sarcasm could give—"everdently we have here a canderdate!"

STORING ELECTRICITY.

IN order to understand the true nature of the operation which is designated in the language of the day as storing electricity, it is essential to begin with those fundamental and important principles of modern science, namely, the conservation of energy and correlation of forces.

Far-reaching and important as these principles are, and obscure as the words indicating them may seem, they admit of very simple exposition, and can be easily comprehended if judiciously approached. The best way of treating the subject, we believe, is by taking an example and developing the general principle from it.

Suppose we have a large reservoir for water on a hill near a river-bank, and at the foot of the hill a pump, by which water from the river may be forced up into the reservoir. Suppose that the pump is worked by a steam-engine, horses, men, or any other *motors*, until the reservoir is filled. Two things will then be manifest: first, that we have expended the energy of the steam-engine, horses, or men in lifting the water from the river into the reservoir; and secondly, that the water so lifted has acquired a power of doing work, or an energy, which it did not possess before. In other words, it can now work a hydraulic engine, water-wheel, or the like, which it could not do while it remained below in the river.

Yet more than this, however—we shall find that if the water from the reservoir were used to operate a hydraulic engine or the like, it would develop an amount of energy exactly equal to that which was expended in raising it from the river into the reservoir. We of course leave out of consideration such side issues as losses by friction and the like, and consider only the energy expended in lifting the water up, and the energy redeveloped in letting it down.

It is manifest, then, that in the case supposed we have a *storage of energy*, or "conservation of energy"; for the energy of the steam-engine, horses, or men expended on the pump is recovered from the hydraulic engine after a greater or less interval of time, during which it has been *stored* or *preserved*, ready for use when wanted.

It is manifest, however, that the energy, *while stored*, was in some very different condition from that in which it existed in the steam-engine, or other motor, when that was working the pumps. There the energy existed as motion of masses of matter, and varied with the weights moving and the velocities with which they moved.* In the reservoir, however, all was at rest, and the energy of the water was in no way manifested or measurable from any action there taking place.

In fact, the energy of the water, while in the reservoir, consisted only in *a capacity of developing energy when it was let out*, and not in anything then active.

This distinction is fully recognized in the scientific treatment of the subject, and we call the energy of the water in the reservoir "potential energy," while that of the steam-engine, or that developed in the hydraulic engine by the water when it is allowed to run out of the reservoir through such hydraulic engine, we call "actual energy."

The potential energy of the water in the reservoir is often called "energy of position," because it manifestly depends on the position of the water at a height above the river into which it can flow. In fact, it depends on two things—the attraction between the earth and the water, *i. e.*, gravitation, which gives the water weight, and the distance through which the water can move in obedience to this attraction.

A few words as to the meaning of the word energy and its distinction from force would, we think, be desirable in this place. Energy implies the combination of two things—force and motion—and is the equivalent of the result of its exercise, which we call *work*, which is also a compound idea involving the exercise of force through space.

Force alone exhibits no energy, and does no work. Thus a weight resting on the ground is attracted toward the centre of the earth by the force of gravity, and exerts against the ground on which it rests a certain force expressed by its weight, but it has no energy, and to the end of time, while simply lying at rest, would do no work.

To do work, or have energy, it must move or be capable of moving in obedience to force. Thus if we raise it from the ground one foot, the force of gravity on it will be the same, but it will now be able to move down one foot, and so develop energy and do work. If we raise it ten feet, it can move ten times as far, and can thus develop ten times as much energy and do ten times as much work. If the weight actually moves, we say that it has "actual energy" in it; if it is only so placed that it can move, we say that it has "potential energy."

The above illustrations will, I think, give a true general idea of the relations between actual energy, or energy of motion (often called kinetic energy), and energy of position, or potential energy, and will show how potential energy comes to be in a certain sense a storage of actual energy, inasmuch as it gives us the ability of turning on at will and re-obtaining actual energy in consequence of a previous expenditure of actual energy in securing the conditions essential to the existence of the potential energy.

Thus by using a small steam-pump running constantly we may accumulate in a high reservoir water enough to operate occasionally a hoist or other machine for a short time with an intensity of power the small engine could not at any one moment exhibit. Of course, however, the total amount of work done is in no case *greater* than that yielded by the small engine, but in fact is always less, by reason of friction and other causes of loss; but the same total amount, or even a less total amount, may be more desirable if furnished in a more concentrated way, or if held in reserve, ready for use when called upon.

There are many other similar applications of the general principle embodied in the above example, such as the "accumulators" used with hydraulic presses, reservoirs of compressed air used to operate drills and various other machines, the winding up of the weights of a clock or the spring of a watch, and the like. In all cases energy is converted from its active into its passive condition by causing motion in opposition to some natural force, by reason of which the substance moved is put in such a position that it can move back again in obedience to the same force, thereby developing actual energy again.

Thus when we wind up the clock weight we expend actual energy of motion in lifting the weight from a position in which it was unable to move, in obedience to the force of gravitation, to a position

---

* We of course refer to the product of mass by square of velocity (mv^2).

where it *can* move in obedience to that force.

So again when we wind up a spring, we change the relative positions of its particles from those in which they are exactly where the elastic and other forces tend to place them (and therefore can not move in obedience to these forces any further) to such relative positions as are *not* what the acting forces would cause them to occupy, and from which, therefore, they can and do move in obedience to these forces whenever they have the opportunity.

So again with compressed air. In its ordinary condition the air particles are as far apart as their mutual repulsion* tends to drive them under existing conditions, and therefore they have no tendency to separate farther; but if by a compressing pump we crowd a vastly greater number into the same space, they are forced to approach each other within reach of powerful repulsion, and are thus in condition to move apart in obedience to this force when the occasion comes.

In all these cases we have a storage of energy in so far that we can at any time reproduce again (losses excepted) the same amount of energy that was expended in producing the change effected in the material acted upon.

So far we have considered this transformation of actual into potential energy only in connection with what may be called mechanical forces, such as gravitation, elasticity, and repulsion; but precisely the same principle applies to any other simple force, such, for example, as chemical affinity. Here likewise we can convert active into potential energy, and then reverse the process in a manner closely analogous to that which we have already described, nor in this case are we at all confined to mere sensible mechanical energy, like that of a moving steam-engine, as the form of energy to be converted.

Thus, to take an example which has been made familiar to most readers of late years, the active energy of the sun-rays acting on a growing plant causes it to separate, to a greater or less degree, the hydrogen and carbon present in the earth's atmosphere in combination with oxygen as water and carbonic acid, and to build up these elements in its structure as wood fibre. While combined in water and carbonic acid the strongest attractions of these elements were satisfied, and no further combination under ordinary conditions was possible; but when torn away by the energy of the sunlight from this condition, and arranged in the relatively feeble combination in which they exist in wood fibre and other related products, they acquire *potential energy*, or the capacity of obeying their stronger attractions, and of uniting again with oxygen so as to reproduce the very form of actual light and heat energy to which they owed their existence.

In this sense a log of wood may be considered as a reservoir charged with sunlight, and the contents of a coal-scuttle a magazine loaded with the tropical sun-rays of the carboniferous era.

So, again, when metallic zinc has been prepared from one of its ores by the use of fuel in the ordinary manner, the active energy of the burning fuel has separated the metal from the other elements with which it was combined in the ore, and has thus given it the power of entering again into like or other combinations, with the reproduction of active energy such as that expended in its production.

In this sense a mass of metallic zinc may be regarded as a reservoir charged with energy, which it will retain unchanged until the proper conditions are fulfilled for its redevelopment in active form.

Instances of this sort may be multiplied indefinitely; nor is the transformation of energy confined to the change of active or actual into potential (although this interests us most in the present connection), but every form of energy may be transformed into every other. As, for example, the potential energy in a mass of coal may be converted into heat energy in the furnace and boiler of a steam-engine; this, through the engine, into mechanical energy in the moving parts; this, by means of a dynamo-electric machine, into electric energy; this again into light and heat energy in an electric lamp; and this again, falling on growing plants, as in Siemens's recent experiments on the growth of plants at night under the electric light, may be transformed into the potential energy of wood fibre fit for fuel. Such cycles as this might be indefinitely multiplied, for every process of nature and art which we

---

* It is unnecessary to consider here what is the *cause* of this repulsion, as this would only complicate the statement without modifying its general character.

see going on around us involves one or many of such transformations.

In each and every one of these transformations, also, this further rule holds good, that precisely the same amount of energy which disappears in one form appears in some other, neither more nor less, so that amid the countless changes every moment in progress the total energy of the universe is absolutely constant.

Such as we have described them being the general relations of all forms of energy and all varieties of forces, we will now turn to the special relations existing between chemical and electrical forces and the energies which are developed in connection with them.

Chemical force is a peculiar sort of attraction existing between the molecules or ultimate particles of unlike substances, causing them to combine together, with the result that compounds are formed having properties which did not exist in any of the combining bodies beforehand.

Thus the two gases oxygen and hydrogen combine to form water, which is a liquid. Copper, a ductile red metal, and sulphuric acid, a colorless liquid, combine to form sulphate of copper, a bright blue brittle solid, and so on.

In most cases chemical combination, when it takes place, develops actual energy in the form of heat; but if some other form of energy is produced, such as light or electricity, then a correspondingly less amount of heat energy is manifested.

Electric force is a peculiar one, involving both attraction and repulsion, and obeying laws whose statement is of necessity rather complex, and which we need not here consider, because we are at present only concerned with electricity in the condition of actual energy, as when it is moving as a current through a conducting circuit. This we know as a *galvanic current*, and its relations to chemical force and energy are the following:

When two dissimilar conductors are plunged in a liquid capable of reacting chemically with one of them, and are united by some conducting substance outside of the liquid, then a current of electricity will be established, starting, as we assume, from the surface where the metal and liquid are reacting, passing through the liquid to the other immersed conductor, and then through the exterior conductor back to the first or active conductor. The amount of this electric current will be directly proportional to the amount of the chemical reaction between the active conductor and the liquid, and its total energy will be exactly equal to the total energy involved in the chemical reaction which goes on between the active element and the liquid.* Thus if the total energy of the reaction between zinc and sulphuric acid is expressed by 3006. thermal units, the total energy of the electric current produced by the solution of a pound of zinc in such a combination would be 3,006. such units, or, in other words, a pound of zinc would heat 3.006 pounds of water one degree, if combined with sulphuric acid directly *without* the development of an electric current, and if it was so arranged that it *did* produce an electric current, then the current so produced would heat 3.006 pounds of water one degree, all losses being excluded.

It is on this principle that we obtain electric currents by what are known as galvanic batteries. These consist in their simplest form of vessels containing dilute sulphuric acid, in which are set plates of zinc for the active element, and carbon for the other (Fig. 1). When these elements are connected by a conductor such as copper wire, the zinc combines with the sulphuric acid, and sets in motion a galvanic current, which continues to flow in the direction already described as long as there is any zinc and acid left to keep up the action.

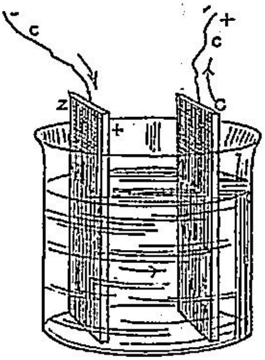

Fig. 1.—Simple Galvanic Couple.

In this case we have the potential chem-

---

* I intentionally omit all reference to the establishment of difference of potential by contact and other matters of detail, as likely to complicate the subject, and as not essential to an understanding of the phenomena now before us.

ical energy of the zinc converted into actual electric energy so soon as the circuit is closed by means of the copper wire, and this conversion is arrested as soon as the connection is broken, so that we may look upon the zinc, when thus arranged in the battery, as a reservoir of electric energy which will remain charged for an indefinite time if not used, and can be drawn upon at any moment by the mere closing of the circuit.

Of course the zinc is not a reservoir of electric energy in the sense that it has any electricity stored in it. All that it contains is potential chemical energy, or the capacity of combining chemically with sulphuric acid; but as this renders it capable of developing electric energy at any moment, we may with as much propriety call it a reservoir of such energy as we can call a water tank on a hill a reservoir of mechanical energy, because it can at any time produce mechanical energy by giving motion to a hydraulic machine, though there is no such motion in the tank.

The galvanic battery, as we have just seen, is a means of converting chemical into electric energy. We will now turn to an apparatus for reversing this operation, or for converting the active energy of an electric current into the potential energy of one or more chemical substances tending to combine. The simplest illustration of this is furnished in the apparatus known as a *voltameter* (Fig. 2). We have here a glass vessel partly filled with water, and having two small plates or wires of platinum passed through from below. Above these are supported two graduated tubes filled in the first instance with water. When the platinum wires are connected with a galvanic battery of sufficient power, the water in the vessel is gradually decomposed, one of its constituent gases, hydrogen, rising in bubbles from one wire, and the other, oxygen, from the other wire. These gases will be collected in the two graduated tubes, and can be there measured and examined.

It is hardly necessary to say that these two gases have a powerful chemical attraction for each other, and if mingled will unite, on the application of a spark, with violent detonation, exhibiting actual energy in a most conspicuous way. As long, however, as they are not mingled, or, being mixed, are not ignited, their energy is purely potential.

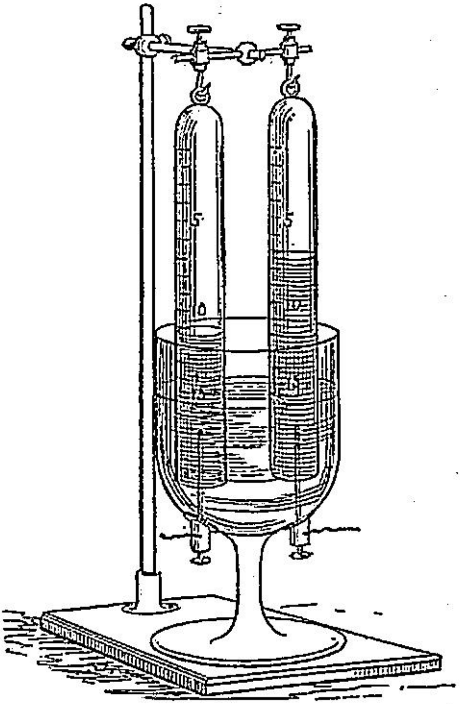

FIG. 2.—A VOLTAMETER.

This sort of electric separation of chemical compounds, with the necessary result that the compounds so separated may unite, and by so doing develop other forms of energy, is by no means rare, but occurs with a multitude of substances, and is manifestly a first step in the direction of that sort of storage of electric energy which consists in converting the active energy of the current into some potential form of energy, capable of indefinite preservation, and of being reconverted into the actual energy of the galvanic current at will. It remains to be seen, however, whether this last conversion is possible, and if so, how it can be carried out in a manner practically useful. This part of the subject we can best develop in a historic sequence.

As early as 1801 a French investigator, by name J. N. Gautherot, observed that when wires of platinum or silver had been used as terminals of a galvanic battery for the decomposition of water containing some salts, they acquired the power of yielding a galvanic current without the aid of the battery, for a brief time.

Ritter of Jena, soon after, in 1803, made a similar observation, and in fact followed it up to the point of producing what he called a "secondary pile." This he constructed of disks of copper and moist paper alternately, and he found that if its ends were connected for a time with a galvanic battery, it would acquire the power of producing by itself for a short time all the effects of the ordinary galvanic arrangement.

Among other curious experiments, he "galvanized" a coin by connecting its two surfaces with the poles of a battery, and showed that it would retain the power of producing certain galvanic effects for many minutes.[*]

Neither of these experimenters seems to have understood the true nature of the reactions which he observed and studied. Ritter, who gave much attention to the subject, regarded it as a mere charging with electricity, similar to that observed with the Leyden-jar. The error of this view was pointed out and proved experimentally by S. Marianini, Professor of Physics and Mathematics in the "Lycée" of Vienna, who showed that the result was due neither to the action suggested by Ritter, nor to the polarization of the fluid between the plates, as suggested by Volta,[†] but to a polarization of the metallic plates of the secondary battery. This memoir is printed in the *Annales de Physique et de Chimie*, 1828, vol. xxxviii., pp. 5–40.

Meantime the theory and true nature of the action of a galvanic current on a liquid conductor had been discussed by Grotthus[‡] in 1806, by Sir Humphry Davy[§] in the same year, De la Rive[‖] in 1825, and in 1833 Faraday established what are known as his laws of electrolysis.

In one or another of these memoirs the true character of the actions taking place in Ritter's secondary battery was more or less fully developed. It was not, however, until Grove, in 1839, began his researches on the "gas battery" that the subject was thoroughly investigated, and the correct theory fully demonstrated.

In a postscript dated January, 1839, to a letter addressed to the editors of the *London and Edinburgh Philosophical Magazine*,[*] the distinguished lawyer and scientist W. R. Grove described an arrangement which corresponds exactly with the voltameter shown in the last figure, but which was operated in the following manner: The two platinum wires were connected through a galvanometer (an instrument to measure galvanic currents), and then the glass tubes, in place of being filled with water, were filled one with oxygen and the other with hydrogen gas, and were then lowered over the platinum wires. As soon as the gases reached the wires a strong galvanic current was shown by the galvanometer, and continued for days. The gases slowly disappeared, and the current ceased when they no longer reached the platinum wires. Here manifestly was a galvanic battery utilizing the potential chemical energy of oxygen and hydrogen gases to develop a current of active electric energy.

In a letter addressed to one of the editors of the same journal, and dated October 29, 1842, Grove details further experiments with such a gas battery made with certain improvements in construction, and among other things shows that a series of such batteries will decompose water in a voltameter such as we have above described, and draws attention to the remarkable circumstance that in this case oxygen and hydrogen, by their combination in one place, are furnishing the energy to decompose water into oxygen and hydrogen at another.

In the *Philosophical Transactions of the Royal Society* for 1843, pp. 91–112, Grove gave a detailed account of numerous experiments with various forms of his gas battery, of which in its most convenient form of construction Fig. 3 will give a good idea.

The jars M M contain water mixed with a little sulphuric acid, in these are supported glass tubes closed at the top by closely fitting brass caps cemented to them, from which hang strips of platinum coat-

---

[*] *Nicholson's Journal*, 1804, vol. vii., p. 288; vol. xii., p. 99. *Tilloch's Philosophical Magazine*, 1805, vol. xxiii., p. 54. *Bulletin des Sciences*, October, 1803, no. lxxix., p. 145. *Journal der Chimie und der Physik*, of Van Mons, March, 1805, no. xvii., p. 183.

[†] Volta's article, *Annales de Chimie et d'Histoire Naturelle de Brugnatelli*, vol. xxii., p. 16.

[‡] Grotthus's memoir on decomposition of water and bodies held in solution, *Annales de Chimie*, vol. lviii., pp. 54–74; also, *Philosophical Magazine*, vol. xxv., pp. 330–339.

[§] *Philosophical Transactions of the Royal Society*, 1807, pp. 1–56.

[‖] De la Rive. Some phenomena presented by voltaic electricity in liquid conductors. *Annales de Chimie et de Physique*, vol. xxviii., p. 190. Also *Quarterly Journal of Science*, vol. xix., p. 346.

[*] *Philosophical Magazine*, 1839, vol. xiv., Third Series, p. 129.

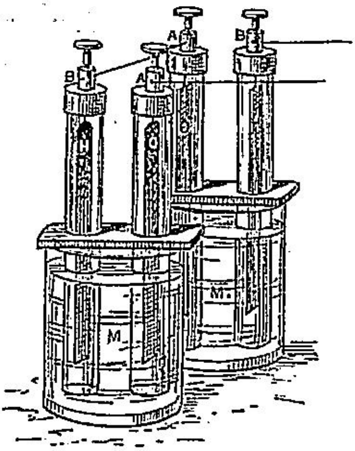

FIG. 3.—GROVE'S GAS BATTERY.

ed with the same metal in a state of fine division obtained by electrolytic deposition in a solution of chloride of platinum. The tubes are filled alternately with hydrogen and oxygen gases, as indicated by the letters H and O.

The elements, or platinum plates, are connected alternately in the several cells by wires, the element hanging in the oxygen of one cell or jar being connected with that hanging in the hydrogen of the next. In some of his experiments Grove used fifty or more of such cells.

The action which takes place in these cells is as follows: The hydrogen in the hydrogen tube is to a certain extent absorbed by the platinum strip, and then, in consequence of certain contact actions which it would occupy too much place here to describe, this absorbed hydrogen acquires an exalted affinity for the oxygen of the adjacent water, which it combines with, just as does the zinc in an ordinary galvanic battery.

The hydrogen thus displaced from the adjacent water molecule travels by a series of interchanges through the mass of liquid to the oxygen tube, where it finds oxygen, likewise in contact with platinum, with which it combines to form water. This is precisely analogous to the action in many forms of ordinary galvanic batteries, and, as in them, the electric current travels in the same direction as the hydrogen.

After what had been already done by Gautherot, Ritter, and others, it was of course perfectly manifest that in place of filling up these tubes with hydrogen and oxygen gases from reservoirs of the same, they might be filled by passing a galvanic current through them from a battery, exactly as if they were so many voltameters.

If this were done, the result would be a storing of electric energy in the sense that we have already explained, namely, a conversion of electric energy into potential chemical energy under conditions which would allow of a reconversion at any time.

Such a "gas battery" as we have above described was, however, a relatively feeble source of electric power, and would have no practical advantage over an ordinary galvanic battery for any of the uses to which such an apparatus is generally applied.

The first important step in the development of a storage battery on the principle involved in Ritter's experiments, and fully developed in those of Grove, was made in 1859 by Gaston Planté.

SECONDARY BATTERY.

In the *Comptes Rendus* of the French Academy, vol. l., p. 640, appears one of the earlier formal accounts of Planté's labors, and from that time to this various notices of his work are to be found in the scientific publications.

In 1879 he published a book entitled *Recherches sur l'Électricité* (Paris: A. Fourneau), which contains a full account of all that he has done. A good abstract of this book will be found in *Gordon's Electricity*, vol. ii., p. 140 *et seq*.

The chief results of Planté's investigations are the following: His secondary batteries consisted each of two sheets of lead about three feet square, kept apart by a sheet of felt or several narrow strips of gutta percha, and rolled up into a cylinder, and immersed in a jar or other vessel filled with dilute sulphuric acid. Fig. 4 shows the appearance of one of these cells. Conductors passed out from each of these plates, and were connected as occasion required.

FIG. 4.—A PLANTÉ CELL.

In order to prepare this battery for use it was found desirable to treat it in a manner which brought it more rapidly into the condition it would otherwise arrive at after prolonged use. To accomplish this it was first repeatedly charged alternately in opposite directions; then charged and allowed to stand for some time; discharged, and charged again. The reason of this treatment will be manifest presently.

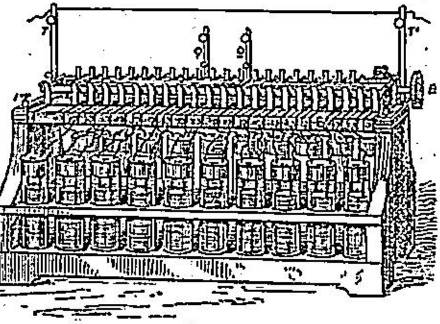

FIG. 5.—BATTERY OF PLANTÉ CELLS.

The charging is effected by connecting the two plates with the terminals of an ordinary battery of two or three Grove or Bunsen cells in series for some time, when the one plate becomes coated with peroxide of lead, and the other with pure metallic lead.

The repetition and reversal of the action causes a penetration of the same into the substance of the plates, thus securing the formation of a larger amount of peroxide of lead on the one surface, and of a spongy layer of metallic lead on the other.

When the battery is charged, which means that as much as is possible of peroxide on one surface and metallic lead on the other is deposited, the charging battery is disconnected, and the secondary battery is ready to go into action whenever its terminals are connected by a conductor.

It then operates like any other battery, the metallic lead on the one side combining with the sulphuric acid to form sulphate of lead, while the liberated hydrogen is combined by the oxide of lead on the other plate into water, the oxide being thereby reduced to its lower form, which then combines to a greater or less extent with the sulphuric acid present to form sulphate of lead. When by this means both plates have been reduced to a nearly identical condition, the action ceases, and the battery is "discharged," or becomes incapable of yielding any further current, until by a fresh application of the charging battery the lead sulphate on one plate is reduced again to metallic lead, and on the other is oxidized into peroxide of lead.

It is manifest that the "storage capacity" of such a battery will depend largely upon the thickness of the layers of peroxide and of spongy metallic lead which are formed on its plates, for the thicker these layers, the more chemical action will they develop in being reduced to sulphate, and the more electric action will they absorb in being changed back again into oxide and metal respectively. Hence the repeated reversed charging employed by Planté in preparing his cells.

A very simple and ingenious method of saving the loss of time and energy involved in this preparation has been recently devised by M. Camille Faure. He coats both plates, before rolling them up, with a paste of red lead and sulphuric acid. This red lead is largely converted into sulphate of lead by the action of the acid mixed with it and present in the battery. Then on the first action of the charging current the sulphate of lead on one plate is reduced to a sponge of metallic lead, while that on the other is oxidized into peroxide. This is the only difference between the "secondary battery" of Planté and the "storage battery" of Faure. Both operate on the same principle and in the same way, with probably some considerable improvement in efficiency (*i. e.*, capacity) in the Faure arrangement. Both batteries are frequently made in the form of numerous flat plates covered with some woven fabric, and packed near together in a rectangular box filled with dilute acid. The sole novelty in the Faure device is in the use of a porous coating of decomposable substance, by which a thick layer of active material can readily be obtained on both plates of the battery.

The general appearance of the Faure cells as they are now constructed for industrial use is shown in the accompanying wood-cuts.

Fig. 6 shows a single cell in a rectangular glass jar, and Fig. 7 a series of cells con-

FIG. 6.—A FAURE CELL.

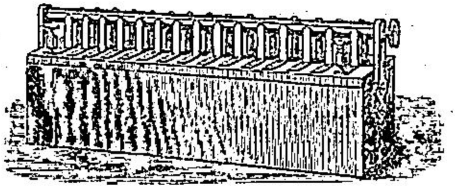

FIG. 7.—BATTERY OF FAURE CELLS.

nected for use, and made with boxes of wood impregnated and heavily coated with an asphalt varnish which enables them to withstand the action of the acid solution which fills them. The weight of a single cell of this battery is about ninety to one hundred pounds.

The great interest which they have excited at the present time comes largely from two causes. First, the enormous improvement in dynamo-electric machines, by reason of which electric currents can be supplied at a small fraction of what they used to cost when they were obtained only from galvanic batteries; and secondly, the great need developed, in the attempts to apply the cheap electricity furnished by dynamo machines to various uses, for some means of storing the electric force either actually or practically.

In order that this desired result should be obtained in a way commercially valuable, several conditions must be fulfilled: 1st, the storage must not involve any great loss of energy in the charging; 2d, the stored energy should be retained with little loss; 3d, the cost of the storage apparatus should be moderate; 4th, the apparatus should be within moderate limits of bulk and weight; and 5th, it should be enduring, and not wear out so as to require frequent replacement.

The most interesting tests of the Faure battery, with a view of determining in how far it fulfilled these conditions, were made at the Conservatoire des Arts et Métiers in Paris, by a committee of which M. Tresca was president, and MM. Allard, Le Blanc, Jubert, and Pottier were members. An extensive extract from the report of this committee to the French Academy will be found in the *Telegraph Journal and Electrical Review*, of London, for March 18, 1882, vol. x., p. 196.

Passing by all details of the experiments, we will only note the general facts and results. The battery experimented upon consisted of 35 cells weighing about 95 pounds each, or in all 3325 pounds, say 1½ tons. It was charged by a Siemens dynamo-electric machine, which absorbed the mechanical energy of 1.558 horse-power during 22 hours 45 minutes, which would be equal to one horse-power for 35 hours 26 minutes, or in foot-pounds, 70,158,000. Of this mechanical energy thirty-four per cent. was expended in useless work in the machine and battery during the operation of charging, and sixty-six per cent. was stored as chemical energy in the battery. Of this stored energy sixty per cent. was recovered as electric energy. This would amount to about 27,782,700 foot-pounds, or one horse-power for 14 hours 4 minutes. In other words, the actual work of one horse for 35½ hours, after being stored in 1½ tons of battery, could be recovered to the extent of about 14 hours' work of one horse, or the equivalent of the same in electric or other energy. Thus Mr. Edison's 16-candle electric lamps require about one-sixth of a horse-power each, and therefore six of them could be run for 14 hours with the energy stored in this battery as above stated. Mr. Edison's smaller lamps, which give about eight candles each, or the same light as an ordinary German student's-lamp, require but half as much power, and thus six of them could be run for 28 hours by this same battery.

This is, of course, not a high degree of efficiency, but, as the above-named committee remark in their report, "In many cases the loss would be fully counterbalanced by the advantage of having at hand and entirely at one's disposal so abundant a source of electricity."

The occasion of the losses experienced in the storage battery, and also the exact character of the actions, chemical and electrical, which go on in it, are very fully developed in a paper on "The Chemistry of the Planté and Faure Accumulators," by J. H. Gladstone and Alfred Tribe, in the English journal *Nature*, of January 25 and March 16, 1882. The main sources of loss there shown are, first, local action between the negative lead plate and the peroxide of lead deposited upon it, and second, the resistance of the oxide and sulphate to the passage of the current, by reason of which energy is lost by being converted into useless heat in the battery both at charging and discharging.

By so regulating the discharge of the battery as to reduce this loss, and by giving seasons of repose in which the battery recovers some of its deterioration, Messrs. Ayrton and Perry succeeded in recovering eighty-two per cent. of the power put into one of these batteries.

A single cell weighing eighty-one pounds without the dilute acid yielded, in three discharges of six hours on three successive days, an electric current whose total energy was 1,440,000 foot-pounds, which represents about one horse-power exerted for about three-quarters of an hour.

This is almost double the efficiency per weight of battery shown by the French experiments, and the recovery of eighty-one in place of sixty per cent. of the stored energy would indicate also a more than double efficiency in this respect also.

Experiments in using the Faure battery for industrial purposes have already been made in various directions. It has been employed to run street cars and other vehicles (including even velocipedes), to propel boats, to operate sewing-machines and others requiring a small amount of power, to illuminate houses and single rooms, and also steamers and railway carriages.

As yet it has only been shown to be economically valuable where peculiar conditions protect it from competition with other means of effecting the same results more directly. Thus it has been used in France at the establishment of M. Duchesne-Fournet, where linen cloth is bleached by exposure to sunlight on bleaching greens, to run a train carrying out the cloth from the factory to the green, and to wind in the cloth from the green after it has been bleached. An ordinary steam-engine could not be used in this case on account of its smoke and cinders. Again, in railway cars it is much more convenient to use a Faure battery than to have a dynamo-electric machine, either run by a special engine or by the motion of the train. The latter would of course be impracticable without some storage arrangement to provide a light when the train stopped.

Indeed, as a regulator of electric currents, to equalize them, or bridge over brief interruptions of the generating machines, a storage battery would seem to have a wide application.

As is well known, a number of these Faure batteries were recently used to maintain four incandescent lights when required on the steamer *Labrador* during her passage to New York, and they accomplished this work successfully. Arrangements are now being made to light some cars on the Pennsylvania Central Railroad in the same manner.

FOR THE MAJOR.

CHAPTER II.

"YOU are a little tired, Major?"

"Possibly. Somewhat. Sara has been reading aloud to me from the *Review*. She read all the long articles."

"She does not know how that tires you. I must tell her. She does not appreciate—she is still so young, you know—that with your extensive reading, your knowledge of public affairs and the world, you can generally anticipate, after the first few words, all that can be said."

The Major did not deny this statement of his resources.

"I am going to the village for an hour or two," continued Madam Carroll; "I shall take Sara with me." (The Major's face seemed to evince a certain relief.) "We must call upon Miss Honoria Ashley. And also at Chapultepec, upon Mrs. Hibbard."

"Yes—widow of General Hibbard, of the Mexican war," said the Major, half to himself.

"I do not pay many visits, as you know, Major; our position does not require it. We open our house—that is enough; our friends come to us; they do not expect us to go to them. But I make an exception in the case of Mrs. Hibbard and of Miss Ashley, as you have advised me to do; for the Ashleys are connected with the Carrolls by marriage, though the tie is remote, and Mrs. Hibbard's mother was a Witherspoon. I know you wish your daughter to understand and recognize these little distinctions and differences."

"Certainly. Very proper," said the Major.

"We shall be gone an hour and a half, perhaps two hours. I will send Scar to you for his lessons; and I shall tell Judith Inches to allow no one to disturb you, not even to knock at this door. For Scar's lessons are important, Major."

"Yes, very important—very."

"Good-by, then," said his wife, cheerfully, resting her hand on his shoulder for a moment, as she stood beside his chair. The Major drew the slender hand forward to his gray mustache.

"Fie, Major! you spoil me," said the little woman, laughing.

She left the room, making, with her light dress and long curls, a pretty picture at the door, as she turned to give him over her shoulder a farewell nod and smile. The Major kept on looking at the closed door for several minutes after she had gone.

Not long after this the same door opened, and a little boy came in; his step was so light and his movements so careful that he made no sound. He closed the door, and laid the book he had brought with him upon a table. He was a small, frail child, with a serious face and large blue eyes; his flaxen hair, thin and fine, hung in soft scanty waves round his little throat—a throat which seemed too small for his well-developed head, yet quite large enough for his short puny body. He was dressed in a blue jacket, with an embroidered white collar reaching to the shoulders, and ruffles of the same embroidery at the knee, where his short trousers ended. A blue ribbon tied his collar, and his slender little legs and feet were incased in long white stockings and low slippers, such as are worn by little girls. His whole costume, indeed, had an air of effeminacy; but he was such a delicate-looking little fellow that it was not noticeable. From a woman's point of view, he was prettily dressed.

He crossed the room, opened a closet door, and took from a shelf two boxes, which he carried to the table, making a separate journey with each. He arranged these systematically, the book in the centre, a box on each side; then he pushed the table over the carpet toward the Major's chair. The table was narrow and light, and made no sound. He moved onward slowly, his hands, widely apart, grasping its top, and he paused several times to peer round the corner of it so as to bring it up within an inch of the Major's feet, yet not to touch them. This accomplished, he surveyed the position gravely. Satisfied with it, he next brought up a chair for himself, which, while not the ordinary high chair of a child, seemed yet to have been made especially for him on account of his low stature. He drew this chair close to the table on the opposite side, climbed into it, and then, when all was prepared, he spoke. "I am quite ready now, papa, if you please." His slender little voice was clear and even like his mother's; his words followed each other with slow precision.

The Major woke, or, if he had not been asleep, opened his eyes. "Ah, little Scar," he said, "you here?" And he patted the child's hand caressingly. Scar opened his book. Then one of the boxes, which contained white blocks with large red letters painted upon them. He read aloud from the book a sentence, once, twice. Then he proceeded to make it from memory with the blocks on the table, working slowly, and choosing each letter with thoughtful deliberation.

"Good—blood—can—not—lie," he read aloud from his row of letters when the sentence was completed. "I think that is right. Your turn, papa."

And then the Major, with almost equal slowness, formed, after Scar had read it, the following adage: "'A brave father makes a brave son.' That's you and I, Scar."

"Yes, papa. And this is the next: 'The—knights—are—dust.—Their—good—swords—rust.—Their—souls—are—with—the—saints—we—trust.' That is too long for one. We will call it three."

Father and little son completed in this slow way eight of the sentences the little book contained. It was a small flat volume in manuscript, the letters clearly printed with pen and ink. The Major's wife had prepared it, "from the Major's dictation," she said. "A collection of the fine old sayings of the world, which he thinks should form part of the preliminary education of our son."

"Eight. The lesson is now finished, papa," said Scar. "If you think I have done sufficiently well, I may now amuse myself with my dominoes." As he spoke he replaced the letters in their box, put on the cover, and laid the manuscript book on the top. Then he drew forward the second box, and took out his dominoes. He played by himself, one hand against the other. "You will remember, papa, that my right hand I call Bayard and my left Roland."

"Yes," answered the Major, looking on with interest.

Roland won the first game. Then the