

showed a carbonmonoxyheme-like absorption spectrum.

After completely removing the bound CO by flushing with nitrogen gas for several hours at room temperature, the film showed a typical hemochromogen spectrum. With polystyrene and 1-(2-phenylethyl)-imidazole mixture of 1:3 weight ratio as the matrix, the absorption maxima are at 5280 and 5560 Å., respectively. When this material was exposed to oxygen or air, it rapidly combined with molecular oxygen to give a product which showed an oxyhemoglobin-type of spectrum with absorption peaks at 5370 and 5630 Å. respectively. The oxygenation is reversible, because the original hemochromogen spectrum can be quantitatively restored by flushing the film with nitrogen or by evacuating at room temperature. The cycle can be carried out repeatedly. For a film with more than 90% of polystyrene, the hemochromogen-like spectrum becomes more diffuse. This film still combines rapidly and reversibly with CO<sub>2</sub> or O<sub>2</sub>, and it may also be kept in contact with air-saturated water for days without being oxidized to Fe(III) state.

Although reversible oxygen-addition compounds of Fe(II)-complexes have been reported,<sup>2,3</sup> the present synthetic material appears to be the first successful hemoglobin model which is stable in the presence of water. These results also sub-

(2) K. Kunz and A. J. Kress, *Ber.*, **60**, 367 (1927).

(3) A. H. Corwin and Z. Reyes, *THIS JOURNAL*, **78**, 2437 (1956).

stantiate our previously suggested picture of the binding sites in hemoglobin and myoglobin.<sup>1</sup>

Besides serving as a protective atmosphere, the function of CO in the preparative procedure for high polystyrene-content films is two-fold: (1) to help each Fe(II) to bind one 1-(2-phenylethyl)-imidazole through the stronger ligand-field of CO<sup>4</sup>; (2) to create a spatial configuration in the matrix near the binding site more favorable to O<sub>2</sub> than to another 1-(2-phenylethyl)-imidazole. This last function of CO is shown by the following observation.

The oxygenation ability of the high polystyrene-content film can be destroyed by heating the film in nitrogen atmosphere. This "denatured" film still readily combines with CO. Its oxygenation ability can be restored by heating in CO-atmosphere, cooling, and subsequently removing the bound CO by prolonged flushing with nitrogen.

A high polystyrene-content film made by the above procedure with free heme to replace the diethyl ester was oxidized immediately to Fe(III)-state on exposure to air. This suggests that, in contrast to the ester, the free hemes are not imbedded in the hydrophobic matrix but are quite exposed.

(4) A. Nakahara, Y. N. Chiu and J. H. Wang, to be published.

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## BOOK REVIEWS

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**The Spectroscopy of Flames.** By A. G. GAYDON, D.Sc., F.R.S., Warren Research Fellow of the Royal Society, John Wiley and Sons, Inc., 440 Fourth Avenue, New York 16, N. Y. 1957. ix + 279 pp. 16 × 24.5 cm. Price, \$9.00.

This book aims at replacing "Spectroscopy and Combustion Theory" and "Flames, their Structure, Radiation and Temperature" from the same author, but covers slightly different ground. Some regions covered in the other books are not repeated here, but a fuller treatment of more recent work is made.

The last decade has been notable for the development of a number of new experimental techniques for controlling flames and for exciting flame-type spectra in special sources. These techniques include the burners for flat diffusion and flat premixed flames, low-pressure flames, controlled low-temperature flames, flames supported by free atoms, flash photolysis, shock-tube excitation and use of isotope tracer methods. Dr. Gaydon and his colleagues at Imperial College have been associated with the development of many of these techniques and he has included a great deal of invaluable experimental information in the first part of the book.

The subject is presented in such a way that the book may be of service to those engaged in research in the field, but so that it may be read easily by the beginner and the non-specialist. It is with this viewpoint in mind that a chapter is devoted to the theory of spectra and gives a condensate of the most useful results.

Hydrogen and carbon monoxide flames are studied in two separate chapters and a large extension is given to the application of the spectroscopic results to combustion mechanism. A description of the various band systems encountered in organic flames with a discussion of the emitting species, is followed by sections in which the effect of fuel-type, mixture strength and flame conditions are detailed.

A very interesting and fruitful chapter exposes the extensive work done during the past few years about temperature measurements. Electronic, translational, vibrational and rotational temperatures have been determined for a great deal of emitting species in a variety of experimental conditions. All this information is gathered here and criticized very carefully. This work helps elucidate the detailed state of the gases in the reaction zone in order to discriminate the thermal excitation from the chemical excitation. A long discussion includes the author's hypothesis accounting for the chemical reactions involving the different excited free radicals.

The book is mainly concerned with interpretation of the visible and near ultraviolet spectra of flames. The infrared region has been shortly treated although this question had been the subject of a great deal of work. Explosions as well as flames containing nitrogen, halogens and metals are also rapidly reviewed.

Some very useful tables of emission and absorption spectra, molecular constants, and an extensive bibliography are convenient references.

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