The following Papers were read :—

I. "The Circulation of the Surface Waters of the North Atlantic Ocean." By H. N. DICKSON. Communicated by Sir JOHN MURRAY, F.R.S.

II. "On Cerebral Anæmia and the Effects which follow Ligation of the Cerebral Arteries." By Dr. LEONARD HILL. Communicated by Dr. MOTT, F.R.S.

III. "The Influence of Increased Atmospheric Pressure on the Circulation of the Blood. Preliminary Note." By Dr. LEONARD HILL. Communicated by Dr. MOTT, F.R.S.

IV. "Contributions to the Comparative Anatomy of the Mammalian Eye, chiefly based on Ophthalmoscopic Examination." By Dr. G. L. JOHNSON. Communicated by Dr. GADOW, F.R.S.

The Society adjourned over Ascension Day to Thursday, May 31.

"Electrical Conductivity in Gases traversed by Cathode Rays." By J. C. MCLENNAN, Demonstrator in Physics, University of Toronto. Communicated by Professor J. J. THOMSON, F.R.S. Received December 7, 1899,—Read February 1, 1900.

(Abstract.)

The object of the experiments which are described in this paper was to investigate the nature of the conductivity produced in different gases when cathode rays of definite strength passed through them.

In a series of papers,* Professors J. J. Thomson and Rutherford have recently shown that gases become conductors, when traversed either by Röntgen or by uranium rays, owing to the production of positive and negative ions throughout their volume.

In the present investigation cathode rays were found to impress a condition of the same kind upon a gas, and laws have been developed which connect the absorption of these rays with the number of ions produced by them in the absorbing gases.

The investigation is described under the following subdivisions :—

(1) Form of tube adopted for the production of cathode rays.
(2) Ionisation by cathode rays.
(3) Discharging action of cathode rays.
(4) Ionisation not due to Röntgen rays.

* 'Phil. Mag.,' November, 1896, p. 393; *ibid.*, January, 1899, p. 109.

(5) Discussion of methods for measuring the ionisations produced in different gases.
(6) Description of apparatus used.
(7) Explanation of the method adopted for comparing ionisations.
(8) Ionisation in different gases at the same pressure.
(9) Ionisation in air at different pressures.
(10) Ionisation in a gas independent of its chemical composition.
(11) Comparison of ionisations produced by cathode and by Röntgen rays.
(12) Summary of results.

The tube used for the production of cathode rays was similar in form to that devised by Lenard,* but, as the brass plate carrying the aluminium window was found to act very well as an anode, the ordinary positive electrode in his apparatus was dispensed with.

The paper commences with a series of experiments illustrating the conductivity produced by cathode rays, and the various phenomena met with are shown to be fully explained on the supposition that positive and negative ions are produced in a gas by the radiation, and that the conductivity arises from the motion of these ions under the action of an electric force.

This view of the conductivity is also shown to explain the loss of charge sustained by a conductor upon which the rays fall. Lenard's experiments† in this connection were repeated, and, contrary to his observations, negative charges were not in any case found to be completely dissipated by the rays, but were reduced, at atmospheric pressure, to small limiting values of the order of 0·25 volt. These values were found to be slightly increased when a blast was directed so as to remove the air close to the conductor, and when the latter was placed in a vacuum, the limiting charge rapidly assumed a very high value. The value of the limiting charge was found to be affected also by the proximity of conductors whose potentials were different to that of the one upon which the rays fell.

Conductors initially unelectrified gained the limiting negative charge under the action of the rays, and positive electrifications upon conductors, surrounded by air at normal pressure, were completely discharged.

The explanation offered regarding this limiting or steady state is that it represents a condition of equilibrium in which the electric convection by the rays to the conductor is just equal to the conduction by the ionised gas away from it.

It has been thought by some that the ionisation under consideration may be due to Röntgen rays sent out from the aluminium window at

* 'Wied. Ann.,' vol. 51, 1894, p. 225.
† 'Wied. Ann.,' vol. 63, 1897, p. 253.

the same time as the cathode rays. The results of experiment, however, are entirely opposed to this view, and lead to the conclusion that, if any Röntgen rays are present in the cathode pencil, they must be of so weak a character that their ionising action can be neglected. A direct comparison showed the ionisation by cathode rays to be about 300 times that due to an intense Röntgen radiation.

In the conductivity produced by cathode rays, the current of electricity does not increase in proportion to the electromotive force applied. The current, after reaching a certain critical value, becomes practically stationary and increases but little when very large increases are made in the electric field. With Röntgen or uranium radiation fields of 400 or 500 volts a centimetre have sufficed to give saturation in the case of most simple gases, but in the present investigation it was necessary to go as high as 1000 volts a centimetre before the maximum current was reached.

In order to compare the ionisations in two different gases, or in the same gas under different conditions, recourse was had to the use of two ionising chambers. The discharge tube was provided with a double cathode, and carried two aluminium windows. Two pencils of rays were obtained in this way, whose intensities were found to maintain a constant ratio, and these were used to produce the ionisations in the two chambers.

The ionisation in air, kept at a constant pressure in one of the chambers, was taken as the standard. The gases, whose ionisations were to be compared, were placed in turn in the other chamber, and their conductivities, as measured by saturation currents, were found in terms of the standard.

An important result, obtained by this method with cathode rays of constant intensity, was the agreement found to exist between the ionisation in hydrogen at atmospheric pressure, and that in air at a pressure of 53 mm. At these pressures the two gases had the same density, and in both cases, therefore, according to Lenard's absorption law, the disposition of the rays, their actual intensities, and the amount of them absorbed from point to point in the ionising chamber, were precisely the same. Under these conditions the equal ionisations obtained not only form a strong confirmation of Lenard's absorption law, but they also show that, where equal absorption of cathode rays occurs, equal ionisation is produced.

In order to test the conclusion more closely experiments were made with air, hydrogen, carbon dioxide, oxygen, nitrogen, and nitrous oxide, and in all cases it was found that, when these gases were reduced to the same density, the same ionisation was produced in them by rays of constant intensity.

It follows, therefore, that an ionisation law exists exactly analogous to that of absorption, namely, that when cathode rays of a given

strength pass through a gas, the number of ions produced per second in 1 c.c. depends only upon the density of the gas, and is independent of its chemical composition.

From the results thus obtained, the conclusion is drawn that, when cathode rays are absorbed to any extent, the positive and negative ions produced by these absorbed rays are of a definite amount, which bears a constant ratio to the quantity of the rays absorbed; that is to say, in order to ascertain the relative ionisations produced in any two gases by cathode rays of the same intensity, it is sufficient to determine the absorbing powers of the two gases for the same rays. In other words, the coefficients of ionisation are determined when the coefficients of absorption for the same gases are known.

The paper then deals with the ionisation in any particular gas under varying pressures. The inference is drawn that, under rays of constant intensity, the ionisation in a particular gas varies directly with the pressure. The very great absorption of the rays by gases at ordinary pressures prevented a direct verification of this relation; but, as Lenard has shown, the coefficients of absorption for any particular gas to vary directly with the pressure, the conclusion seems quite justifiable in the light of the connection established between ionisation and absorption.

Assuming this relation to be true, it follows at once that, if rays of constant intensity are allowed to traverse different gases at the same pressure, the ionisations produced would be directly proportional to the densities of these gases.

These numbers for the gases examined are given in column 1 of the appended table, while in column 2 are given the values found by Professor J. J. Thomson for the relative ionisation produced in these same gases by Röntgen rays of constant intensity.

Gases examined.	Column I. Ionisation by cathode rays (calculated).	Column II. Ionisation by Röntgen rays (observed).
Air	1·00	1·00
Oxygen	1·106	1·10
Nitrogen	0·97	0·89
Carbon dioxide	1·53	1·40
Hydrogen	0·069	0·33
Nitrous oxide..........	1·52	1·47

The numbers, with the exception of those for hydrogen, present a fair agreement, and they show that although the two forms of radiation are so very different in many respects, still the products of their actions on the gases examined are practically the same.