

reactions occurring in hydrogen and hydrocarbon flames.

The infra-red radiation from hydrogen flames is usually ascribed to the water molecule, on the grounds that so many of the emission bands of water vapour (600° C.) and absorption bands of water vapour (700° C.) agree with the emission bands from the flame (Paschen, *Ann. der Phys. und Chem.* 52, 214; 1894). If, however, the hydroxyl radical is present in water vapour at high temperatures, then some of the infra-red emission from the flame may be due to it and not to water vapour. Confirmation of this idea is obtained from a study of measurements of the total radiation (mainly infra-red) from flames of hydrogen and oxygen with varying compositions.

The radiation from this flame has been measured by the methods described previously (Garner and Johnson, *Jour. Chem. Soc.*, 280; 1928). The mixed

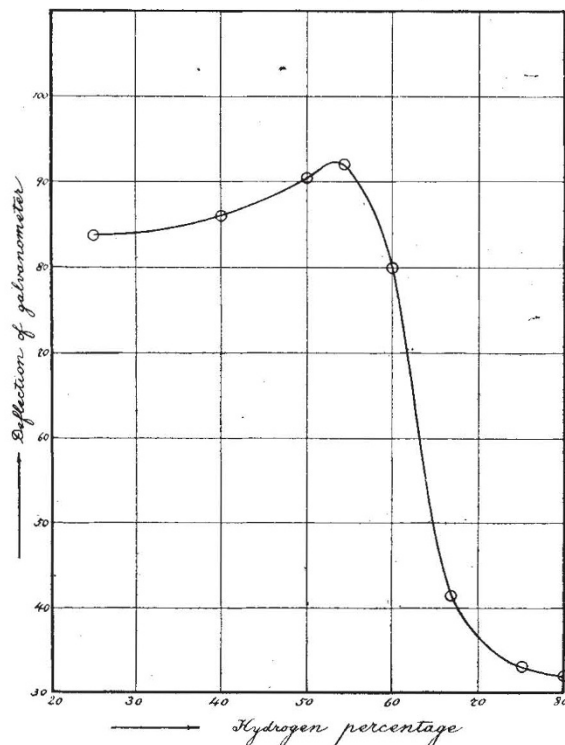


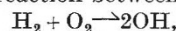
FIG. 1.

gases were burnt in a cylindrical bomb 40 cm. long and 2.5 cm. diameter, at an initial pressure of 1 atmosphere. The radiation emitted through a fluorite window was measured by means of a Moll thermopile and a Downing galvanometer. The results are shown for a number of mixtures of oxygen and hydrogen in Fig. 1, where the galvanometer deflections are plotted against percentage composition. The deflections have been corrected so that in all cases they correspond to the radiation from the same quantity of burnt gas. The results are of a preliminary character, and the position of the maximum is not known accurately.

The maximum emission of radiation does not occur for the mixture of two volumes of hydrogen with one of oxygen, which would be expected, since this mixture gives the highest flame temperature. It occurs for the mixture $H_2 + O_2$ very nearly, which indicates that the hydroxyl radical may be responsible for the emission of part of the radiation from the hydrogen flame.

On this assumption it is possible to explain the

above curve. If the hydroxyl radical is produced as a first stage in the reaction between H_2 and O_2 ,



and it emits a fraction of the energy of chemical change as chemiluminescence, then the quantity of radiation emitted will depend on its average duration of life. The hydroxyl radical will undergo reaction in the presence of hydrogen to give water at a rate which will depend on the hydrogen concentration. Thus, excess hydrogen will diminish average life of the radical. Excess oxygen would be unlikely to produce such a marked effect as hydrogen, and the decrease on the oxygen side may be due to inelastic collisions, $OH' + O_2 \rightarrow OH + O_2'$.

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Molecular Hydrogen in Sunspots.

WHILE carrying out research on the elements of rare earths in sunspots, I happened to notice some lines in a photograph taken at the Arcetri solar tower by Prof. G. Abetti which, so far as I know, have not been hitherto identified. These lines, which were relatively intense in the spots, and very faint, or entirely absent in the photosphere, may be attributed to the secondary spectrum of hydrogen, that is, to the molecular spectrum.

The photograph was taken in the second order with dispersion 1 A. = 1 mm., and comprised the red portion of the spectrum between $\lambda 5900$ to $\lambda 6200$, one of the regions where partial bands of striking intensity appear in the secondary spectrum. It will be noted that the region photographed does not include bands of calcium hydride, which covers a large portion of the spot spectrum with very numerous and very crowded lines, rendering it impossible to identify, with any certainty, the lines of the secondary spectrum.

Since experimental data and thermodynamical considerations do not conflict with the presence of molecular hydrogen under the conditions of temperature and pressure prevailing in the spots (4000° K. and 10^{-2} or 10^{-3} atm.), I resolved to compare a wider region of the spot spectrum with the secondary hydrogen spectrum to ascertain whether coincidence between the two spectra might strengthen the hypothesis of the presence of molecular hydrogen.

For this purpose I made use of the recent and accurate measurements of the secondary spectrum of hydrogen carried out by H. G. Gale, G. S. Monk, and K. O. Lee (*Astrophys. Jour.*, 67, 89; 1928), and of a large scale map (0.25 A. = 1 mm.) of the sunspot spectrum taken at Mt. Wilson, a copy of which is in the Arcetri Observatory. This map, prepared by Ellerman at the great solar tower, using the polarising system for the study of magnetic fields, has not yet been published. The comparison, which was extended to the region between $\lambda 6400$ and $\lambda 4450$, shows numerous coincidences with a maximum error of about ± 0.03 A. in the I. A. system.

I noticed, further, that all the lines which are presumed to be those of the secondary spectrum of hydrogen show no trace of the Zeeman effect as is seen in the map. In fact, they behave exactly as do the lines of calcium hydride, magnesium hydride, etc., also present in the spots. This means that molecular hydrogen can be present in the higher regions of a sunspot, beyond the influence of the magnetic field, where the possibility of the existence, at least of certain molecules, is positively assured.

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