and discharges up to nearly half an ampere were obtained. Some of the published photographs are very remarkable. One of them showing the electric corona and streamers round the magnetised globe might easily be mistaken for a genuine photograph of a typical solar eclipse. Many of the phenomena of sunspots are also very strikingly imitated in the experiments.

Birkeland proceeds to discuss the cause of the general magnetic field of the sun, the fact of the existence of which has been established by Hale. He attributes it to induced currents circulating in the interior of the rotating mass, which, he argues, can only have a comparatively feeble electric conductivity. He says (*loc. cit.* p. 540):—

"We know that electric currents circulating in large globes formed of good electric conductors are of great persistence. Lamb found that for a globe of copper as large as the earth, ten million years would elapse before the currents fell to $1/\epsilon$ of their former intensity. The induction effects produced by electric rays emanating from sunspots may therefore give rise to currents of long duration if circumstances permit. It is probable that as regards the sun, we shall be obliged to suppose a somewhat feeble conductivity of the gaseous interior, to the intent that the electric currents created and circulating within it are reduced with a fairly high rapidity and are transformed into heat."

In a recent communication to the Royal Astronomical Society,[2] the writer brought forward some evidence deduced from laboratory experiments, which led to a contrary conclusion, namely, that the gaseous matter composing the sun must be a highly conducting medium. The experiments of Kaye[3] and the writer showed that carbon and a number of metals emit on heating ionisation currents of a relatively very high order of magnitude, and this in absence of any external applied potential and at atmospheric pressure. The currents are almost certainly carried by swarms of negatively charged particles of relatively considerable mass, the emissivity of the emitting surface increasing very rapidly with increase of temperature.

In the interior of a carbon-tube resistance-furnace heated by alternating current, the apparent gaseous resistance of the order of megohms at 1400° C. fell at the highest attainable temperature to a small fraction of an ohm, due to the emission from carbon alone. In one series of experiments where temperature measurements were made, the conductivity increased exponentially nearly two hundred-fold for each rise of 1000° C. Impurities such as iron and silicon, which are generally present in ordinary samples of carbon, may further increase the conductivity four or five fold during the first heating of a new furnace. Though influenced somewhat by the surrounding gas, the emissivity appears to be invariably present in neutral or reducing media. The experiments of King, briefly referred to by Hale in his paper in the current number of *The Astrophysical Journal*, show that though the emissivity of carbon falls with increase of pressure, it is still apparent at 20 atmospheres.

Seeing that the temperature of the sun is probably between 5600° and 6000° abs. and that of those elements shown to possess an appreciable electric emissivity, carbon, and iron at any rate are present in the solar atmosphere in considerable quantity, it is difficult to avoid the conclusion that the degree of ionisation, and consequently of electric conductivity, must be very high; probably at least as good as that of the globe of copper considered in Lamb's computation.

The bearing of these conclusions on Birkeland's solar theory seemed worthy of some consideration.

J. A. HARKER.

Teddington, September 16.

[2] Harker, "On the Origin of Solar Electricity." Monthly Notices of the Royal Astron. Soc., June, 1913.

[3] Harker and Kaye "On the Emission of Electricity from Carbon at high Temperatures." Proc. Roy. Soc. A. vol. lxxxvi, 1912, pp. 379 to 396. "On the Electric Emissivity and Disintegration of Hot Metals." Proc. Roy. Soc. A. vol. lxxxviii, 1912, pp. 522 to 538.

A New Aquatic Annelid.

ABOUT the middle of September I received from Dr. H. F. Parsons, of Croydon, a fresh-water Annelid which had been found in the water supply of Ringwood, Hants, and sent to the Local Government Board for identification. It proved to be an immature but very beautiful specimen of *Rhynchelmis limosella*, Hoffm., a member of the Lumbriculidæ. It is of peculiar interest, inasmuch as it confirms a suspicion expressed by Beddard in 1895. He remarks ("Monograph of the Order Oligochæta," p. 215) that "the genus Rhynchelmis is, so far as our present knowledge goes, confined to the fresh waters of Europe. . . . I have seen a specimen from some part of England, but cannot give any details. I believe this specimen to be in the Oxford Museum. There is every probability that it is a native of this country."

I have collected annelids in almost every part of the British Isles, but hitherto have never had the good fortune to come across the species here named. It is, therefore, very gratifying to be able to record it as a new addition to our Annelid fauna.

HILDERIC FRIEND.

Pocklington, York, September 20.

MODERN ELECTROMETERS.

RECENT research on the electron and radioactivity has necessitated so many refined electrostatic measurements that much attention has been directed to the design of electrometers, and several different instruments distinguished by their sensitiveness and convenience in working have been devised. Two types have served as the starting-points for modern improvements, the first being the gold-leaf electroscope, and the second the quadrant electrometer of Lord Kelvin; great progress has been made by bettering the insulation, the sensitiveness, and the accuracy and ease of observation, and further by important modifications of design. Polished amber or ambroid, a substance made from compressed fragments of amber, is now generally used as insulating substance, and for the first type of instrument the deflection is now measured with a reading microscope; for the second the mirror and scale is employed.

The gold-leaf instrument is used in many forms. In a modification by Exner a leaf is fastened on either side of a narrow, vertical, insulated metal plate, while opposite each leaf is a metal plate the distance of which from the central plate can be adjusted, thus controlling the sensitiveness; for potentials of some hundred volts this is a convenient form. For higher potentials of thousands of volts Braun's pattern, with a light rigid needle pivoted a short distance above its centre of mass, is much used. For very sensitive measurements C.T.R. Wilson has recently modified the gold-leaf electroscope in his so-called "tilted electrometer." In this instrument a single hanging gold leaf is attracted out of the vertical by an inclined insulated plate, which is kept charged at a constant potential. On varying the inclination of the plate by tilting the instrument, a position can be found for which the leaf is only just in stable equilibrium; slightly increasing the tilt would cause the leaf to fly over to the plate. In such a case, as is well known, the sensitiveness of an instrument is very high, a familiar example being the suspended magnet galvanometer, in which, by adjusting the field magnet, the controlling field is so arranged that the magnet is only just in stable equilibrium. The capacity of this instrument of Wilson's is very small, and a reading microscope attached to the stand enables accurate readings to be taken. Fig. 1 shows in section the instrument as made by the Cambridge Scientific Instrument Co.

To avoid difficulties, known to all physicists, which occur in working with a gold leaf, Wulf

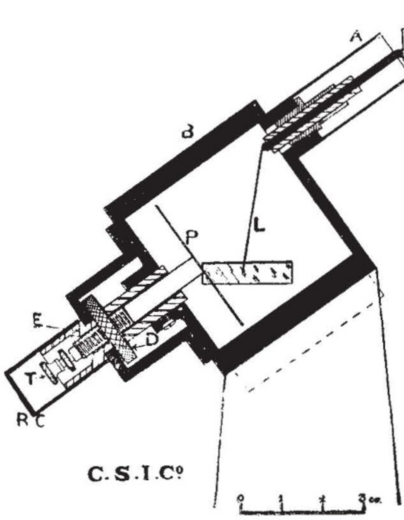

FIG. 1.—The tilted gold leaf electrometer.

has devised a very effective instrument, put on the market by the firm of Günther and Tegetmeyer, in which the leaf is replaced by quartz fibres rendered conducting by sputtering with a thin film of platinum in a kathode-ray tube. Two such fibres hang side by side, loaded with a minute weight: on being charged the fibres repel one another, and the separation is read with a microscope. The fibres give a very sharp image, and thus all difficulty connected with reading by one irregular edge of a gold leaf is avoided. The capacity is smaller than that of the smallest leaf instrument, and practically independent of the potential. The sensitiveness never approaches that of the tilted electrometer, but this instrument is excellent for measuring potentials of either a few volts or a few hundred volts, according to the fineness of the fibres, the size of the weight, and other details of construction. It fills the gap between the tilted and the Braun electrometer, and is very convenient and portable. A somewhat similar design is the Einthoven string electrometer, in which a silvered quartz fibre is stretched between, and parallel to, two metal plates, kept at a constant difference of potential.

The pattern of quadrant electrometer devised by Dolazalek is so widely used at present that it suffices to mention very briefly the improvements introduced, the small dimensions of the needle and quadrants, the quartz suspension, the amber insulations, and the light needle of silvered paper, rendered rigid by its peculiar form. Dolazalek has, however, recently devised an instrument differing in many important particulars from that familiar to English physicists, which he calls the binant electrometer, from the fact that the four

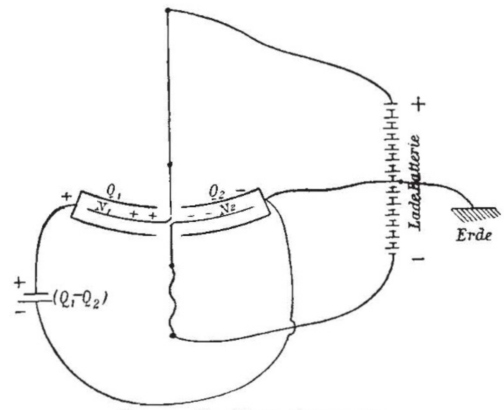

FIG. 2.—The binant electrometer.

quadrants are replaced by two semicircular "binants"[1]; it is made by Herr Georg Bartels, of Göttingen. This instrument has many advantages over the quadrant pattern, and is being widely used in Germany, although at present it seems to be unknown in England. The "needle" is a disc formed of two semicircular segments of the thinnest sheet-aluminium, stiffened by means of embossed ridges, and insulated from one another with amber. The box which encloses them is likewise made up of two semicircular parts supported on amber, arranged so that their line of separation is perpendicular to the line of separation of the needle segments. Needle and box are not plane, but formed from shallow concentric spherical shells the centre of which coincides with the point of suspension of the needle. Owing to this simple device an oscillation of the needle does not bring it any nearer to the enclosing walls, and the needle is stable at very much higher potentials than in the case of the quadrant electrometer; this form also lends increased rigidity to the delicate needle. When in use, one of the segments of the needle is charged positively, the other negatively, by earthing the middle of the battery used for charging; contact is made for the one segment through the suspension, which is an exceedingly fine Wollaston wire, and for the other through a still finer coiled wire arranged

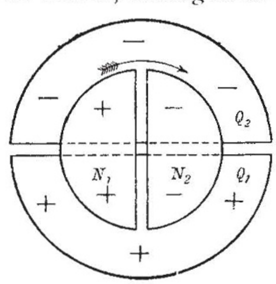

FIG. 3.—The binant electrometer. Plan.

1 "Annalen der Physik," (iv) 26, 1903. F. Dolazalek, "Binantelektrometer." Figs. 2, 3, and 4 are from this paper.

in a similar way to the lower connection in a moving-coil galvanometer. The binants of the box are connected to the potential difference to be measured.

Advantages of the instrument are the wide proportionality between deflection to one side and potential difference, and the large range of potential which may be given to the needle with satisfactory results; in addition we have the stability of the needle already mentioned. The deflections to one side are proportional to the applied potential difference over a range seven times as great as is the case when, with the quadrant instrument, readings to both sides are taken. This property has led to the construction of a portable binant instrument with a pointer, which can be used as a voltmeter, measuring directly potentials to a fraction of a volt without passage of current. If used idiostatically, the deflections are, of course, proportional to the square of the potential, and, connected in this way, the instrument measures alternating potentials very effectively.

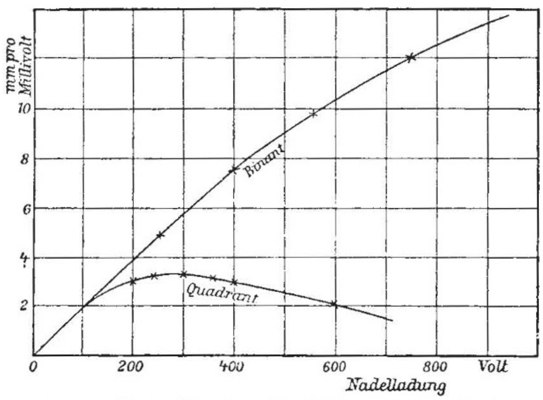

FIG. 4.—The sensitiveness of the "binant" and quadrant electrometer compared.

The potential of the needle in the binant instrument can be taken as small or as large as may be desired. The variation of the sensitiveness with the potential of the needle is shown in the diagram (Fig. 4) for a quadrant and a binant instrument of similar dimensions throughout. The abscissæ are the difference of potential of the two halves of the needle for the binant, the potential of the needle above earth for the quadrant, and the ordinates are millimetres deflection per millivolt applied potential. With the binant form the deflection is proportional to the potential of the needle up to about 400 volts, and still continues increasing up to 1500 volts (off the diagram); in the case of the quadrant instrument the sensitiveness increases slowly with the potential of the needle, and reaches a maximum at about 300 volts, after which increasing the potential of the needle is disadvantageous. Further, for the quadrant electrometer the potential of the needle cannot be taken very small, as in this case the readings are too asymmetrical on reversal, as will be seen from the ordinary formula of the text-books. For the binant the potential of the needle may be taken as small as desired; in fact, by altering the potential of the needle alone measurements of potential can be made over a region of five powers of ten.

The cause of the peculiar variations of the sensitiveness of the quadrant electrometer with the potential of the needle, increasing to a maximum and then decreasing again, is to be found in the fact that the change of capacity per unit angular displacement is not constant, as assumed in Maxwell's accepted treatment, but decreases with increasing needle potential and increasing displacement. This is due to the lines of force from the radial edges of the needle, which are to a large extent diffused not perpendicularly to the top and bottom of the box, but horizontally. The connection of such horizontal lines of force with one of the quadrants is unaltered by the displacement of the needle, and this influences the changes of capacity. The form of the needle and its position avoid these disturbances in the binant instrument; the narrow gap between the two halves of the needle, and their opposite potentials, cause the lines of force from the diametral edges to spring from one half to the other, instead of to the walls of the box, and the position of the gap perpendicularly to the gap in the box further diminishes the effect. The wide proportionalities of the binant electrometer are largely attributable to this result of its peculiar construction.

E. N. DA C. ANDRADE.

THE TECHNICAL PRODUCTION AND UTILISATION OF COLD.[1]

THE appearance of an English translation of the work by Georges Claude (1), the successful French inventor in the field of the liquefaction and rectification of air, affords an occasion for reviewing the progress made in this, which seems destined to become one of the leading departments of twentieth-century scientific industry. Eighteen years have elapsed since the inventions of Linde and Hampson solved the problem of the production of liquid air in quantity, and extended the range of low temperatures practically attainable to as great an extent as the electric furnace did in the opposite direction. It is sufficient to recall the names of Faraday, Andrews, Dewar, Hampson, and Ramsay to show that this country has not been behindhand in pioneers in this field, both in regard to the attainment of low temperatures and to their utilisation for scientific investigation. But there, as in other cases, progress in this country seems to have come to a standstill, and the commercial application and utilisation of these results has been developed entirely abroad, in this case chiefly in Germany and France.

It is on this side of the subject that the present book furnishes much information difficult to acquire easily elsewhere. Part i., dealing with elementary principles and the history of the subject, and part iii., with the properties of liquid

[1] (1) "Liquid Air, Oxygen, Nitrogen." By Georges Claude. Translated by H. E. P. Cottrell. With a Preface by D'Arsonval. Pp. xxv.+418. (London: J. and A. Churchill, 1913.) Price 18s. net.
(2) "Le Froid industriel." By L Marchis. Pp. xx+328+104 figs. (Paris: Félix Alcan, 1913.) Price 3.50 francs.