

One interpretation consistent with this result is that the water molecules coordinated to the iron atoms in hemoglobin tend to slow down its rate of oxidation to ferrihemoglobin.⁴ In order to obtain additional information concerning the role of these coordinated water molecules we have studied the rate of oxidation of ferrocytochrome c by ferricyanide ions and compared this rate with that of the ferroheme-globin-ferricyanide reaction.

Two sources of cytochrome c were used. Cytochrome c, prepared from fresh beef hearts according to the Keilin and Hartree procedure,⁵ and horse heart cytochrome c, supplied by the California Corporation for Biochemical Research (Boehringer), were purified by chromatography on Amberlite XE-64 resin.^{6,7} The preparations were reduced with hydrogen and palladium⁸ and the ferrocytochrome estimated spectrophotometrically.⁹

The rate of the ferrocytochrome c-ferricyanide reaction was followed spectrophotometrically using the rapid flow apparatus which has been previously described.¹⁰ The reaction was investigated at 25° in a phosphate buffer with a pH of 6.0 and an ionic strength of 0.10. Second order kinetics were observed. The specific rate constants obtained with the two preparations of cytochrome c were the same within the experimental error of the

measurements. The mean of these measurements together with the rate constant of the ferroheme-globin-ferricyanide reaction and the standard free energy changes of the reactions is presented in Table I.

It is apparent from Table I that the oxidation of ferrocytochrome c by ferricyanide ions proceeds much more rapidly than the oxidation of ferroheme-globin. This is contrary to what one might expect from considerations of the relative values of the standard free energy changes of the two reactions.¹¹

In contrast to the position of the heme group in cytochrome c, which is buried in the interior of the protein, the heme groups in hemoglobin are situated on the surface of the molecule.^{12,13} This makes it unlikely that the difference in the rates of the two reactions is due to a type of steric hindrance in which it is more difficult for a ferricyanide ion to approach close to a heme group in hemoglobin than to one in cytochrome c.

The above measurements are consistent with the suggestion that the relatively slow rate of the ferroheme-globin-ferricyanide reaction might be due to the water molecules coordinated to the iron atoms in hemoglobin.⁴ On the other hand, the conjugated groups coordinated to the iron atom in cytochrome c create an environment which is particularly suited to the rapid transport of electrons, such as is required in the respiratory chain.¹⁴

We wish to thank Dr. Lucile Smith for her helpful suggestions concerning the preparation of cytochrome c, Dr. Robert Smillie and co-workers in the Biology Department of this Laboratory for making some of their facilities available to us, and Mrs. Catherine Paul for assisting in the preparation and purification of the cytochrome c.

(11) M. H. Ford-Smith and N. Sutin, *ibid.*, **83**, no. 8 (1961).

(12) M. F. Perutz, M. G. Rossman, A. F. Cullis, H. Muirhead, G. Will and A. C. T. North, *Nature*, **185**, 416 (1960).

(13) A. Ehrenberg and H. Theorell, *Acta Chem. Scand.*, **9**, 1193 (1955).

(14) D. E. Green and Y. Hatefi, *Science*, **133**, 13 (1961).

CHEMISTRY DEPARTMENT
BROOKHAVEN NATIONAL LABORATORY
UPTON, LONG ISLAND, NEW YORK

NORMAN SUTIN
DAVID R. CHRISTMAN

RECEIVED FEBRUARY 8, 1961

TABLE I

OXIDATION OF FERROHEMOGLOBIN AND FERROCYTOCHROME C BY FERRICYANIDE IONS AT 25° IN A PHOSPHATE BUFFER WITH A pH OF 6.0 AND AN IONIC STRENGTH OF 0.10

Reaction ^a	ΔG° , kcal. mole ⁻¹	l. mole ⁻¹ sec. ⁻¹
Hb(H ₂ O)-Fe(CN) ₆ ³⁻	-6.2 ^b	$7.0 \pm 0.5 \times 10^{4c}$
Cyt. c-Fe(CN) ₆ ³⁻	-3.5 ^b	$1.6 \pm 0.1 \times 10^7$

^a Hb(H₂O) is ferroheme-globin; Cyt. c is ferrocytochrome c. ^b W. Mansfield Clark, "Oxidation-Reduction Potentials of Organic Systems," The Williams and Wilkins Company, Baltimore, Md., 1960, p. 455. ^c N. Sutin, *Nature*, **186**, 000 (1961).

(5) D. Keilin and E. F. Hartree, *Biochem. J.*, **39**, 289 (1945).

(6) E. Margoliash, *ibid.*, **56**, 529 (1954).

(7) L. Smith, private communication.

(8) L. Smith, *Arch. Biochem. Biophys.*, **50**, 285 (1954).

(9) E. Margoliash and N. Frohwirt, *Biochem. J.*, **71**, 570 (1959).

(10) N. Sutin and B. M. Gordon, *J. Am. Chem. Soc.*, **83**, 70 (1961).

BOOK REVIEWS

Nouveau Traité de Chimie Minérale. Tome XV. Uranium et Transuraniens. Premier Fascicule. Uranium. Edited by PAUL PASCAL, Membre de l'Institut. Masson et Cie., 120, Boulevard Saint-Germain, Paris 6, France. 1960. 1 + 734 pp. 17.5 × 26 cm. Price, broché, 115 NF.; cartonné toile, 127 NF.

The fifteenth volume of Pascal's *Nouveau Traité* describes uranium and the transuranium elements. Only uranium is covered in the first part. Actinium, thorium and protactinium are not treated as beginning an actinide series, but are discussed separately in volumes 7, 9 and 12, respectively.

The most striking feature of the volume on uranium is its sheer bulk. There are 725 pages devoted to this element, a larger number than are allotted to any other single element discussed in the eleven volumes which have appeared thus

far. The metals of the sixth group, chromium, molybdenum and tungsten, for comparison, are allotted only 1012 pages altogether. This emphasis on uranium does not reflect its current commercial importance in the chemical world, of course, but rather is due to the great interest it commands as a possible energy source.

Following an introduction by M. Salesse, Chef du Département de Métallurgie du Commissariat à l'Énergie Atomique, there are eleven chapters which have been prepared by more than twenty authors. The first eight chapters cover such topics as isotopes, minerals, preparation and production from the ore, physical properties, mechanical properties, alloys and their use as nuclear fuels, and metallography. The last three chapters, which discuss chemical properties, analysis and aqueous corrosion of uranium and

its alloys, will be of greater interest to the average chemist outside the atomic energy program.

Chapter nine, on chemical properties of uranium, unfortunately opens with a table containing at least three misprints of the sort which the reader cannot easily correct for himself. The reactions of uranium with other elements are discussed first, then reactions with compounds. The discussions include products and, where available, the energies of the reactions. The ions of uranium in aqueous solution are discussed next. Some of the properties of the ions which are described include color, reactivity and stability, and oxidation-reduction potentials. Hydrolysis of the various uranium species and complex-ion formation are treated in several pages.

Analytical behavior of uranium is discussed under the headings of separation, gravimetric and volumetric determination, and determination by means of optical methods. Physical methods of analysis are then described such as polarography, coulometry, emission spectroscopy, neutron activation and isotopic dilution analysis.

Chapter six contains 137 pages discussing alloys of uranium, including almost every possible binary alloy and many ternary alloys. This chapter should be especially useful to the metallurgist.

As in previously issued volumes of this treatise, references follow each section of text and are given with the closing date for the compilation. This date is December 30, 1958, for most sections, and no list of references was closed earlier than January 1, 1958.

The reader will find this volume to be similar in style to the other volumes of the Treatise which have already appeared. It has the customary defect of a rather inadequate index, but covers the literature pertaining to uranium quite thoroughly.

INORGANIC CHEMISTRY SECTION
NATIONAL BUREAU OF STANDARDS ROLF B. JOHANNESEN
WASHINGTON 25, D.C.

Que Sais-Je? No. 874. La Chimie Électronique et ses Applications Industrielles. By ANDRÉE GOUDOT, Chercheur au C.N.R.S. Presses Universitaires de France, 108, Boulevard Saint-Germain, Paris 6, France. 1960. 128 pp. 11.5 × 17.5 cm. Price, NF2.

The title of this book is certainly too general. The real aim of the work is to introduce the reader to the field of organometallic complexes and their many applications in chemistry. Topics treated include ion exchangers, electro-deposition of metals from complexes, dyestuffs and catalysts. The book starts with a necessarily short review of the electronic structures of atoms and concepts related to the chemical bond. A considerable amount of knowledge is thus concentrated in a few pages. It will very likely stimulate the reader to study further some of the many subjects touched upon in this book.

DEPARTMENT OF CHEMISTRY
UNIVERSITY OF MONTREAL C. SANDORFY
MONTREAL, P.Q., CANADA

Statistical Theory and Methodology in Science and Engineering. By K. A. BROWNLEE, Associate Professor of Statistics, The University of Chicago. John Wiley and Sons, Inc., 440 Fourth Avenue, New York 16, N. Y. 1960. xv + 570 pp. 16 × 23.5 cm. Price, \$16.75.

Professor Brownlee's goal in preparing "yet another elementary textbook on statistical methods" is "to convey understanding of principles rather than practice." His method of accomplishing this goal is to establish as much of the mathematical theory of statistical methods as possible using only college algebra and some elementary calculus. Although this leads to some rather tedious mathematical passages, the result is, on the whole, satisfying. The topics covered are substantially the same as those in other current books on statistical methods; the treatment careful, competent and comprehensive.

DEPARTMENT OF RADIATION BIOLOGY
THE UNIVERSITY OF ROCHESTER LEE CRUMP
ROCHESTER, N. Y.

Substitution at Elements other than Carbon. Being the Fifth Weizmann Memorial Lecture Series, May, 1958. By C. K. INGOLD, University College, London. Interscience Publishers, Inc., 250 Fifth Avenue, New York 1, N. Y. 1960. 52 pp. 14 × 22 cm. Price, \$3.50.

This book of only two chapters contains the four lectures given by Sir Christopher Ingold as the Chaim Weizmann Lecturer for 1958. Two of these lectures on "Nucleophilic Substitution at Octahedral Metal Atoms" make up the first of the two chapters of the book. Sir Christopher describes how he became interested in such reactions for central atoms with coordination greater than four and why he chose cobalt (III) for this study. In his well-known forceful manner he compares the conclusions reached from the data obtained at University College, London, with those reached by Adamson, Basolo and Pearson. Although he points out that much work is still necessary to reach conclusions which can be considered fully proven; he also believes that the S_N2 mechanism does more correctly describe these substitution reactions.

Chapter Two contains the third and fourth lectures; in it electrophilic substitution at nitrogen and oxygen are discussed. The vulnerability of the unshared 2p electrons of trivalent nitrogen and bivalent oxygen is compared to that of the 2p electrons of unsaturated carbon. It is shown that nitration at N and O goes *via* the nitronium ion in all cases. The conjugate acid of nitric acid undergoes itself an S_N1 substitution and the nitro group is carried by the nitronium ion.

The author next reviews the history of the kinetic investigations on nitrosation from Hantzsch through Hughes to Bunton and demonstrates that nitrosation is carried out by S_N2 substitutions in mostly the nitrous acidium ion.

In a short appendix Sir Christopher refutes some of the recent arguments of Pearson and Basolo against the S_N2 mechanism proposed by the author in Chapter One of this book.

This little book is well written and should be of value to scientists interested in this field.

DEPARTMENT OF CHEMISTRY
TULANE UNIVERSITY HANS B. JONASSEN
NEW ORLEANS 18, LOUISIANA

The Chemistry and Biology of Sialic Acids and Related Substances. By ALFRED GOTTSCHALK, M. D. (Bonn), D. Sc. (Melbourne), F.R.I.C., F.R.A.C.I., F.A.A., the John Curtin School of Medical Research, Australian National University, Canberra, A.C.T. Cambridge University Press, 32 East 57th Street, New York 22, N. Y. 1960. ix + 115 pp. 14.5 × 22 cm. Price, \$4.50.

This monograph is the first of its kind which deals with the chemistry and biological significance of the sialic acids (also known as the neuraminic acids). It therefore represents the timely appearance of a relatively short but comprehensive text on a new class of biochemical compounds which hold great promise with respect to their biological function as receptor sites for some viruses and their role in the mucopolysaccharides and mucoproteins.

The context of this monograph is as follows: Chapter I, historical aspects of mucoproteins and mucopolysaccharides; Chapter II, the isolation, composition, structure, physical and chemical properties and distribution of sialic acids; Chapter III, the preparation and analysis of sialic acids including various color reactions and paper chromatography; Chapter IV, the mode of linkage of sialic acid in oligosaccharides, mucoproteins and gangliosides; Chapter V, the role of sialic acid in some biologically active mucoproteins and mucolipids; Chapter VI, the sialic acid content of tissues and body fluids in normal and pathological states; Chapter VII, the neuraminidases and a brief comment on aldolases; Chapter VIII, short treatise regarding the isolation and chemistry of muramic acid; and Chapter IX, brief comments on the biological function of sialic acid and muramic acid. Chapters I-X have a valuable list of references. The only error to this reviewer's knowledge is the structure of muramic acid on page 110 in which an ether oxygen has been left out.

The monograph is well written and deals with most of the important aspects of these biochemical compounds. However, an exhaustive coverage of the literature apparently was not intended. For example, the isolation and immunological