LUMINOUS JETS FROM PULSED GAS DISCHARGES

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Lord Rayleigh (1944-5) investigated hydrogen afterglow by inducing an electrodeless discharge into a continuous circular tube to which a side tube, or neck, was joined. The hydrogen was at a pressure of .2 mm Hg. During discharge, the flash extended as a jet into the relatively field-free neck, where it showed the H_α, $H\beta$, and $H\gamma$ lines. Using a rotating mirror, Rayleigh found that this luminosity advanced along the neck with a velocity of about 4×10^6 cm/sec. He then determined, by linear measurements of the jet, that the decay time was of the order of 10^{-5} sec. This result was termed anomalous in view of the fact that the mean lifetimes of the hydrogen states giving rise to the observed radiation are considered to be of the order of 2×10^{-8} sec.

More elaborate investigation of the after-glow was carried on under the direction of Dr. R. G. Fowler in 1948. The initial work was done by J. S.

Goldstein and R. J. Lee, and will constitute the subject of this paper. Further work is now in progress.

Two tubes were constructed, one similar to Rayleigh's and one in the shape of a T with the gas excited directly by electrodes. Two main side tubes were attached to the first discharge tube, one being fitted with plates on either side of the jet, the other being left empty. The side tube containing the plates was of larger bore than the other. Hydrogen was used exclusively in this tube. Nitrogen, argon, helium, and neon were investigated in the second tube.

Preliminary investigations with the hydrogen filled tube disclosed decay times of the order of $.3\times10^{-3}$ sec. and velocities of the order of 2×10^{4} cm/sec. along the smaller side tube. For these measurements the power input was considerably greater than Rayleigh used. Most of the rotating mirror pictures indicated quite clearly that the luminosity advanced as a ball, rather than as a tongue; this was seen directly, since the traces on the film represented successive slit images in time. It was also observed that the luminosity went considerably farther along the larger bore side tube than along the smaller tube.

It was desirable to know whether ions were significantly present in the hydrogen after-glow. To test this, the plates in the large side tube were connected into a circuit containing only a milliammeter. A small U magnet was hung over this neck near its juncture with the rest of the tube to deflect any charged particles to one of the plates. The ammeter registered a deflection of about 20 microamperes on discharge, and a reversed deflection of the same amount occurred when the magnet was turned around. A potential applied across the plates produced no observed effect on the flame.

Work with the T-shaped tube established that a phenomenon apparently similar to the Rayleigh effect occurred in nitrogen, argon, helium, and neon. Velocities found for these gases ranged from 1.4×10^{5} cm/sec. for argon to 13×10^{5} cm/sec. for helium, and the decay times ranged from $.22\times10^{-3}$ sec. to 3.5×10^{-3} sec. The power dissipated in this tube was much greater than in the previously described tube. Both tongues and advancing balls were indicated by the rotating mirror pictures. The entire spark spectrum of helium was identified in the jet in the range from $\lambda5041$ to $\lambda3187$.

Under certain conditions a back-flash, or returning ball of luminosity was observed in argon, and it returned with a greater velocity than it had before "reflection". In the side tube there was a constriction at which the glass tubing was reduced one half in bore, and it was apparently at this constriction that the ball of luminosity was "reflected". It was also observed that the luminosity would not go past the constriction.

The pressure range employed in the first tube was between .1 and .8 mm Hg and the range for the second tube was between .7 and 10 mm Hg. In neither tube was there an intensity discontinuity at the base of the jet, but the luminosity seemed to fade gradually.

It is assumed, tentatively, that the processes occurring in both tubes are similar. Numerous suggestions have been advanced in an attempt to account for the long after-glow time in the Rayleigh discharge. Two important possibilities are recombination and compression wave excitation. It is shown theoretically by H. Zanstra (1946) that ions formed in the Rayleigh discharge might conceivably take a time of the order of 3×10^{-3} sec. to recombine, after which they would promptly (2×10^{-8} sec.) radiate, and there is ample evidence that ions are present in the gas. According to the wave excitation theory, a compression wave traveling down the tube may cause excitation, and the return flash in argon acts like a wave. The recombination process should result in a tongue of flame, and the compression wave should result in a ball or advancing front of luminosity. A third process that has been suggested for prolonging the after-glow is resonance radiation or absorption and re-radiation.

It seems likely that at least two independent processes occur in the after-glow, one producing a tongue and the other producing a luminous ball moving down the side tube. However, no explanation yet offered is entirely satisfactory.

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