that the cleveite gases, which I obtained by the process of distillation, accounted to a very great extent for the first set.

In 1897 in a series of three communications to the Royal Society,[1] I pointed out that some of the other set of unknown lines in the stars of intermediate temperature, taking α Cygni as an example, were due to the enhanced spark lines of iron and other metals, the arc lines being almost entirely absent.

During the last year, this research has been continued; and latterly, by the kindness of Mr. Hugh Spottiswoode, the photographs of the enhanced lines have been obtained by the use of the large induction coil, formerly belonging to Dr. Spottiswoode, P.R.S. I am anxious to express here my deep obligation to Mr. Hugh Spottiswoode for the loan of such a magnificent addition to our instrumental aids.

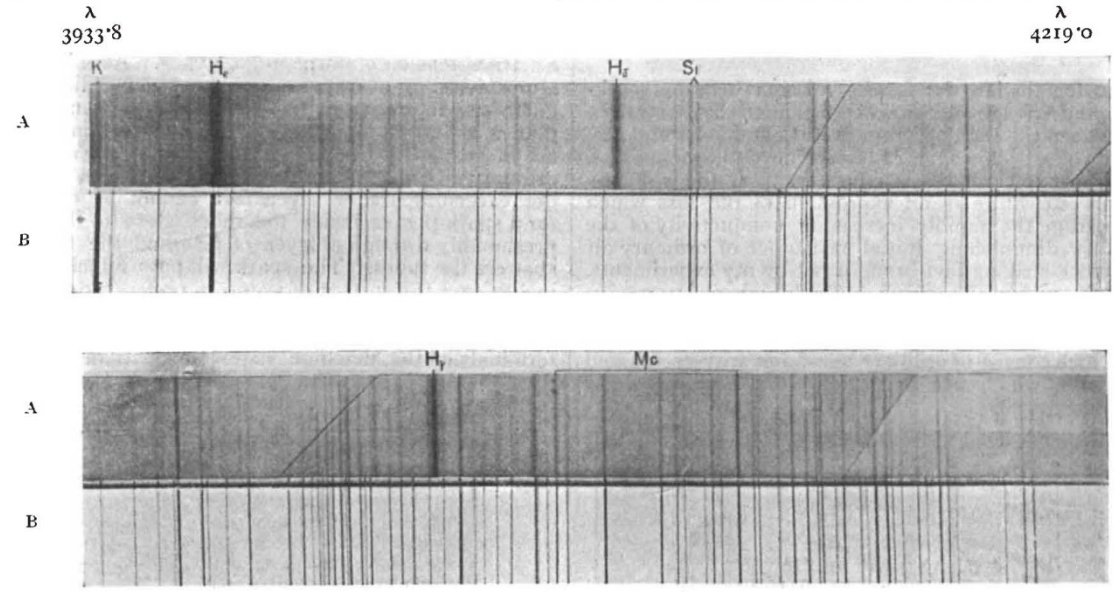
The spark obtained by means of the Spottiswoode coil is so luminous that higher dispersions than those formerly employed can be effectively used, and in consequence of this, the detection of the enhanced lines becomes more easy; their number therefore has been considerably increased.

I shall deal in a subsequent communication, when the inquiry has reached a further stage, with the details for each element.

The lines of the stars of intermediate temperature, like α Cygni, have long been recognised by the Harvard observers as well as by myself as presenting great difficulties.

In 1893 I wrote as follows[1]: "With the exception of the K line, the lines of hydrogen and the high temperature line of magnesium at λ4481, all the lines may be said to be at present of unknown origin. Some of the lines fall near lines of iron, but the absence of the strongest lines indicates that the close coincidences are probably accidental." In the Harvard "Spectra of Bright Stars," 1897, p. 5, the following words occur, relating to the same stars: "This system of lines should perhaps be regarded as forming a separate class, as in the case of the Orion lines, and should not be described as 'metallic,' as has just been done in the absence of any more distinctive name."

From the fact that these unknown lines have now been traced to a "proto-metallic" origin, as effectively as the unknown lines of the hottest stars have been traced to



Comparison of α Cygni and the enhanced lines of certain metals (chiefly of the iron group).
A = spectrum of α Cygni between wave-lengths stated. B = spectrum of enhanced lines.

The observations have already been mapped for the following substances:—

Iron, manganese, nickel, cobalt, magnesium, chromium, calcium, strontium, copper, vanadium, titanium, silicon.

In the accompanying photograph, a comparison is shown between the lines of α Cygni and the enhanced lines of the above substances thrown together. The extraordinary number of coincidences is seen at a glance. The facts are as follows:—

The number of lines measured in the spectrum of α Cygni at Kensington between λ3798·1 and λ4861·6 is	307
Of these the number which approximately coincides with the enhanced metallic lines so far observed is	120
The number of lines (excluding the hydrogen series) in α Cygni of intensity over 4 (the maximum being represented by 10) is	40
Of this number, the coincidences with enhanced metallic lines with the dispersion employed amount to	38

[1] *Roy. Soc. Proc.*, vol. 60, p. 475; *ibid.*, vol. 61, p. 148; *ibid.*, vol. 61, p. 441.

helium and asterium, we may expect that the consequences of this determination in relation to stellar classification and other connected matters, will be very far-reaching. At present I am using this new spectrum consisting of enhanced lines as an explorer, in relation to some further details of stellar classification having special reference to stars of Groups III. and IV. in which bright as well as dark lines occur.

HIGH ELECTROMOTIVE FORCE.[2]

IN the course of my investigation of electrical oscillations I have been enabled, by a simple transformation of my apparatus, to study electrical discharges of greater intensity and length than have hitherto been obtained in atmospheric air. These discharges are produced by means of a storage battery of ten thousand

[1] *Phil. Trans.*, A, vol. 184, p. 694.

[2] Extract from a lecture delivered by Prof. John Trowbridge before the American Academy of Arts and Sciences, at a meeting held in the Jefferson Physical Laboratory, Harvard University, Cambridge, U.S., December 14, 1898.

cells, giving approximately twenty thousand volts. This battery charges Leyden jars or Franklin plates, in multiple, and a simple mechanical contrivance enables me to discharge them in series. Thus I have followed the path indicated by Planté; but my experiments have covered a far greater range.

The discharges in ordinary air produced by my apparatus, with a voltage of three millions, are from 6½ feet to 7 feet in length. Prof. Elihu Thomson has obtained discharges of 60 inches by means of transformers. The discharges produced by my apparatus should be at

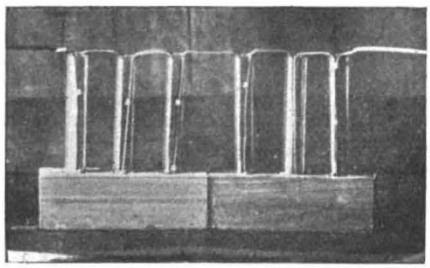


FIG. 1.

least 10 feet in length: for the relation between spark-length and voltage is closely represented by a straight line between the limits of twenty thousand volts and one million volts. This line, however, beyond one million volts, curves towards the axis representing the voltage; and this curvature is an expression of the loss which comes from the rapidly increasing conductivity of the air. This diminishing initial resistance of ordinary air is the most striking fact brought out by my experiments. Before describing the effects of such high electromotive forces, let me speak of the main features of the storage battery. There are, as I have mentioned, ten thousand cells, which consist of ordinary test-tubes with corrugated lead strips, which are separated from each other by

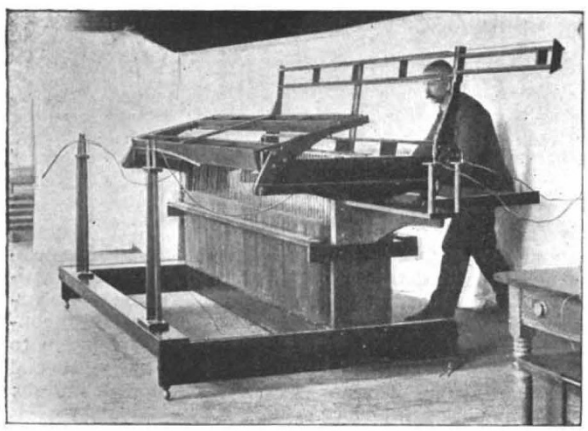


FIG. 2.

rubber bands. These strips are immersed in dilute sulphuric acid; and thus constitute Planté cells. The test-tubes are held upright in wooden blocks which have been boiled in paraffin. Lead wires are employed to connect the cells with each other and with the switch-boards. The cells are charged in multiple—forty cells being in each branch circuit—and a system of switches is employed to throw the cells into series. Fig. 1 shows the type of cells.

The construction of the apparatus for charging the Leyden jars in multiple and discharging in series, when high electromotive forces are generated, required a complete departure from the method employed by Planté; and consists, in the main, of a system of levers which obviate short circuiting. Fig. 2 exhibits this apparatus, which, in a certain sense, can be termed a step-up condenser. The figure of the operator shows the size of the apparatus, which produces in ordinary air a spark 50 inches in length. A larger apparatus, constructed on a similar plan, enables me to experiment with discharges 6½ to 7 feet in length.

I wish, especially, to call attention to the results obtained with this latter more powerful apparatus, which gives an

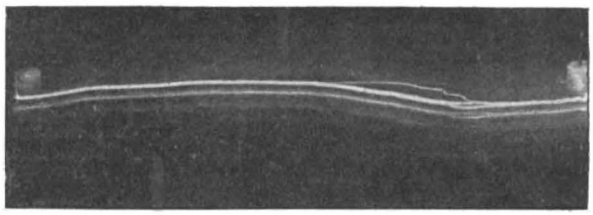


FIG. 3.

electrical tension of three million volts. At this tension, atmospheric air at ordinary pressure behaves like a fairly good conductor, and exhibits an initial resistance of less than a thousand ohms between pointed terminals five or six inches apart. Resistances of distilled water, or of ordinary city water, contained in glass tubes, of length not exceeding six or seven feet, cannot be employed; for a spark passes inside the tubes close to the walls—presumably through a layer of air—and the heated air shatters the tubes. The spark will pass fifteen or more inches over the surface of water, in preference to passing the same distance through it. Fig. 3 is a photograph of such a spark passing over the surface of water. The terminals of the machine were immersed in the water, fifteen inches apart. The photograph shows the reflection

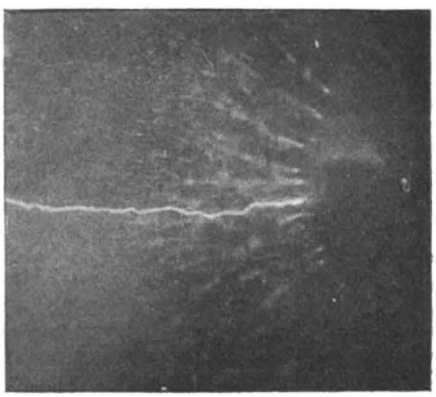


FIG. 4.

of the spark from the surface of the water, and thus gives two views, so to speak, of different sides of the spark. No ribbon effect is observable, and an absence of a zigzag path is noticeable.

A peculiar stratified appearance is seen in photographs of the brush discharge from the positive pole. Fig. 4 shows this stratification. The pole consisted of a metallic sphere one foot in diameter. Fig. 5 exhibits the brush discharge from the negative pole. In both cases these are photographs of single discharges, which are thus seen to consist both of forked white discharges,

like lightning discharges, and numerous brush discharges, which fill the air between the terminals.

It seemed an interesting question to ascertain whether the spectrum of atmospheric air obtained by means of the great electromotive force of three million volts would show more lines than are produced by lower voltages. Photographs were therefore taken between brass terminals of the spectrum produced by the spark; and comparison spectra between zinc and copper terminals were obtained by means of the spark of a transformer giving about one hundred thousand volts, with large

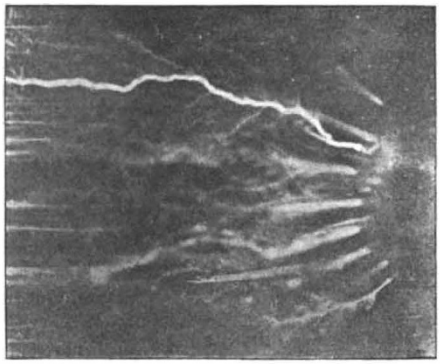


FIG. 5.

quantity of electricity. The characteristic atmospheric lines can be seen common to the three spectra. The photograph, however, of the spark produced by three million volts (A, Fig. 6) shows an absence of metallic lines, and must closely resemble, I believe, the spectrum of lightning. The photographs were taken by means of a Browning direct vision spectroscope, on orthochromatic plates, which were sensitive from the D line to the neighbourhood of the H lines. It is interesting to discover that no new lines apparently come out by the employment of very high electromotive force.

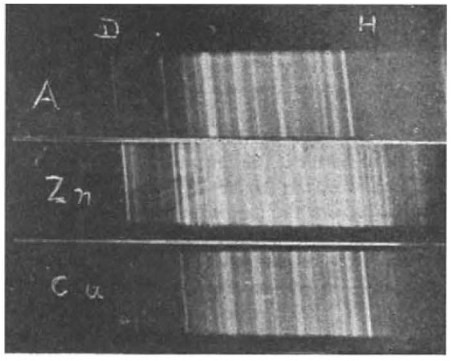


FIG. 6.

The condensers of the apparatus, which develops three million volts, were at first raised only six inches above the floor. When the room was darkened, luminous discharges were observed, which passed from the edges of the condensers to the floor. The condensers were then lifted to a height of three feet: these brush discharges were much lessened, and the length of the electrical discharges between the terminals was increased. There was still considerable loss; for sparks could be drawn from the neighbouring gas-pipes, and even from the brick walls. In order to obtain discharges in ordinary air of greater length than seven feet, by the employment of three million volts, the entire apparatus should be lifted to a considerable height above the earth, and should be remote from neighbouring objects.

The inductive effect of such high tension extends to a remarkable distance. Photographic plates contained in ordinary holders, held six to ten feet from the terminals of the apparatus, show on development arborescent figures, evidently caused by inductive electrical discharges. X-ray photographs of the skeleton of the hand can be taken by a single discharge passing through a Crookes' tube. The tube, however, is spoiled in the operation. The discharge will penetrate a space so highly rarefied that an eight-inch spark from a powerful Ruhmkorf coil cannot pass through it. If a Crookes' tube could be constructed which would resist the destructive effect of the discharge, great penetrating effect could undoubtedly be obtained.

NOTES.

THE new Session of Parliament was opened on Tuesday with the customary formalities. The legislative plans of the Government include, as stated in the Speech from the Throne to the Commons, "a measure for the establishment of a Board for the administration of primary, secondary, and technical education in England and Wales."

AT the last meeting of the Institution of Electrical Engineers, Lord Kelvin was elected an honorary member of the Institution. Lord Kelvin is the oldest surviving past president of the Institution, having held the office of president in 1874, when it was the Society of Telegraph Engineers, and again in 1889, which was the first year after the society had received the designation that it now bears.

IT is reported that the Russian Government contemplates sending an expedition to Samarkand and Merv, to investigate and report upon the recent outbreaks of malarial fever which have greatly alarmed the inhabitants of those districts.

WE learn from *Science* that the sculptor Herr Ernst Herter has completed the statue of von Helmholtz, which is to be erected in the court of the University of Berlin, between the statues of the two Humboldts. The monument will be unveiled in the spring.

M. ROUX has been elected a member of the Section of Rural Economy of the Paris Academy of Sciences, in succession to the late M. Aimé Girard.

M. E. A. MARTEL, general secretary of the Paris Société de spéléologie, has been awarded the grand medal of honour of the Société de topographie.

PROF. PERCY FRANKLAND, F.R.S., has been elected president of the Physics, Chemistry, and Biology Section of the Sanitary Institute, for the congress to be held in Southampton in August next.

THE Earl of Rosse will give an address upon the heat of the moon, at the Camera Club this evening.

THE annual general meeting of the Royal Horticultural Society will be held on Tuesday next, February 14. The annual meeting of the Royal Photographic Society will also be held on the same day.

THE annual general meeting of the Malacological Society will be held to-morrow (Friday), and a presidential address will be delivered by Lieut.-Colonel H. H. Godwin-Austen, F.R.S.

THE death is announced of Major J. Hotchkiss, who in 1895 was president of the Section of Geology of the American Association for the Advancement of Science, and was the author of a number of papers on economic geology and engineering.