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On a Method of making Visible the Paths of Ionising Particles through a Gas.

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[Plate 9.]

The tracks of individual α- or β-particles, or of ionising rays of any kind, through a moist gas may be made visible by condensing water upon the ions set free, a suitable form of expansion apparatus being used for the purpose.

In order that the clouds formed should give a true picture of the trails of ions left by the ionising particles, it is necessary that little or no stirring up of the gas should result from the expansion. It is desirable that no interval long enough to allow of appreciable diffusion of the ions should elapse between their liberation and the production of the super-saturation necessary for the condensation of water upon them; and that the cloud-chamber should be free from all ions other than those in the freshly formed trails.

The apparatus which has proved effective for the purpose differs from that used in my former experiments on condensation nuclei mainly in the form of the cloud-chamber. This is cylindrical, with flat horizontal roof and floors, its diameter being 7·5 cm., and its height between 4 and 5 mm. before expansion, and about 6·2 mm. after expansion. The expansion is effected by the sudden downward displacement of the floor of the cloud-chamber; this is constituted by the flat top of a hollow brass piston open below, and set in motion by the method described in former papers.

The clouds are viewed through the roof of the cloud-chamber, which is of glass, coated below with a uniform layer of clear gelatine. The floor is also covered by a layer of gelatine, in this case blackened by the addition of a little Indian ink.

Besides serving as a cement to attach the glass roof of the cloud-chamber, the gelatine lining avoids altogether one of the principal sources of trouble in all cloud experiments—the deposition of dew on the inner surface of the glass. In addition it forms, when moist, a conducting layer which may be maintained at a constant potential; the connection with a source of potential being made through an annular strip of tinfoil fixed by means of the gelatine round the margin of the glass plate which forms the roof, and extending to just within the cylindrical glass wall of the cloud-chamber.

The potential difference applied between the roof and floor, in the observations described below, amounted to 8 volts. Any ions set free before an expansion were thus exposed to a field of about 16 volts per centimetre, and had at the most about $\frac{1}{2}$ cm. to travel. The only ions "caught," on expansion, were thus those which had been produced within less than 1/40th of a second before the expansion, and such as were set free in the short interval after the expansion during which the super-saturation exceeded the limit necessary for condensation upon the ions.

A horizontal stratum of the air in the cloud-chamber was illuminated by a suitable source and condensing lens; for eye observations a Nernst lamp is a convenient source. For the purpose of photographing the clouds a Leyden jar discharge through mercury vapour at atmospheric pressure was employed, the mercury being contained in a horizontal capillary quartz tube, of which the central portion was heated to vaporise the mercury. The spark was fired by the mechanism which started the expansion, and took place one- or two-tenths of a second later. The camera was inclined at an angle of 30° to the horizontal, the distances being arranged to give a picture of approximately the natural size, and the photographic plate being tilted so that the whole illuminated layer might be approximately in focus.

Results.

Clouds with Large Expansions.—The clouds formed with large expansions in the absence of ions ($v_2/v_1 > 1{\cdot}38$) showed, so far as the eye could judge, a uniform distribution of drops.

Ionisation by α-Rays.—The radium-tipped metal tongue from a spinthariscope was placed inside the cloud-chamber, and the effect of expansion observed after removal of the dust particles. The cloud condensed on the ions, while varying infinitely in detail, was always of the same general character as that of which fig. 1 (Plate 9) is a photograph. The photograph gives, however, but a poor idea of the really beautiful appearance of these clouds. It must be remembered, in interpreting the photographs, that trails of all ages, up to about 1/40th of a second, may be present, the most sharply defined being those left by particles which have traversed the air while super-saturated to the extent required to cause condensation upon the ions. The trail of ions produced by a particle which traversed the gas before the expansion may have had time to divide into a positively and a negatively charged portion under the action of the electric field, and in each of these a certain amount of diffusion of the ions may have taken place before expansion. It is possible, therefore, that the few remarkably sharply defined lines, about 1/10 mm. wide, alone represent the actual

Fig. 1.

Cloud formed on Ions due to *a*-Rays.

Fig. 2.

Cloud formed on Ions due to X-Rays.

distribution of ions immediately after the passage of the α-particles, before any appreciable diffusion has had time to take place.

Ionisation by β-Rays.—A small quantity of impure radium salt in a thin glass bulb was held against a small aperture, closed by aluminium weighing about 1 mgrm. per sq. cm., in the cylindrical vertical wall of the cloud-chamber. On making an expansion sufficient to catch all the ions, two or three absolutely straight thread-like lines of cloud were generally seen radiating across the vessel from the aperture. In addition, other similar lines were occasionally seen crossing the vessel in other directions, probably secondary β-rays from the walls of the vessel.

Ionisation by γ-Rays.—The γ-rays from 30 mgrm. of radium bromide, placed at a distance of 30 cm. on the same horizontal level as the cloud-chamber, produced on expansion a cloud entirely localised in streaks and patches and consisting mainly of fine, perfectly straight threads, traversing the vessel in all directions—the tracks of β-particles from the walls of the vessel.

Ionisation by X-Rays.—When the air is allowed to expand while exposed to the radiation from an X-ray bulb the whole of the region traversed by the primary beam is seen to be filled with minute streaks and patches of cloud, a few due to secondary X-rays appearing also outside the primary beam. A photograph shows the cloudlets to be mainly small thread-like objects not more than a few millimetres in length, and many of them being considerably less than 1/10 mm. in breadth. Few of them are straight, some of them showing complete loops. Many of them show a peculiar beaded structure. In addition to the thread-like cloudlets, there are minute patches of cloud which may be merely foreshortened threads. Other fainter and more diffuse patches and streaks are also present, possibly representing older trails, in which the ions have had time to diffuse considerably before the expansion.

The droplets composing the threads have been deposited on the ions produced along the paths of the actually effective ionising rays. These are probably of the nature of easily absorbed secondary β- or cathode-rays; some doubtless starting from the roof or floor of the cloud-chamber, others, however (the larger number when a limited horizontal beam of X-rays is used), originating in the gas. The results are in agreement with Bragg's view that the whole of the ionisation by X-rays may be regarded as being due to β- or cathode-rays arising from the X-rays.

The question whether the original X-radiation has a continuous wave front, or is itself corpuscular as Bragg supposes, or has in some other way its energy localised around definite points in the manner suggested by

Sir J. J. Thomson, remains undecided. The method already furnishes, however, a very direct proof that when ionisation by X-rays occurs corpuscles are liberated, each with energy sufficient to enable it to produce a large number of ions along its course.

The few preliminary photographs which have been taken were not obtained under conditions suitable for an examination of the relation of the initial direction of the cathode rays produced in the air to that of the incident Röntgen radiation. I hope shortly to obtain photographs which will admit of this being done.

The Vacuum Tube Spectra of Mercury.

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The 'Proceedings of the Royal Society' for 1860 contain a paper by Plücker,* which gives an account of the first observations of the spectrum of the luminous discharge through mercury vapour at a low pressure. Plücker used a vacuum tube with mercury electrodes, and he observed and made measurements of the wave-lengths of ten lines. A few years later, working with Hittorf,† he found that the mercury spectrum may be obtained more brightly when a Leyden jar and spark gap are used in parallel with the tube. Other conditions affecting the lines observed in the vacuum tube spectrum of mercury have since been recorded by various investigators; for instance, the widening of the lines with increased pressure was observed by Ciamician,‡ and the effect of the presence of different gases in the vacuum tube on the brightness of the mercury lines was investigated by Sundell,§ who found that the mercury lines were visible when the tube contained hydrogen at considerable pressures, but that with oxygen or nitrogen they could only be seen when the pressure was very low.

The spectrum of the light from the mercury arc was first investigated by Liveing and Dewar,|| and afterwards very completely by Kayser and

* Plücker, 'Roy. Soc. Proc.,' 1860, vol. 10, p. 256.
† Plücker and Hittorf, 'Phil. Trans.,' 1865, vol. 155, p. 1.
‡ Ciamician, 'Wien. Ber.,' 1878, vol. 78, p. 867.
§ Sundell, 'Phil. Mag.' [5], 1887, vol. 24, p. 98.
|| Liveing and Dewar, 'Phil. Trans.,' 1883, vol. 174, p. 187.