

mum equivalent temperature of more than  $10^7$  degrees in our case) and the observed short-period meter fluctuations, it seems improbable that the radiation should originate in atomic or molecular processes, but suggests an origin in gross electrical disturbances analogous to our thunderstorms.

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<sup>1</sup> Jansky, *Proc. Inst. Radio Eng.*, 21, 1387 (1933).

<sup>2</sup> Reber, *Astrophys. J.*, 279 (Nov. 1944).

<sup>3</sup> Army Operational Research Group (British). Report No. 275. (Restricted report.)

<sup>4</sup> Alexander, Radio Development Laboratory Report No. RD. 1/518. (D.S.I.R., New Zealand.) (Restricted report.)

## Long Duration of the Balmer Spectrum in Hydrogen

A RECENT paper published by Lord Rayleigh<sup>1</sup> under this title contains observations and measurements indicating a duration of the Balmer lines of more than  $10^{-5}$  sec., that is, approximately a thousand times the duration found by experiments with positive rays<sup>2</sup> and also calculated from quantum mechanics. While earlier experiments<sup>3</sup> do not allow quantitative conclusions to be drawn, Lord Rayleigh's recent experiments must be regarded as being conclusive. The method mainly consists in producing in an electrodeless glass tube a strong luminosity of the Balmer spectrum induced by a powerful condenser discharge. Part of the gas is blown out of the electric field by thermal expansion into a side tube, where the luminosity extends a considerable distance outside the region of excitation and where the decay of the Balmer lines is observed and measured. Lord Rayleigh attempts no explanation of this apparent discrepancy; but especially asks for one. It may be appropriate and worth while, therefore, to point out that it seems to us that his experiments and similar ones can be understood on the basis of the known relatively long life of free hydrogen atoms and their re-excitation by radiation and especially by diffusing electrons and positive ions; also the recombination of positive ions (protons) may play some part.

The fact that hydrogen atoms 'live' relatively long in their normal state was discovered by Wood and studied in detail by Bonhoeffer<sup>4</sup>; it is explained by the theory of Born and Franck<sup>5</sup>, who showed that the recombination of two atoms can occur only in a triple coincidence either with a third particle or with the walls of the vessel. In sufficiently wide vessels the life-time can be of the order of a few tenths of a second.

To explain the persistence of the luminosity, it is necessary to assume a re-excitation of the atoms in the ejected jet. There are no electric stray fields penetrating into the side tube in the present case, nor is the energy set free by the formation of hydrogen molecules sufficient to excite normal hydrogen atom. But the strong radiation from the main discharge<sup>7</sup> and diffusing electrons of sufficient energy can produce the excitation. The observed 'tapering' of the jet as it proceeds along the exit

tube can be understood on the basis that the hydrogen atoms near the wall have a greater chance of hitting the wall than those near the centre, and therefore 'live' a shorter time. Incidentally, the fact that the blue-green  $H\beta$ -line (4861 Å.) alone is visible at the utmost end of the luminous tongue, whereas the red  $H\alpha$ - and the violet  $H\gamma$ -line have died out, is probably due to the sensitivity of the eye, which has a maximum in the green part of the spectrum.

It may be possible to check the explanation given here for the observed long duration of the Balmer lines by special experiments.

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<sup>1</sup> *Proc. Roy. Soc., A*, 183, 26 (1944); see also *Nature*, 155, 84 (1945), and Jablonski, A., *Nature*, 155, 397 (1945).

<sup>2</sup> Wien, W., *Ann. Phys.*, 73, 483 (1924); for a critical discussion of these and other experiments, see Mitchell, A. C. G., and Zemansky, M. W., "Resonance Radiation and Excited Atoms" (Cambridge, 1934), chap. 3, §3 and §7.

<sup>3</sup> Strutt, R. J., *Proc. Roy. Soc., A*, 94, 88 (1917).

<sup>4</sup> See Jablonski, A., *Nature*, 155, 397 (1945).

<sup>5</sup> Bonhoeffer, K. F., *Phys. Chem.*, 113, 199 (1924); 116, 393 (1925); see also *Erg. d. exakten Naturwiss.*, 6, 207 (1927), etc.

<sup>6</sup> Born, M., and Franck, J., *Z. Phys.*, 31, 411 (1925).

<sup>7</sup> The subject of 'imprisoned' radiation in atomic gases and its re-absorption diffusion and 'persistence' is collected and discussed in Mitchell and Zemansky's "Resonance Radiation and Excited Atoms", chapters 3 and 4; the exact quantum mechanical theory of this subject has been worked out by E. A. Milne, *J. Lond. Math. Soc.*, 1, 1 (1926).

## Halloysite-organic Complexes

I HAVE recently directed attention<sup>1</sup> to the complexes which montmorillonite forms with polyhydric alcohols, a subject which has been further discussed in a paper by Bradley<sup>2</sup>. In these complexes, the alcohol takes the role of water in hydrated montmorillonite, and adsorption depends on polar forces (or secondary valences) only, not on base exchange. For this reason it seemed likely that similar complexes would be formed by halloysite, a clay mineral that is known to exist in hydrated and non-hydrated forms<sup>3</sup>, but which has practically no base exchange capacity (that which exists being probably due only to surface adsorption).

The existence of such halloysite-organic complexes has now been confirmed. They are obtained from the hydrated form of halloysite by treating with certain alcohols in the cold, when the inter-layer water in the halloysite will be replaced by the alcohol. Some of the substances with which complexes have been obtained so far are listed in the accompanying table, together with the corresponding (001) spacing, as determined from measurement of the basal reflexion, and the degree of expansion as compared with the non-hydrated halloysite ('metahalloysite').

No.	Complex with	<i>d</i> (001)	Expansion compared with metahalloysite
1	Ethylene glycol .. ..	10.9 Å.	3.5 Å.
2	Glycerol .. ..	11.0 "	3.6 "
3	Trimethylene glycol .. ..	11.6 "	4.2 "
4	Ethylene chlorohydrin .. ..	10.8 "	3.4 "
5	Ethylene bromohydrin .. ..	diffuse	—
6	Methanol .. ..	10.6 Å.	3.2 "