Doppler Effect in Canal Rays.

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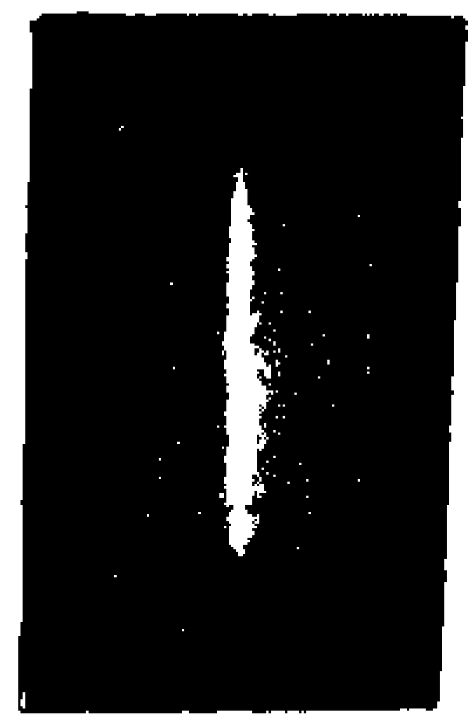
EXPERIMENTING with the electric discharge in gases at low pressures, Goldstein[1] first noticed that, when a perforated cathode is employed, streams of violet light passed through the perforations or canals and emerged behind the cathode on the side remote from the anode. Because of the method by which these streams of light were obtained, he called them *Kanalstrahlen* or canal rays. On account of the fact that the rays are normally positively electrified, Sir J. J. Thompson named them 'positive rays'. The simplest type of positive ray is a positively charged atom, which in virtue of its falling through a large potential drop, possesses energy enough to manifest itself. Positive rays are formed from molecules as well as atoms, and any measurement of their mass will yield direct information in regard to the masses of those molecules and atoms. The results of these measurements refer individually to the atoms and molecules and not, as in chemical determinations, to the average value of a large aggregate.

The positive ions which have attained high speeds in the cathode fall of potential pass through the perforations in the cathode, where they gradually lose their speed by impacts with the randomly-moving particles of gas. The principal difference between the canal rays and cathode rays is that the positive ions constituting the former are self-luminous, while the electrons are capable only of causing other substances to radiate. The Doppler effect may be perceived in the light of the canal rays, as first recognised by Stark[2] by a spectroscopic examination. When the light which falls on the slit of the spectroscope is received in the direction of the rays, so that the positive ions are approaching the spectroscope, the spectrum lines are broadened towards the violet, in some cases leaving a dark interval between the normal position of the line and the displaced line. The displacement at any radiation of wave-length λ is given by $d\lambda = \lambda \frac{v}{c}$, where v is the velocity of the positive ions and c the velocity of light. Stark found that all the lines of a given gas were displaced by the same amount and deduced a velocity for the ions of $1 \cdot 2 \times 10^8$ cm. per sec. From the existence of a dark interval between the normal position of the line and the displaced position, it is concluded that the emission of the line spectrum does not begin until a certain velocity of the positive ions is reached. Using a water-cooled hollow cathode[3] about a centimetre long and having an axial slot measuring 1 cm. $\times$ 1 mm., a photograph of the spectrum of the positive rays of hydrogen excited by a D.C. generator of 1 kilowatt capacity exhibits easily the Doppler shift in the Balmer lines. Fig. 1 which is repro-



duced from a photograph taken by Mr. L. Sibaiya shows the Doppler shift in $H\alpha$, the displaced component being relatively weaker than the undisplaced line.

Hydrogen Positive Rays.—Riezler[4] measured the Doppler effect for homogeneous hydrogen canal rays, and it was found that the velocity calculated from this effect agreed with the velocity deduced from the deflection by an electric or magnetic field. Behind the cathode the charged canal ray particles are actually composed of H^+, H_2^+ and H_3^+. These particles on their further

[1] Goldstein, *Ber. Sitz. Ber.*, 1886, 691.

[2] Stark, *Phys. Zeitschr.*, 1905, 6; 1906, 7; *Nature*, 1906, **73**.

[3] Venkatesachar and Sibaiya, *Proc. Ind. Acad. Sci.*, 1935, **1**, 955.

[4] Riezler, *Ann. d. Physiy.*, 1929, **2**, 429.

path may become neutralised or decomposed and then as neutral hydrogen particles, send out the Balmer lines Batho and Dempster[5] obtained sharp displaced lines of the Balmer series indicating homogeneous velocities, the displacements agreeing with those calculated from the potential for the H^+, H_2^+ and H_3^+ particles At lower pressures the displaced line due to H_2^+ was found to become the strongest Hogness suggested that the double absorption lines observed in some novæ might be of similar origin Rough measurements of spectra of two novæ gave pairs of velocities approximately as $\sqrt{2}$ 1 in each case Anna McPherson[6] observed an apparent minimum velocity for excitation of radiation in the neutral hydrogen atom at about 40 volts In the helium hydrogen mixture the hydrogen Doppler lines due to H_2^+ and H^+ alone were perceptible, that due to H_3^+ not appearing

Positive Rays of Neon, Argon and Helium — Romig[7] found that the neon canal ray stream exhibited Doppler effect among the stronger lines in the first and the second spark spectra of neon, the arc spectra almost exhibiting no Doppler shift The stream consists of rapidly moving neon atoms which radiate only when in the ionised state, hence the radiation from the canal rays is almost entirely from atoms in the ionised condition Anna McPherson[8] showed that with the exception of λ 3418 of neon, the arc lines of neon and argon have no Doppler shift, while the lines of the first spark spectrum are accompanied by sharp displaced lines only slightly less intense than the rest lines whose separation corresponds accurately to the speeds acquired by singly charged ions in the accelerating field Experimentally, the ions of hydrogen, argon, neon and helium, formed in a low voltage arc, were accelerated to high speeds in an electric field of high potential gradient forming beams of positive ions which had the same energy The spectra of the beams of such positive rays observed in the direction of motion showed the characteristic Doppler effect, with the displaced lines fully as sharp as the rest lines Satisfactory observations were made at a pressure of about 5×10^{-3} mm, the intensity and the sharpness of the displaced lines diminishing with increasing pressure In helium the arc lines showed relatively faint displaced lines corresponding to singly charged ions, one spark line λ 4686 was accompanied by a relatively intense displaced line, while the only other spark line observed λ 4541 showed no Doppler effect Further investigation alone can reveal the true nature of these divergent results

[5] Batho and Dempster *Astrophys J*, 1932, **75,** 34

[6] Anna McPherson *Phys Rev* 1934 **45,** 485

[7] Romig, *ibid* 1931 **38,** 1709

[8] Anna McPherson, *Phys Rev* 1933, **44,** 711.

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