Recent Researches in Positive Rays.[1]

PROF. W. WIEN, in delivering the tenth Guthrie Lecture to the Physical Society, described the researches on positive rays carried out in his laboratory at Würzburg, passing over the subject of isotopes, as worked out in England, on the ground that this was already familiar to British audiences.

Prof. Wien dealt mainly with the determination of the mean free paths appropriate to the various states of the particles composing the positive or canal rays. Such a particle is alternately in the charged state, owing to loss of an electron by collision, and in the uncharged state, owing to the recapture of an electron in a further collision. The mean free path in the first state being denoted by L_1, in the second by L_2, the first problem attacked was the determination of the ratio L_1/L_2. It is not difficult to show that this is equal to n_1/n_2, where n_1, n_2, are the respective numbers of charged and uncharged particles composing the stream; and it is found that n_1 is less than n_2.

In the first apparatus employed, a narrow pencil of canal rays has to run the gauntlet of a series of ten condensers 1 cm. wide and separated each from its neighbour by a distance of 1 mm., the plates of each condenser being also 1 mm. apart. These ten condensers are arranged side by side in a line and the pencil of rays passes between each pair of plates in turn and finally strikes a thermopile, which thus measures the kinetic energy of the aggregate of particles falling upon it; and when the condensers are short-circuited, this energy is the sum of those of the charged and of the uncharged particles. When, however, a potential difference is established between the plates of the condensers, a diminution is observed in the thermopile reading in consequence of the elimination of some of the charged particles, and as the potential difference is increased this reading approaches a constant value which gives the energy of the uncharged particles alone. From these data the ratio of L_1 to L_2 can be calculated.

If now the pencil of canal rays be entirely freed from charged particles by the first condenser, the remaining uncharged particles continue the process of acquiring and losing charges after they have passed away from that condenser, and a fresh determination similar to that just described can be made by charging a further one of the ten condensers, in addition to the first. It is then found that the ratio of L_1 to L_2 for this (initially uncharged) beam depends on the distance between the two charged condensers, and in this way L_2 itself can be found.

In the investigation just described the pencil of positive rays consisted of particles of very mixed velocities and chemical character. Rüchart, however, afterwards employed a tube made in two parts with a universally swivelling joint, and spread the pencil out into parabolic sheets by applying simultaneous electric and magnetic fields. Particles of a particular velocity and chemical character were selected by means of slits, and the selection could be varied by relative movement of the two parts of the tube. The measurements already described were then repeated with the homogeneous pencils obtained. If the reciprocal of L_2 as thus found be plotted against the pressure in the tube, the resulting graph is a straight line the gradient of which depends on the velocity, as would be expected, but it does not pass through the origin. The latter discrepancy has been explained by Rüchart as due to residual gases emitted from the metal parts of the tube and from the cement, and can be reduced by reducing the size of these elements. As the velocity of the particles is increased by increasing the accelerating potential, L_2 becomes smaller while L_1 becomes larger, the ratio L_1/L_2 ranging from about 0·05 to 0·5. From the mean free path the collisional radius of an atom can be calculated, and this is found to lie between the first and second Bohr orbits in the case of hydrogen. The free paths are given by Rüchart's method with an accuracy of a few per cent.

A further investigation has been made on the subject of the mean free paths by the study of the light emitted. Three kinds of mean free path have to be considered in this connexion. (1) The first is the path for the "duration of luminosity"; this path begins when the atom is excited by the raising of an electron to a higher energy level within the atom, and ends when the electron returns with emission of light. Eighteen years ago Prof. Wien compared the luminosity of a black body at a temperature of about 1100° C. with that of the canal rays, in a vacuum so high (0·001 mm. for hydrogen) that the effect of collisions could be neglected. The energy emitted by the canal rays as light was thus determined in absolute measure, and from this it was possible to calculate the light energy emitted per atom per cm. of an atom's path. The observations were made in a vacuum chamber separated by a very fine slit (through which the canal rays passed) from the tube in which the rays were produced, and were concerned with the strongest lines of hydrogen, oxygen, nitrogen, helium and mercury. It was found that the luminosity fell off exponentially with distance along the path of the rays, and from the exponential constant the mean free path for duration of luminosity can be calculated by introducing quantum considerations. It amounts to a few centimetres. The measurements just mentioned related to the state of things in a very high vacuum, the slit referred to being so fine that the vacuum in the experimental chamber could be kept at much lower pressure than that in the discharge tube.

At higher pressures, however, the effect of collisions comes into play, and it becomes necessary to consider two further kinds of mean free path, namely, (2) the path which begins when an atom becomes normal and ends when it is excited, on collision, by the raising of an electron to a higher energy level; and (3) the path which begins when the atom is excited, as described, and ends not with the emission of light but with ionisation by a further impact. Prof. Wien termed the latter process "perturbation."

This question has recently been investigated by Prof. Wien by the use of a discharge tube separated from the experimental chamber by a slit so fine that a great difference of pressure could be maintained between its two sides by the use of a diffusion pump; with a vacuum in the tube of 0·02 mm., the pressure in the experimental chamber could be raised to 8 mm. or more. The intensity of the line H_a (displaced by the Doppler effect) was then compared at various pressures, and it was found that for high vacua the intensity was proportional to the pressure, but for pressures above about 0·5 mm. the intensity was constant. At low pressures few perturbations take place, and as the excitations are proportional to the number of collisions, the intensity is proportional to the pressure. At high pressures, however, the mean free path for collision is small compared with that for the "duration of luminosity"; the excited atoms are more frequently prevented by "perturbing" collisions from emitting light, and ultimately the perturbations balance the excitations and the intensity becomes constant.

The apparatus used for measuring the "duration of luminosity" has also been adapted for use in a method

[1] Substance of the tenth Guthrie Lecture delivered before the Physical Society of London on April 25, by Prof. W. Wien.

for discriminating between the spectral lines from charged and those from uncharged particles. A small condenser is placed close to the slit so that the canal rays pass between its plates, the vacuum being as high as possible so that the particles may not, after passing through the slit, become charged or uncharged through collisions. The spectrum of the light emitted by the rays is then photographed, first with the condenser short-circuited and then with the condenser charged. (Apparently the slit ordinarily employed in a spectroscope is here dispensed with, the line corresponding to each wave-length being an image of the pencil of rays itself.) Since the charged particles are deflected by the electric field, the lines due to these particles are distorted when the condenser is charged and can thus be distinguished from the lines due to uncharged particles. Photographs were shown in which certain oxygen and hydrogen lines were seen to be undistorted by the influence of the condenser, while others were clearly distorted. The latter belong to the spark spectrum of oxygen, while the former are arc lines. A similar distortion was observable with the band spectrum of nitrogen.

The foregoing considerations throw light on an apparent discrepancy between measurements of the velocity of the rays by electromagnetic methods and by the Doppler effect respectively. The velocities as measured electromagnetically increase in proportion to the square root of the accelerating potential, in accordance with theory, but the velocities as measured by the Doppler effect have been found by several observers to reach a limiting value as the accelerating potential rises beyond a certain stage. Dr. Krefft, however, raised the accelerating potential in a tube filled with hydrogen to 70,000 volts, and in this case he found no limiting value for the Doppler displacement; the latter indicated a velocity increasing in proportion to the square root of the potential, but its absolute value was less than what would be expected from the velocities measured electromagnetically. The arc lines of oxygen also show an unexpectedly small shift, while the spark lines show a larger shift. The discrepancy referred to may therefore be attributed to the fact that the bulk of the luminosity comes from uncharged atoms while the electromagnetic measurements relate to charged particles, which on the average have greater velocities.

A further investigation has been made by Ran, who arranged a glass cylinder close to the canal rays and with its axis perpendicular thereto. In this way light from both approaching and receding particles is collected by the cylinder and focussed on the slit of a spectroscope. Ran found some evidence for regarding the band spectrum of nitrogen as emanating from positively charged particles.

New results have been obtained by Döpel in the analysis of positive rays by Sir J. J. Thomson's method, negatively charged particles of H, H_2, He, and Ne (or ? O) having been found. Most positive-ray parabolas show two regions of maximum intensity, and a new explanation is suggested for this phenomenon, namely, that the second maximum is due to particles of double mass originating in the discharge chamber but afterwards dissociated. The existence of molecules of He_2 and H_4 would be implied by this theory, but not H_6, since there is no second maximum in the case of H_3.

Prof. Wien remarked in conclusion that the work on positive rays affords an excellent example of the results of international co-operation in science, which he regards as of the utmost value and importance.

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International Commission for the Investigation of the Upper Air.

A MEETING of the International Commission for the Investigation of the Upper Air was held in London on April 17-22.

At the meeting of the Commission in Bergen in July 1921, the Commission adopted the view that the international publication of the results of the investigation of the upper air ought to be resumed, and that an International Bureau should be established and supported by contributions from the different States, so that the preparation and compilation of the results should not in future be done at the sole cost of the National Service which undertook the work. Unfortunately, it did not prove practicable, in the stringent economic times which followed the meeting of 1921, to obtain the funds which were necessary to carry out the recommendations of the meeting at Bergen. In consequence of this, Prof. V. Bjerknes, who had been president of the Commission, resigned his position, as he could not spare the time from his purely scientific work to carry out unaided the large amount of work involved in the preparation and publication of the international upper air results. Sir Napier Shaw, then President of the International Meteorological Committee, took over the presidency of the Commission at the request of the members.

Various methods for securing the object of an international publication of upper air results have been considered or tried experimentally since that time. No satisfactory solution of the question has been achieved. A short meeting of the Commission was held after the International Conference at Utrecht in 1923 at which the results of the inquiries were briefly surveyed, and a preliminary discussion took place on the most appropriate form for an international publication.

In 1924, at the meeting of the International Union for Geodesy and Geophysics at Madrid, the Union voted the sum of 500*l.* towards the expenses of publication of a specimen volume of upper air data, and Prof. van Everdingen, the director of the Meteorological Institute of Holland, promised a contribution of about 100*l.* for the same purpose.

The meeting of the Commission in London was concerned primarily with the consideration of the form which the specimen publication should take. Representatives from the following countries attended: France (Capt. Wehrlé); Germany (Prof. Hergesell); Great Britain (Sir Napier Shaw, Sir Gilbert Walker, Capt. C. J. P. Cave, Lieut.-Col. E. Gold, Mr. L. H. G. Dines, Mr. L. F. Richardson); Holland (Prof. van Everdingen, Prof. van Bemmelen); Italy (Lt.-Col. Matteuzzi, Prof. Gamba); Norway (Dr. Hesselberg); Russia (Dr. Molchanoff); Spain (Col. Meseguer). The meetings of the Commission were divided into business meetings and scientific meetings, on the ground that a right solution of the questions which the Commission had to consider could only be achieved by a correct appreciation of the scientific principles involved. There were four business meetings and three scientific meetings.

At the first meeting of the Commission on Friday, April 17, the president read a letter from Mr. la Cour, director of the Danish Meteorological Service, giving the Commission the welcome news that four wireless stations would be in operation in Greenland during the coming summer, at Angmagsalik, Julianehaab, Godthaab, and Godhavn; and that all four stations would be equipped with instruments for observations of pilot balloons. The work of the four stations as regards investigation of upper wind would be co-ordinated by wireless with the view of obtaining simultaneous ascents to great heights from all stations at the same time.