This is a very important fact to bear in mind, as by the measurement of the copper resistance of the conductor in a cable, a basis is at once established by which to determine the distance of a fracture. Knowing the value of the resistance of the whole length of the cable conductor —assume for 2,000 miles the value to be 2,000 units (the measure of the unit being the resistance of one mile of the copper conductor)—an interruption occurs, continuity is broken, and the copper resistance only gives 760 and 1,240 units respectively when measured from either end. Thus is clearly established a basis upon which the approximate distance of the "fault" may be ascertained. Again, it was pointed out that the insulating medium surrounding the conducting wire absorbed an appreciable amount of electricity in the passage of the current through

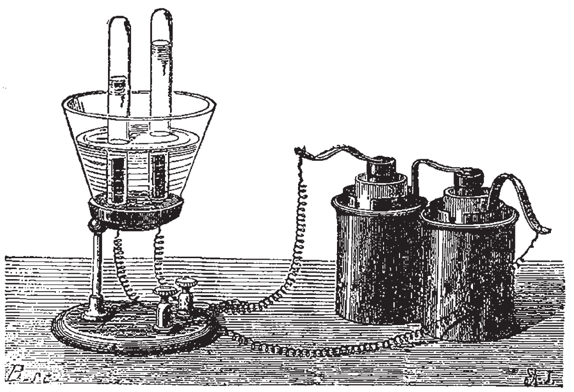

FIG. 13.—Decomposition of water by the chemical action (electro-motive force) of the voltaic battery.

the conducting wire. This absorption may be taken as a constant quantity, and the absorption for any length of cable be determined from given data as regards the time of electrification or the saturation of the circuit, and the time of discharge, or the percentage of leakage from the mechanical imperfections of all the insulating substances. Thus again is established a process by which, under certain conditions of injury to a cable, by correctly measuring the discharge, the position of a fault may with more or less accuracy be localised. The commercial value of a submarine cable depends upon the rapidity of its transmitting capacity, and the speed depends upon the time required to produce a variation in the tension of the current at the distant end sufficient to influence the recording instrument. The working speed depends, therefore, upon the delicacy of the apparatus employed, as then a small difference in the tension will suffice. In cables similarly constructed, but of different length, the speed of each is inversely proportional to the square of the length; because, when the length is doubled, the capacity for charge is doubled, and the electrical waves of charge and discharge have twice the distance to travel; therefore the retardation is increased fourfold. When the dimensions and weight of the insulating medium are fixed, there is a loss of speed if the conducting wire is too small; and again, if the conducting wire is too large, the speed is reduced by the increased capacity of the wire in a greater degree than it is augmented by the reduced resistance of the wire. The best accepted ratio of the insulator to that of the conductor is when the insulator is somewhat less than $3\frac{1}{2}$ times that of the copper conductor, or, more accurately speaking, in the proportion of 3·41 of insulator to 1 of copper. On long cables and where high speed is required, every current transmitted through the cable should be at equal intervals and of equal duration, so that the charge may be maintained constant between the signals.

(*To be continued.*)

ECLIPSE OF THE SUN, APRIL 6

As no telegram has been received from Dr. Schuster's party on its arrival at Singapore, we are compelled to estimate the date of its arrival by the telegram in yesterday's papers, which informed us that the *Pera*, in which vessel the Expedition was conveyed from Galle, arrived at Shanghai. The vessel was due there on the 3rd, and arrived on the 5th. Assuming all the delay to have occurred on this side of Singapore, Dr. Schuster's party would have reached that place on the 24th of March, which would give them ample time to reach Chulai Point and make their preparations, especially as the colonial steamer which has been detached for the service is very swift.

It is not probable that news will be received from either of the parties for some little time, as it will probably be carried by local steamers to Rangoon, Singapore, or Calcutta.

In the meantime we take the following extracts from an article in the *Times* of Tuesday, showing the final arrangements adopted so far as they are known:—

"The advantages of scientific, and especially of astronomical expeditions, are by no means confined to the record of those special phenomena which the observers go out to see. The growing interest taken by all classes in the study of nature, while it makes a large number anxious to participate in the results obtained, at the same time puts them in presence of a class of facts which the stay-at-home student finds it hard to realise for himself. The total eclipse of the sun, which is visible in the Nicobar Islands, Burmah, Siam, and Anam to-day is a case in point. While early risers are breakfasting this morning, with the beams of the sun, low down in the east, not yet able to break through the morning mists, some quarter of the way round the world there will be at least three parties of anxious observers battling with the fierce noontide heat of that same luminary nearly overhead, soon, indeed, to have his light and heat entirely withdrawn for a time, but, all the same, under conditions so different from those we are familiar with here, that the sun and the surroundings of the observers might seem to form part of another universe. Another point—and this is one which will doubtless disappoint many—is that this eclipse, which, as we stated in a former article, on the high authority of Mr. Hind, in the time of obscuration will not be surpassed by any other available one during the present century, is totally invisible here. Although there is almost total darkness for nearly five minutes in Burmah and Siam, no trace of an eclipse will be seen in these islands, for the reason that although it began as early as two minutes to four this morning, and continued till sixteen minutes past nine, the moon's shadow falls first to the south, and then to the east of us. In fact, the line of total eclipse runs from the Cape of Good Hope to Burmah and Siam, and thence to the North Pacific. We lie, therefore, in no part of the track of the shadow.

"To pass from what may be considered geographical considerations, we may remind our readers that in a former article (the *Times*, Jan. 11, reprinted in NATURE, p. 201) we pointed out the value which many men of science attached to securing observations of this eclipse, and we attempted to give a general statement of the various questions pressing for solution, which, in the opinion of the Council of the Royal Society, justified an application to the Government for aid, not only in sending out expeditions from this country, but in organising a party of observers in India. Our readers have also been informed (the *Times*, Jan. 16) of the fact that the application to Government was at once acceded to in the warmest manner, and that Sir Stafford Northcote, the Marquis of Salisbury, and the Viceroy of India, as well as the Admiralty authorities, have been unceasing in the encouragement and assistance which they have afforded. Nor was this all. The assistance afforded by the directors of the Peninsula and Oriental Steam Navigation Company in aid of the grant from Government was of so material a kind that the committee were enabled to send no less than six fully equipped observers from Europe to take part in the observations, as well as spare instruments for the use of the Indian parties.

"As a final result of all the efforts made, both in England and India, the location and composition of the various parties this morning, so far as is known, are as follows:—

"Camorta, in the Nicobars.—Capt. Waterhouse, Messrs. Meldola and Reynolds.

"Mergui (British Burmah).—Professors Pedler, of Calcutta; Tacchini, of Palermo; and Vogel, of Berlin, and assistants.

"Chulai Point (Siam).—Dr. Janssen and assistants, Dr. Schuster, Messrs. Lott and Beasley.

"The Royal Society Committee will certainly have to be congratulated if it has really been able to secure the valuable co-operation of all the distinguished foreign workers it has enrolled. We know that Herr Vogel joined at Suez, and that Prof. Tacchini, who was in India when the invitation reached him, joined at Calcutta, and that his instruments, which had been despatched to Europe, were only stopped by telegram at Aden; but with regard to Dr. Janssen, it is not yet known whether he really joined at Singapore or not; indeed, no telegram has yet been received from the Siam party since they left Galle, and there parted from the Camorta party, which was then transhipped to the *Enterprise*, a despatch boat belonging to the Indian Government, which left Calcutta on the 11th of March, having Capt. Waterhouse and Professors Tacchini and Pedler, with their assistants, on board. The *Enterprise* was to land the Camorta party and then proceed to Mergui to establish a second station. We may also mention that the Siam party was to proceed from Singapore to Siam on board the steamer belonging to the Government of the Straits Settlement, the *Charybdis* having been disabled by an accident.

"From this digression as to arrangements we may return to the question of *personnel*. In no eclipse expedition, perhaps, has such a large percentage of the observers been under fire before. Dr. Schuster and Mr. Meldola, the chiefs of the English part of the Siam and Camorta expeditions respectively, and Mr. Lott, are the only ones who have not taken part in the observation of former eclipses. Mr. Reynolds assisted Mr. De la Rue to photograph the eclipse of 1860. Professors Tacchini, Vogel, Pedler, and Mr. Beasley formed part of the expeditions of 1870. Capt. Waterhouse assisted Major Tennant to obtain the beautiful series of photographs of the eclipse of 1871 at Ootacamund, which are so valuable when taken in connection with those obtained at Baikul by the British Association party. With regard to Dr. Janssen, we are unable to say how many eclipses he has seen; he has certainly been at most which have occurred since 1860, if not before that date.

"With regard to the objects to be obtained and the instruments to be employed, the Instructions drawn up by the Royal Society, and issued to the observers by its authority, come to our aid, and, by the minute and careful references to each instrument and to each part of the attack which they contain, enable us almost to picture to ourselves each observing party with its complement of telespectroscopes and prismatic cameras, the 'time-teller' going through his terribly responsible task, the silent activity of the photographic 'dark room,' and, above all, the ever-sharpening 'cusps,' and final total extinction of the Lord of Day—an extinction out of which, however, is born one of those sights for gods and men, which, once seen, so impress every power of the mind that they can ever afterwards be recalled as transcendent instances of the beauty and glory which attach themselves to some of the rarest as well as to some of the more common phenomena of nature.

"The most striking thing about the Royal Society programme is its simplicity. For the first time in eclipse expeditions, no eye observations are arranged for; all the phenomena are to be photographically recorded. Here we see the enormous advance which has lately been made in these studies; for we may remind our readers that in 1871, when the Astronomical Society were appealed to to use their influence to secure observations of the eclipse of that year, a committee of that Society would not agree to employ photography at all!

"There is another point. It is now more than probable that not even polariscopic observations will be attempted, although, thanks to the care of Mr. Spottiswoode, arrangements have been made for photographing the polariscopic corona, as it may be called, if a spare observer presents himself.

"The ground has been cleared in yet another way. The photographs of the corona, which were so strongly insisted upon by Mr. Lockyer in the observations of the eclipse of 1871, and objected to by the Astronomical Society, were necessary to determine the solar or non-solar origin of the corona. This question has now been set at rest by showing that part of it is really at the sun, and this is now termed the coronal atmosphere. When this was settled, it was suggested by the same observer that this atmosphere would be very likely found to vary in shape and dimensions with the sun-spots. This is the question, then, that is to be attacked in the old way on this occasion; and, on the suggestion of the Royal Society Committee, the Viceroy has charged Capt. Waterhouse with this duty. He will use the same instrument that was used by Major Tennant and himself in 1871, on Dodabetta. . . . .

"The instruments termed 'prismatic cameras' are ordinary $3\frac{3}{4}$-inch achromatics, with a large prism of small angle ouside the object-glass, and a camera replacing the eye-piece. Such an instrument will give a spectra of small dispersion.

"Of course with such an instrument as this employed on the full sun, the impression on the plate would be a blurred spectrum containing no detail, but as the advancing moon reduces the part of the sun still remaining visible to a thin silver crescent, then the instrument will begin its work; the actual shape and thickness of each stratum of vapour above the photosphere will be impressed by each coloured ray its light contains, and will stand out on a band of continuous spectrum, which will get feebler and narrower as the silver crescent thins to nothingness. Then the whole ring of chromosphere and coronal atmosphere which will burst upon the eye will be sorted out, if all goes well, into its various metallic constituents, by means of a chain of rings of greater or less thickness and regularity upon the photographic film. The vapours extending furthest outwards from the photosphere will be represented by the broadest rings, those lying closest to the photosphere by the narrowest. The Instructions are careful to insist upon complete rehearsals before the day of the eclipse, so that we may be assured that the simple programme we have sketched may be simply carried out, and that the observers will not attempt too much. It is as well to state this because persons unaccustomed to observations might imagine from the multiplicity of detail in the Instructions that the labours of the observers will be more than ordinarily complicated.

"Each party will have a telespectroscope and a prismatic camera. In addition to this equipment, Prof. Pedler will use a heliostat, focussing the image of the sun on a spectroscope from which the slit has been removed. As a camera, he uses a Janssen slide, which he has arranged so as to get thirty pictures.

"We are reminded incidentally by the Instructions on 'the multiplication of results,' of the enormous advantage of the photographic method; there is no chance of error or forgetfulness. The observations sent home to the Royal Society will enable those on whom the labour and responsibility of reducing them will fall to almost reconstruct the eclipse for themselves.

"We may remark in conclusion that not only may we hope for many important results in solar physics if the weather be favourable, but that the benefit to science arising out of the expedition will be by no means limited to the eclipse results. Already Drs. Vogel and Schuster, the latter of whom is a distinguished pupil of Owens College, have done some important work on the varying intensities of the different parts of the solar spectrum at different times of the day, and in different climates on the voyage out, but both will remain some months in India to pursue their inquiries—Dr. Vogel in photographing the solar spectrum, with variously coloured photographic films; Dr. Schuster in establishing himself at a considerable height for the purpose of photographing the various solar phenomena and the spectra of some of the most important of the southern stars. The observers, all of whom have made considerable sacrifices in travelling a quarter round the globe and back again in the pursuit of science, certainly command our sympathy and deserve success. The Government grant of 1,000*l*. has been the means of calling forth, and, we hope sincerely, rendering fruitful, a vast amount of individual effort which would have been powerless without it. We may add that all the instruments have either been purchased by the Royal Society out of its own funds or lent by private individuals."

*ON THE DISSIPATION OF ENERGY**

THE second law of thermodynamics, and the theory of dissipation founded upon it, has been for some years a favourite subject with mathematical physicists, but has not hitherto received full recognition from engineers and chemists, nor from the scientific public. And yet the question under what circumstances it is possible to obtain work from heat is of the first importance. Merely to know that when work is done by means of heat, a so-called equivalent of heat disappears, is a very small part of what it concerns us to recognise.

A heat-engine is an apparatus capable of doing work by means of heat supplied to it at a high temperature and abstracted at a lower, and thermodynamics shows that the fraction of the heat supplied capable of conversion into work depends on the limits of temperature between which the machine operates. A non-condensing steam-engine is not, properly speaking, a heat-engine at all, inasmuch as it requires to be supplied with water as well as heat, but it may be treated correctly as a heat-engine giving up heat at 212° Fahr. This is the lower point of temperature. The higher is that at which the water boils in the boiler, perhaps 360° Fahr. The range of temperature available in a non-condensing steam-engine is therefore small at best, and the importance of working at a high pressure is very apparent. In a condensing engine the heat may be delivered up at 80°Fahr.

It is a radical defect in the steam-engine that the range of temperature between the furnace and the boiler is not utilised, and it is impossible to raise the temperature in the boiler to any great extent, in consequence of the tremendous pressure that would then be developed. There seems no escape from this difficulty but in the use of some other fluid, such as a hydrocarbon oil, of much higher boiling point. The engine would then consist of two parts—an oil-engine taking in heat at a high temperature, and doing work by means of the fall of heat down to the point at which a steam-engine becomes available; and secondly, a steam-engine receiving the heat given out by the oil-engine and working down to the ordinary atmospheric temperature.

Heat-engines may be worked backwards, so as by means of work to raise heat from a colder to a hotter body. This is the principle of the air or ether freezing machines now coming into extensive use. In this application a small quantity of work goes a long way, as the range of temperature through which the heat has to be raised is but small.

If the work required for the freezing machine is obtained from a steam-engine, the final result of the operation is that a fall of heat in the prime mover is made to produce a rise of heat in the freezing machine, and the question arises whether this operation may be effected without the intervention of mechanical work. The problem here proposed is solved in Carré's freezing apparatus, described in most of the text-books on heat. There are two communicating vessels, A and B, which are used alternately as boiler and condenser. In the first part of the operation aqueous ammonia is heated in A, until the gas is driven off and condensed under considerable pressure in B, which is kept cool with water. Here we have a fall of heat, the absorption taking place at the high temperature and the emission at the lower. In the second part of the operation A is kept cool, and the water in it soon recovers its power of absorbing the ammonia gas, which rapidly distils over. The object to be cooled is placed in contact with B, and heat passes from the colder to the hotter body. Finally, the apparatus is restored to its original condition, and therefore satisfies the definition of a heat-engine. M. Carré has invented a continuously working machine on this principle, which is said to be very efficient.

Other freezing arrangements depending on solution or chemical action may be brought under the same principle, if the cycle of operations be made complete.

When heat passes from a hotter to a colder body without producing work, or some equivalent effect such as raising other heat from a colder to a hotter body, energy is said to be dissipated, and an opportunity of doing work has been lost never to return. If on the other hand the fall of heat is fully utilised, there is no dissipation, as the original condition of things might be restored at pleasure; but in practice the full amount of work can never be obtained, in consequence of friction and the other imperfections of our machines.

The prevention of unnecessary dissipation is the guide to economy of fuel in industrial operations. Of this a good example is afforded by the regenerating furnaces of Mr. Siemens, in which the burnt gases are passed through a passage stacked with fire-bricks, and are not allowed to escape until their temperature is reduced to a very moderate point. After a time the products of combustion are passed into another passage, and the unburnt gaseous fuel and air are introduced through that which has previously been heated. The efficiency of the arrangement depends in great degree on the fact that the cold fuel is brought first into contact with the colder parts of the flue, and does not take heat from the hotter parts until it has itself become hot. In this way the fall of heat is never great, and there is comparatively little dissipation.

The principal difficulty in economy of fuel arises from the fact that the whole fall of heat from the temperature of the furnace is seldom available for one purpose. Thus in the iron smelting furnaces heat below the temperature of melting iron is absolutely useless. But when the spent gases are used for raising steam, the same heat is used over again at another part of its fall. There is no reason why this process should not be carried further. All the heat discharged from non-condensing steam-engines, which is more than nine-tenths of the whole, might be used for warming or drying, or other operations in which only low temperature heat is necessary.

The chemical bearings of the theory of dissipation are

* A lecture given at the Royal Institution on Friday, March 5, 1875, by Lord Rayleigh, M.A., F.R.S., M.R.I.