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LIV. *On the Gaseous Constitution of the H and K lines of the Solar Spectrum, together with a Discussion of Reversed Gaseous Lines.* By JOHN TROWBRIDGE*.

[Plate XIII.]

I DESCRIBED in the Phil. Mag. July 1902 and Feb. 1903 the discovery of reversed lines in the spectra of gases, when the latter are submitted to powerful disruptive discharges.

In this paper I shall show that the continuous spectrum observed when glass tubes are employed is not due to the incandescence of the walls of the tubes; and also that the lines obtained by me which apparently coincide with calcium lines at wave-lengths 4227 and 3933, 3968 are not due to calcium but are gaseous lines. The group of H and K lines, therefore, of the solar spectrum, although being doubtless a composite spectrum, has a strong basis of gaseous lines. This seems more than reasonable when we consider that the solar protuberances are observed through these lines; and when we also take into account the rarefied nature of the gas and the improbability of a metallic vapour like that of calcium being projected so far from the limb of the sun.

It seemed necessary, in the progress of my work, to determine to what degree metallic electrodes influence the spectra in Geissler tubes of the dimensions I have employed. When long and powerful sparks are produced in air the metallic lines disappear at a distance of less than two inches from the terminals. The photograph, therefore, of the spectrum produced by a spark of three or four feet in length shows nothing but air-lines when the slit of the spectroscope receives the light from the middle of the spark. This is true even when sparks of eight inches are examined. The most effective way, therefore, of sifting out air-lines from metallic spectra is to employ long and powerful sparks. At one time I believed that the oscillatory nature of the discharge influenced the nature of the spectra. I am now of the opinion that self-induction acts merely by diminishing the instantaneous energy of the discharge.

In the present paper I shall confine my attention mainly to the immediate region of the H and K lines of the solar spectrum.

In Geissler tubes, having capillaries not less than two inches in length, the terminals being three and a half or four inches apart, no metallic lines were observed under the conditions of my work. Indeed, to produce metallic spectra at

* Communicated by the Author.

such distances from the electrodes during the time of duration of the discharges would demand a prodigious velocity of the particles. I have made a careful study of the influence of metallic electrodes in the tubes employed by me and find no spectra due to them.

In order to determine whether the walls of the glass tubes could give lines due to calcium, I first placed aluminium terminals on a sheet of glass of the same kind as that from which the Geissler tubes were made; and having placed the glass against the slit of the spectroscope, I passed powerful discharges of the same nature and energy as were employed in the study of the spectra of gases. The glass was badly corroded along the path of the discharge, showing the same corrosion which was observed in the capillary of the glass Geissler tubes.

No continuous spectrum was observed and no calcium lines. Similar discharges were passed through fifty ohms of No. 36 iron wire; the wire was barely raised to a dull red heat. A photograph was taken of ten centimetres of such wire, illuminated by the discharge from a Geissler tube placed in the same electrical circuit. The photograph showed the wire intact at the moment of the illumination of the tube. It took time to communicate sufficient heat to melt the wire. On the same photograph was shown the subsequent melting of the wire. That is the wire is seen intact, and also the two ends of the wire contorted and burning. If the walls of the capillary of the glass vessels are heated to incandescence the time element must be large, for the gas must first be heated by the discharge and then the walls of the glass by conduction and radiation. Thermodynamic considerations make it impossible that the walls of the glass vessels are heated to incandescence; moreover, Wiedemann* has shown that the heat of electrical discharges in Geissler tubes has been much exaggerated. A photograph was taken of the light from a Geissler tube by means of a rapidly revolving mirror. Beside the tube and in the same circuit was a spark-gap between magnesium terminals. The duration of the light of the Geissler tube was one-fourth of that of the spark between the magnesium terminals in air. There was absolutely no duration of the light of the Geissler tube due to a supposable incandescence of the glass. The light in the Geissler tube arising from powerful disruptive discharges is the strongest and most instantaneous light which has been obtained, and would be useful in the study of rapid motions.

If the glass is not vaporized by the discharges I have

* Wied. *Ann* vi. (1878).

employed, the spectrum of calcium cannot be produced in the capillary of the glass vessels. A direct test of the question whether the reversed lines observed by me are due to the glass is afforded by the use of quartz vessels, of which the ends were closed by metal plates. There being a complete absence of glass, and previous investigation having shown that the metallic plates or terminals, and the luting employed, gave no metallic spectra. In the case of quartz the powerful disruptive sparks produced absolutely no corrosion of the walls of the quartz capillaries; and the reversed line at approximately wave-length 4227 and wave-lengths 3968, 3963 (H.H.) of the solar spectrum came out with the same intensity as in the case when glass was employed. Moreover, the strong calcium lines towards the ultra-violet, besides those which apparently coincide with the H.H. lines of the solar spectrum, were conspicuously absent.

The reversed lines which I described in my previous article, and which are shown on the plates of that article, are not due to calcium.

These lines may arise from an electrical decomposition of residual air. It seems impossible to fill spectrum-tubes with perfectly dry and pure hydrogen; traces of air must enter from the purifying and drying apparatus, and the impurities may be brought to light by powerful discharges. I have shown in a previous paper that the electrical decompositions in a tube apparently filled with pure hydrogen can produce various spectra, among them that of argon. The most promising method of obtaining pure dry hydrogen appears to be by the use of liquid hydrogen.

In my paper in this Journal, Feb. 1903, I spoke of a remarkable reversal of lines in the ultra-violet which were obtained by the use of quartz tubes. Fig. 4 (Pl. XIII.) shows these lines with a companion spectrum of magnesium.

These reversed lines apparently coincide with spark-lines of silicon in air; and one might conclude that the lines come from a volatilization of the walls of the quartz capillary. There is, however, absolutely no corrosion of the walls of the quartz vessel. The surface of the quartz remains limpid and clear. I have concluded that, just as in the case of the supposed calcium lines discussed above, these reversed lines are also due to a gas. In order to discover whether these lines can be obtained from some gaseous constituent of the air, I have studied the spectra obtained from powerful sparks in air taken from a great variety of metallic terminals. The spectra from terminals of pure platinum, electrolytic silver, and iridium show strong lines which coincide, with the dispersion I have employed, with the great H.H. lines of the

solar spectrum, and also with the gaseous lines I have obtained in rarefied hydrogen*. Terminals of aluminium, copper, iron, tin, magnesium, show these lines faintly. The noble metals, which are least affected by the electric discharge and which are therefore used for nonoxidizable contact in electric apparatus, give these lines strongly. Is it not probable that when the electric discharges volatilize to a high degree the metallic terminals, electric discharge prefers a passage through the metallic vapour, and does not sufficiently heat the air to bring out certain air lines? The method of sifting out air lines from metallic spectra by observing the lines which are apparently common to these spectra, and setting down such lines as air lines, is a fallacious method. Silicon is not easily volatilizable, and certain important groups of lines attributed to that metal, obtained by the use of the spark in air, may be atmospheric lines. I have obtained traces of such lines which seem to coincide with the gaseous lines I obtained with rarefied hydrogen in quartz tubes by employing water electrodes. These electrodes were made as follows:—two iridium terminals were placed on pieces of kiln-dried wood four inches apart. The condenser spark could leap only one inch. The wood was wrapped with cotton, inclosing the metallic terminals, around the cotton was wrapped chamois skin; the clear space between the ends of the wood thus protected was half an inch. The terminals thus prepared were soaked in distilled water. A very powerful spark was thus obtained in air which was entirely free from metallic lines. With these terminals it is undoubtedly true that the water-vapour conducted the main body of the discharge, just as the metallic vapour does in dry air. The edges of this spark show a strong red tint, and give the line-spectrum of hydrogen. The centre of the spark is of a brilliant whiteness. Strong bands appear in the position of the reversed lines which I have obtained with rarefied hydrogen in the quartz tubes. I therefore believe that these lines are gaseous lines.

I believe that these lines, and also the great H.H. lines of the solar spectrum, are due to oxygen. At very high temperatures the oxygen atom set free from the salts of calcium and its allied metals is free to vibrate in its own periods. It does not seem improbable that many lines attributed to metals may be oxygen lines; the metal releasing its hold of the oxygen atom at very high temperatures.

* Compare with paper "On the Constitution of the Electric Spark," Arthur Schuster, F.R.S., and Gustav Hemsalech, Phil. Trans. Roy. Soc. vol. cxciii. series A.

When the liquid terminals described above are saturated with chemically pure chloride of calcium, with nitrate of strontia, with nitric acid, the great H.H. lines and the line at wave-length 4227 are greatly enhanced. This gives strong colour to the above hypothesis. There is evidently an electro-chemistry of the air which has been opened by the discovery of argon.

The continuous spectrum observed with disruptive discharges in gases occurs also when electrical discharges are obtained in distilled water, and in certain other liquids. Prof. Wilsing*, Prof. Hale†, and Sir Norman Lockyer‡ have discussed the reversed lines observed under this condition. The phenomenon of continuous spectrum and of reversals is, I believe, of the same nature as the phenomenon observed by me in gases. The continuous spectrum is due to a sudden compression of the medium under the powerful disruptive electrical explosion, and the reversals are due to a polarization and not to a reversing layer. The reversed lines observed by me increase in intensity toward the ultra-violet, and also are strengthened by repeated exposures. This is the case also with the reversed lines observed under water.

The conclusions of my first paper in the Phil. Mag. July 1902 are therefore confirmed by further investigation. At the basis of the great H.H. lines of the solar spectrum, there are strong gaseous lines which I believe to be oxygen lines. The reversed lines are not due to calcium but are due to oxygen.

The accompanying Plate (XIII.) shows the normal spectra which illustrate this article. Fig. 1 represents the gaseous lines which closely correspond with the great H.H. lines of the solar spectrum. Fig. 2 represents the spectrum of calcium in the neighbourhood of the H.H. lines. It is seen that strong lines of calcium are conspicuously absent in fig. 1.

Fig. 3 shows the gaseous lines obtained in a quartz tube filled apparently with pure hydrogen. A strong group of magnesium lines is added for comparison. These magnesium lines are the strongest lines of that metal between wave-length 3000 and 2000.

Fig. 4 gives also the same comparison spectrum of magnesium, and reversed lines of the gas contained in the quartz tube.

In fig. 3 there is no continuous spectrum. The argument of incandescent walls to account for the continuous spectrum in the case of the employment of glass Geissler tubes, would

* Kayser, *I. C. I. P.* p. 228.

† G. E. Hale, *Astrophys. Journ.* p. 15 (1902).

‡ N. Lockyer, *Proc. Roy. Soc.* p. 70 (1902).

require also a heat of at least incandescence to volatilize the silicon in order to produce the bright unreversed lines seen in fig. 3 at wave-length 2882, and wave-lengths from 2542 to 2507.

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LV. *On the Influence of Magnetic Field on Thermal Conductivity.* By VINCENT J. BLYTH, M.A. (*Glasgow*), 1851
*Exhibition Research Scholar, Emmanuel College, Cambridge**.

IN a circuit composed of bismuth and another metal, the thermo-electric E.M.F. is altered if the bismuth be placed in a magnetic field. This alteration was observed by Leduc† and by Righi‡, while using such a circuit as a means of measuring the difference of temperature between two points of a heat-conveying bar of bismuth. Assuming that the change represented a change in the temperature-difference between the junctions, they deduced the result that the thermal conductivity of bismuth was altered by the magnetic field. But von Ettingshausen and Nernst§ have shown that such a change in the E.M.F. takes place without any alteration of temperature-difference, and that it represents the "longitudinal thermomagnetic effect," which may also be regarded as an alteration of the thermoelectric nature of bismuth by application of magnetic field¶. If thermo-electric junctions are to be used for observing temperature-differences with a view to measuring the effect of magnetic field on thermal conductivity, it is necessary that the intrusion of the von Ettingshausen and Nernst effect should be prevented; and this may be done either by keeping the junctions out of electrical contact with the bar under test, or by obtaining the temperature-differences by independent observations of the two temperatures in each case with reference to a standard junction. It is the purpose of this paper to describe a number of experiments made with a view to determining the effect of magnetic field on thermal conductivity.

A cast rod of bismuth (14 cms. long and 1 cm. in diameter) was warmed at one end to 100° C. and kept at zero at the other end; the ends of the rod were soldered into large copper blocks within the heating and cooling chambers, and

* Communicated by Prof. J. J. Thomson, F.R.S.

† *Journ. de Phys.* (2) vi. p. 379. ‡ *Compt. Rend.* cv. p. 168 (1887).

§ *Wied. Ann.* xxxi. p. 760 (1887).

¶ See Lownds, *Phil. Mag.* Oct. 1901.

FIG. 1.

FIG. 2.

FIG. 3.

FIG. 4.