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diameter, electrified to the same electric density, reckoned according to the total electricity in any small volume (electricity of air and of spherules of water, if there are any in it), would produce a difference of potential of 38 million volts between its surface and centre. In a thunderstorm, flashes of lightning show us differences of potential of millions of volts, but not perhaps of many times 38 million volts, between places of the atmosphere distant from one another by half a kilometre.

XXV. *Preliminary Note on the Spectrum of the Electric Discharge in Liquid Oxygen, Air, and Nitrogen.* By Professors LIVING and DEWAR*.

IN making the experiments here described we desired, if possible, to observe the emission-spectra of the several substances, stimulated by the electric discharge, while at temperatures of 180° to 200° below zero. It seemed probable that the characters of these spectra would give some indications of the physical state of the substances operated on.

In order to prevent the rapid heating of the electrodes by the discharge, they were made of considerable size. One was a disk of platinum about one centimetre in diameter, convex on one side, and having its convexity turned towards the other electrode, which was made of a piece of platinum wire about two millimetres thick. Even these electrodes were much heated, became red-hot when they were not in the liquid, but the spark passed through the gas immediately above the liquid. When actually immersed in the liquid they could hardly have been, except locally at the point of discharge, at any temperature sensibly different from that of the liquid. Experiments were made also with electrodes of aluminium, but with no different results as regards the spectrum except the introduction of the shaded bands due to alumina instead of the lines of platinum.

The liquids experimented on were contained in double test-tubes of large dimensions, having the space between the two tubes highly exhausted. The electrodes, insulated, except at the extremities, by glass tubing and wax or gutta-percha, were passed through a rubber-stopper which closed the tube. Through this stopper was also passed a glass tube, which was left open while experiments were made at the atmospheric pressure, but was connected with a powerful rotary air-pump when it was desired to exhaust the gas in the tube.

* Communicated by the Authors.

Liquid oxygen, air, and nitrogen, like non-electrolysable compound liquids, offer very great resistance to the passage of an electric discharge, so that with a powerful induction-coil we could hardly make the spark pass through a thickness of one millimetre of liquid. When the thickness of liquid traversed was less than this, a succession of sparks could be maintained; but the resistance appeared to be very great, and the disruptive effect on the electrodes sufficient to discolour the liquid by the particles thrown off their surfaces.

The discharge through the liquid in all cases gave a continuous spectrum and some bright lines traceable to the electrodes, while the rays which we suppose to have been emitted by the molecules of the liquid were less conspicuous. It seems not unlikely, therefore, that the continuous spectrum was due to the particles thrown off the electrodes.

Liquid Oxygen.

When both electrodes were immersed in liquid oxygen boiling at atmospheric pressure, and therefore at about -180° C., and the distance between the electrodes about one millimetre or less, the spectrum of the spark, without jar, was chiefly a continuous one, brightest in the yellowish-green but extending for some distance both on the red and on the blue side. The absorption-bands of oxygen were conspicuous on this bright background. A few bright lines were also seen, of which the most prominent were three in the green and yellowish-green, with the approximate wave-lengths 505, 533, and 547. These lines were not much brighter than the continuous spectrum. Glimpses of other lines were seen, but too faint and intermittent to be measured. Of these lines that with wave-length about 533 is no doubt due to oxygen, for it is described as a triple line of the discharge in vacuum oxygen tubes by Piazzzi Smyth, and as a double line by Schuster. The other two lines appear to be lines of platinum, 5059 and two lines 5475, 5478, according to Thalén.

The introduction of a Leyden jar into the circuit increased the brilliance both of the continuous spectrum and of the lines, or of some of them, and brought out some additional lines; but the intermittent character of the sparks made it almost impossible to measure the places of any of the lines.

When the discharge from a Wimshurst machine was used instead of that from the coil, only a continuous spectrum, with the usual oxygen absorptions, was seen. No bright lines could be detected on the continuous spectrum.

By keeping only the lower electrode (the convex disk) immersed in the liquid, so that the spark passed partly

through the liquid and partly through the gas immediately above it, the discharge took place more easily, and the continuous spectrum became, relatively to the lines, less bright. Without the jar, however, the spectrum had generally the same character as before. The three lines above mentioned were still the most conspicuous bright lines. On putting the jar into the circuit, however, many more bright lines came out. The well-known orange line of oxygen, $\lambda 6171$, appeared expanded into a band with its sharper edge on the more refrangible side at a wave-length of about 615, and fading towards the red but traceable as far as $\lambda 618$. Schuster and Piazzzi Smyth give a compound line at about wave-length $\lambda 6156$; and it is possible that this band may represent this compound line. It will be noticed that, as to the shading, it follows the character of A and B, but with the dispersion we used it was not possible to resolve it into lines. Probably, under the circumstances, the lines of which we may suppose the band composed would be so much expanded as to overlap one another. Besides this band, blue lines were conspicuous at wave-lengths about 435, 441, 459, 465, 470, all corresponding to known lines of oxygen. The green line of platinum at wave-length about 530 came out brightly, as well as platinum lines at about $\lambda 583$ and $\lambda 580$. Another line, less bright, appeared at wave-length about 557, and at times a second line near it at about 555. These have not been described as oxygen lines by other observers, but they fall within one of the green bands described by Schuster as seen in the negative glow in a vacuous oxygen tube.

We next proceeded to exhaust the gas above the liquid in the vessel, until the pressure was reduced to about 1 centim. of mercury. The liquid, of course, boiled away fast until the temperature had fallen to something like -200° ; and the gas at the reduced pressure offered comparatively little resistance to the passage of the discharge.

So long as both electrodes were immersed in the liquid, the reduction of pressure and of temperature did not make any marked difference in the appearance of the spectrum. But as the liquid evaporated and only the lower electrode was immersed, so that the discharge was partly through the gas, the continuous spectrum was much weakened, and two bright green bands came out extending from about $\lambda 521$ to $\lambda 531$, and from about $\lambda 553$ to $\lambda 561$. This was without a jar in the circuit. The bands were nearly uniformly bright with both edges diffuse. They were much better seen when both electrodes were out of the liquid, and were brightest in the glow which surrounded the poles. They were equally well

seen in the glow about both poles, and equally well when the electrodes were cold, and when they were hot, even red-hot. There was a third much fainter band in the orange a little less refrangible than the D lines of sodium. There is no doubt that these bands are the same as have been described by Schuster in the negative glow in a vacuous oxygen-tube.

When a jar was put in the circuit, these bands disappeared or nearly so. While one electrode remained in the liquid, a good many bright lines came out on putting the jar into the circuit. One of these was a line at wave-length about 557, the same as previously seen, nearly in the middle of one of the green bands. In fact, it seemed to replace the band when the jar was put into the circuit. It was not, however, so permanently seen as some of the other lines. Only a few of these other lines were measured. One appeared to be an oxygen line at about λ 544; a pair at about λ 566 may have been air-lines as the oxygen usually contains a little air. Another was a platinum line about λ 455.

The line above mentioned, λ 557, appears to be of some interest because it falls very near the place of the auroral line, and the conditions under which it is produced resemble, in regard to the low temperature, and to some extent in regard to the pressure, those in which Auroras are produced. The place of this line was measured several times, but the circumstances of these experiments were not very favourable for exact measurements. The measure which we marked as the best gave a wave-length for the line 5572, but other measures gave figures between that and 5578. It seems, therefore, not improbable that this line may be identical with the auroral line, of which the exact wave-length cannot even now be said to be quite certainly determined, but which has probably the value 5571.

The identity of the line we have observed with the auroral line cannot be said to be proved as yet. Further observation is needed, and we hope to carry our experiments further. The broad green bands do not seem to be connected with a low temperature, but were produced by the discharge without a jar; this line was, so far as we observed, only produced when one electrode was immersed in the liquid, and therefore cold, and when a jar was in circuit.

The passage of the discharge through the liquid produced much ozone. Not only was the smell of ozone very strong, but the liquid took the indigo tint, deeper than the blue of ordinary oxygen, which is characteristic of ozone. On one occasion, after the sparks had been passed through the liquid for a short time, an explosion ensued which shattered the

vessel. We can assign no cause for this, unless it were an explosion of ozone.

Liquid Air.

The effects of a discharge through liquid air were very similar to those produced with liquid oxygen, so long as the pressure was that of the atmosphere, and no jar was in circuit. There was the same continuous spectrum. When a jar was used a much larger number of lines, generally resembling the ordinary air-lines, were seen but not measured. When the pressure was reduced, the usual banded spectrum of nitrogen was seen, and was strong relatively to the spectrum of oxygen. As the liquid evaporated, and thereby lost more nitrogen than oxygen, the two green bands due to oxygen appeared to become stronger actually as well as relatively to the nitrogen bands.

In this case the discharge produced oxides of nitrogen, which were detected in the residual gas when the air had all evaporated.

Liquid Nitrogen.

We next tried liquid nitrogen. At the pressure of the atmosphere, both electrodes in the liquid, and no jar, the spectrum was continuous with three bright lines in the green and yellowish-green, generally resembling the three lines seen in liquid oxygen. On taking measures of their wave-lengths it was found that they were platinum lines, the same as had been seen in oxygen at wave-lengths about 505, 530, and 547. The oxygen line at 533 was not seen. Besides these three lines, a faint very diffuse line was observed at about λ 501, and glimpses of blue bands of the usual banded spectrum of nitrogen. When only one electrode was immersed in the liquid, the line at about λ 501 was more distinct. We have no doubt that this represents the strong double line of nitrogen in that position. When the jar was in the circuit, the spectrum was a series of bright lines similar to those given by gaseous nitrogen at atmospheric pressure.

When the gas above the liquid was pumped out until the pressure fell to about 1 centim. of mercury, one or both electrodes being immersed, and no jar used, the band-spectrum of nitrogen appeared. On putting on the jar this was replaced mainly by the line-spectrum.

Spectrum of the Spark in Water.

For the sake of comparison we next observed the spectrum of the spark between platinum electrodes in distilled water at the ordinary temperature and pressure. When no jar was

used the spectrum was continuous, with the red line (C) of hydrogen conspicuous, and the F line just visible, and glimpses of the three platinum lines in the green and yellowish-green. When the jar was put into the circuit the hydrogen lines became very diffuse, but the platinum lines came out much more distinctly, and the readings proved their identity. There were no lines which we could identify with oxygen lines.

The water became quite brown with the particles thrown off the platinum wires used as electrodes.

XXVI. *Proceedings of Learned Societies.*

GEOLOGICAL SOCIETY.

[Continued from p. 157.]

February 7th, 1894.—W. H. Hudleston, Esq., M.A., F.R.S.,
President, in the Chair.

MR. C. J. ALFORD, F.G.S., in explanation of specimens of auriferous rocks from Mashonaland exhibited by him, stated that several of them were vein-quartz occurring as segregations in the slates, generally forming veins between the cleavage-planes. Another specimen was a mass of chromate of lead, with pyromorphite and other lead minerals, occurring in masses in decomposed and dislocated talcose slate in the Penhalonga Mine near Umtali, and probably resulting from the alteration of masses of galena by weathering, as a broken vein of galena was found in close proximity. This Crocoisite was supposed to be a somewhat rare mineral, but he had found it and also the native red oxide, Minium, in several places in South Africa. The most interesting specimen was, however, a mass of Diorite showing visible gold throughout the rock, an assay of which gave upwards of 130 ounces of gold per ton. From information obtained from the prospector who made the discovery, he gathered that the deposit was a dyke of Diorite running for a considerable distance, about 8 feet in width, flanked on one side by granite and on the other by slates. There were extensive ancient workings extending to a depth of about 60 feet, and the prospecting shafts had not gone much below that depth, so not much information was obtainable at present. The Diorite showed a development of Epidote, but little or no quartz; and the gold appeared to enter in an extraordinary manner into all of the composing minerals. Mr. Alford hoped, after his next visit to Mashonaland, to be in a position to lay before the Society more definite information regarding these interesting rocks.

The following communications were read:—

1. 'On some cases of the Conversion of Compact Greenstones into Schists.' By Prof. T. G. Bonney, D.Sc., LL.D., F.R.S., F.G.S.

By the path leading from the Bernina Hospice to the Grüm Alp