

R
54.5
W 432(3)
21-1

TECHNIQUE OF ORGANIC CHEMISTRY

Volume I—Part I

PHYSICAL METHODS of Organic Chemistry

Third Completely Revised and Augmented Edition

Editor:

ARNOLD WEISSBERGER

Authors of Part I

A. E. ALEXANDER

J. R. ANDERSON

J. C. ARTHUR, JR.

N. BAUER

G. L. BEYER

A. H. CORWIN

W. D. HARKINS

S. Z. LEWIN

W. J. MADER

H. MARK

L. D. MOORE, JR.

D. R. SIMONSEN

EVALD L. SKAU

J. M. STURTEVANT

W. SWIETOSŁAWSKI

J. F. SWINDELLS

G. W. THOMSON

M. J. VOLD

R. D. VOLD

R. ULLMAN

R. H. WAGNER

H. WAKEHAM

PART ONE

INTERSCIENCE PUBLISHERS, INC., NEW YORK
INTERSCIENCE PUBLISHERS LTD., LONDON



LIBRARY OF CONGRESS CATALOG CARD NUMBER 59-12438

COPYRIGHT© 1946, 1949, 1959, BY INTERSCIENCE PUBLISHERS, INC.

First Edition, 1946
Second Revised Edition
First printing, 1949
Second printing, 1952
Third Edition, 1959

ALL RIGHTS RESERVED. *This book or any part thereof must not be reproduced in any form without permission of the publisher in writing. This applies specifically to photostat and microfilm reproductions.*

INTERSCIENCE PUBLISHERS, INC., 250 Fifth Ave., New York 1, N. Y.

For Great Britain and Northern Ireland:

INTERSCIENCE PUBLISHERS LTD., 88/90 Chancery Lane, London W. C. 2

PRINTED IN THE UNITED STATES OF AMERICA BY MACK PRINTING COMPANY, EASTON, PA.

TECHNIQUE OF ORGANIC CHEMISTRY
ARNOLD WEISSBERGER, *Editor*

Volume I

PHYSICAL METHODS OF ORGANIC CHEMISTRY

Third Completely Revised and Augmented Edition

Part One

125 19

TECHNIQUE OF ORGANIC CHEMISTRY

ARNOLD WEISSBERGER, *Editor*

- Volume I:* Physical Methods of Organic Chemistry
Third Edition
Parts I to IV
- Volume II:* Catalytic, Photochemical, and Electrolytic
Reactions
Second Edition
- Volume III:* *Second Edition*
Part I. Separation and Purification
Part II. Laboratory Engineering
- Volume IV:* Distillation
- Volume V:* Adsorption and Chromatography
- Volume VI:* Micro and Semimicro Methods
- Volume VII:* Organic Solvents
Second Edition
- Volume VIII:* Investigation of Rates and Mechanisms of
Reactions
- Volume IX:* Chemical Applications of Spectroscopy
- Volume X:* Fundamentals of Chromatography



TECHNIQUE OF ORGANIC CHEMISTRY

INTRODUCTION

Organic chemistry, from its very beginning, has used specific tools and techniques for the synthesis, isolation, and purification of compounds, and physical methods for the determination of their properties. Much of the success of the organic chemist depends upon a wise selection and a skillful application of these methods, tools, and techniques, which, with the progress of the science, have become numerous and often intricate.

The present series is devoted to a comprehensive presentation of the techniques which are used in the organic laboratory and which are available for the investigation of organic compounds. The authors give the theoretical background for an understanding of the various methods and operations and describe the techniques and tools, their modifications, their merits and limitations, and their handling. It is hoped that the series will contribute to a better understanding and a more rational and effective application of the respective techniques. Reference is made to some investigations in the field of chemical engineering, so that the results may be of assistance in the laboratory and help the laboratory chemist to understand the problems which arise when his work is stepped up to a larger scale.

The field is broad and some of it is difficult to survey. Authors and editor hope that the volumes will be found useful and that many of the readers will let them have the benefit of their criticism and of suggestions for improvements.

A. W.

*Research Laboratories
Eastman Kodak Company
Rochester, New York*

11980

TECHNIQUE OF ORGANIC CHEMISTRY

GENERAL PLAN OF THE SERIES

- Volume I** (Third Edition—in four parts). **Physical Methods of Organic Chemistry.**
Authors: A. E. Alexander, D. H. Anderson, J. R. Anderson, J. C. Arthur, Jr., E. D. Bailey, N. Bauer, G. L. Beyer, E. R. Blout, L. O. Brockway, L. M. Corliss, A. H. Corwin, R. L. Custer, B. P. Dailey, G. Donnay, J. D. H. Donnay, K. Fajans, D. D. Fitts, G. K. Fraenkel, A. L. Geddes, H. S. Gutowsky, F. A. Hamm, W. D. Harkins, J. M. Hastings, W. Heller, E. E. Jelley, W. Klyne, C. G. Le Fevre, R. J. W. Le Fevre, S. Z. Lewin, W. N. Lipscomb, W. J. Mader, H. Mark, L. Meites, D. H. Moore, L. D. Moore, Jr., O. H. Müller, J. B. Nichols, W. C. Nixon, G. Oster, A. C. Parker, M. A. Peacock, R. B. Pontius, J. G. Powles, H. A. Scheraga, P. W. Selwood, T. Shedlowsky, R. Signer, D. R. Simonson, W. M. Siri, E. L. Skau, C. P. Smyth, M. Spiro, D. W. Stewart, J. M. Sturtevant, W. Swietoslawski, J. F. Swindells, C. Tanford, G. W. Thomson, B. M. Tolbert, R. Ullman, M. J. Vold, R. D. Vold, R. H. Wagner, H. Wakeham, C. E. Waring, S. Wawzonek, W. West, N. B. Woodall, and N. Wotherspoon
- Volume II** (Second Edition). **Catalytic Reactions,** V. I. Komarewsky, C. H. Riesz, and F. L. Morritz; **Photochemical Reactions,** C. R. Masson, V. Boekelheide, and W. A. Noyes, Jr.; **Electrolytic Reactions,** S. Swann, Jr.
- Volume III** (Second Edition).
Part I. Separation and Purification. C. M. Ambler, G. Broughton, D. Craig, L. C. Craig, A. B. Cummins, F. B. Hutto, Jr., A. L. Jones, K. Kammermeyer, F. W. Keith, Jr., E. MacWilliam, E. G. Scheibel, R. E. Stauffer, and R. S. Tipson.
Part II. Laboratory Engineering. J. W. Axelson, R. S. Egly, R. F. Eisenberg, M. P. Hofmann, R. R. Kraybill, G. H. Miller, J. H. Rushton, W. C. Streib
- Volume IV. Distillation.** J. R. Bowman, C. S. Carlson, A. L. Glasebrook, J. C. Hecker, E. S. Perry, A. Rose, E. Rose, R. S. Tipson, and F. E. Williams
- Volume V. Adsorption and Chromatography.** H. G. Cassidy
- Volume VI. Micro and Semimicro Methods.** N. D. Cheronis. With contributions by A. R. Ronzio and T. S. Ma
- Volume VII. Organic Solvents.** A. Weissberger and E. S. Proskauer. *Second Edition* by J. A. Riddick and E. E. Toops, Jr.
- Volume VIII. Investigation of Rates and Mechanisms of Reactions.** *Editors:* S. L. Friess and A. Weissberger. *Authors:* G. M. Burnett, B. Chance, L. Grunwald, S. L. Friess, F. M. Huennekens, T. H. James, T. S. Lee, J. E. Leffler, R. Livingston, H. W. Melville, B. K. Mores, P. R. O'Connor, W. J. Priest, F. J. W. Roughton, and W. D. Walters
- Volume IX. Chemical Applications of Spectroscopy.** *Editor:* W. West. *Authors:* A. B. F. Duncan, W. Gordy, R. N. Jones, F. A. Matsen, C. Sandorfy, and W. West
- Volume X. Fundamentals of Chromatography.** H. G. Cassidy

From the Prefaces to the First and Second Editions

In recent years, the science of physics has become increasingly important to the organic chemist. Physics has given much greater precision to the concepts of atoms, bonds, and structural formulas, and it has made possible the development of new, and the improvement of older, methods for the examination of chemical systems. With the increasing number and complexity of physical methods for the treatment of organic chemical problems there has resulted a specialization of research workers in the methods which they employ, and the selection of a research problem is frequently governed more by the physical method to be used than by the chemical nature of the problem. Some workers have made themselves familiar with several methods in order to deal with their individual problems. In other cases, however, physical methods have been used without adequate preparation.

The chemist, in order to acquaint himself with a certain physical method, has in the past been compelled to search through periodicals and specialized books. The present work has been compiled with the hope of relieving him of much of this burden. It has been the object of the authors to provide a description of tested methods, the theoretical background for understanding and handling them, and the information necessary for a critical evaluation of the experimental results.

Because of the diversity of the methods discussed, no attempt has been made to secure a uniformity of presentation which might have been desirable for formal reasons. In some chapters a discussion of theory was unnecessary, in some a relatively brief theoretical treatment sufficed, and in other chapters a rather complete exposition of the theory appeared necessary. Some methods have been treated in monographs, while for others no comprehensive modern presentation is available. Therefore, a rather severe selection and delimitation of material was exercised in some chapters and a more complete treatment given in others.

The book is also calculated to appeal to the student who seeks to increase his understanding of the methods described, although he may not practice them himself. For him, chapters like those on x-ray and electron diffraction should be adequate, but the practical application of these techniques will require the use of the supplemental literature to which reference is made.

The title, *Physical Methods of Organic Chemistry*, has been called too narrow. "Organic Chemistry" distinguishes the methods described from

those physicochemical methods which, though essential in other fields, are less important for, or not applicable to, organic chemistry—for example, methods employing very high temperatures. We do not, of course, suggest that the methods described are applicable to organic problems only. Though it is gratifying that workers in other fields have found the book useful, it is our chief object to provide information on the physical methods used by chemists, physicochemists, physicists, biologists, and other research workers in dealing with organic chemical problems.

Preface to the Third Edition

The Second Edition of this treatise was published in 1949 and brought up to date by Part III in 1954. Since then the continued high demand for Parts I and II has indicated the need for either a reprinting or a new edition, and a survey has shown that only a new edition would cope with the changes in, and the additions to, the rapidly developing field.

In the Third Edition of *Physical Methods* new topics have been added, as chapters on "Automatic Control" by J. M. Sturtevant, "Automatic Recording" by D. R. Simonsen, "Weighing" by A. Corwin, "Determination of Particle Size and Weight" by G. Beyer, "X-Ray Microscopy" by W. Nixon, "Determination of the Kerr Effect" by R. J. W. and C. G. Le Fevre, "Determination of the Faraday Effect" by C. E. Waring and R. Custer, "Nuclear Magnetic Resonance" by H. S. Gutowsky, "Electron Spin Resonance" by G. K. Fraenkel, "Determination of Transference Numbers" by M. Spiro, and "Coulometric and Related Methods" by L. Meites.

Automatic control and automatic recording are applicable to many of the methods described in the treatise, and the systematic discussions of Chapters I and II obviate repetitious references. Weighing, likewise, is of general importance. Particle size is influential on, and determined by means of, measurements with so many different methods that a unifying survey appeared desirable. Other new chapters take care of omissions in the earlier editions and of recent additions to the arsenal of methods which are applicable to organic compounds.

The two chapters on "Spectroscopy and Spectrophotometry" and on "Colorimetry, Photometric Analysis, Fluorimetry, and Turbidimetry" by W. West have been divided into five chapters: "Visible and Ultraviolet Spectroscopy and Spectrophotometry" by W. West, "Infrared Spectrophotometry" by D. Anderson, W. West, and N. B. Woodall, "Colorimetry and Photometric Analysis" by W. West, "Determination of Fluorescence and Phosphorescence" by G. Oster and N. Wotherspoon, and "Determination of Light Scattering" by G. Oster. The importance of "Optical

Rotatory Dispersion" is reflected in a chapter by W. Klyne and A. C. Parker which supplements the chapter on "Polarimetry."

We deeply regret the death of Dr. W. D. Harkins, Dr. L. Michaelis, and Dr. M. A. Peacock. Their topics have been taken over by Dr. A. E. Alexander, "Determination of Properties of Insoluble Monolayers at Mobile Interfaces" and "Determination of Surface and Interfacial Tension," Dr. J. D. H. Donnay and Dr. Gabrielle Donnay, "Determination of Crystal Morphology," Dr. P. W. Selwood, "Determination of Magnetic Susceptibility," and Dr. C. Tanford and Dr. S. Wawzonek, "Potentiometry." Where substantial parts of the original chapters were retained, credit is given in the titles to the former authors.

Dr. S. Z. Lewin, Dr. J. Arthur, Dr. W. J. Mader, Dr. J. F. Swindells, Dr. R. Ullman, Dr. L. D. Moore, Dr. R. Pontius, Dr. G. Donnay, Dr. W. N. Lipscomb, Dr. D. D. Fitts, Dr. H. C. Scheraga, Dr. B. M. Tolbert, and Dr. W. Siri have joined or replaced authors of the earlier editions in the writing of the chapters, "Determination of Density" by N. Bauer and S. Z. Lewin, "Determination of Melting and Freezing Temperatures" by E. Skau and J. Arthur, "Determination of Solubility" by W. J. Mader, R. D. Vold, and M. J. Vold, "Determination of Viscosity" by J. F. Swindells, R. Ullman, and H. Mark, "Determination of Osmotic Pressure" by R. H. Wagner and L. D. Moore, "Determination of Diffusivity" by A. L. Geddes and R. Pontius, "Refractometry" by N. Bauer, S. Z. Lewin, and K. Fajans, "Crystallochemical Analysis" by J. D. H. Donnay and G. Donnay, "X-Ray Diffraction" by W. N. Lipscomb, "Polarimetry" by W. Heller and D. D. Fitts, "Determination of Streaming Birefringence" by H. S. Scheraga and R. Signer, and "Determination of Radioactivity" by B. M. Tolbert and W. Siri.

Some physical methods have been omitted from this volume because they are discussed elsewhere in the Series. Certain techniques useful in preparative work are treated in Volume II, Catalytic, Photochemical, and Electrolytic Reactions, and in Part I of Volume III, Separation and Purification. Additional information on vapor pressure and volatility may be found in Volume IV, Distillation. Special techniques for work on a micro and semimicro scale are presented in Volume VI. Adsorption and Chromatography are treated in Volumes V and X, respectively.

The application of certain of the methods discussed in the present treatise to the study of rates and mechanisms of reactions is elaborated in Volume VIII. Chemical Applications of Spectroscopy are the topic of Volume IX, but applications of the non-spectroscopic physical methods are discussed in the present volume in order to explain the use and the scope of the respective techniques.

In sub-dividing the treatise into Parts I to IV we have tried not to separate

closely related topics. Individual indices summarize the contents of Parts I, II, and III, and an index of the whole treatise is contained in Part IV.

I am grateful to many colleagues for help in the editorial work; to Dr. E. K. Blout, Dr. H. S. A. Gilmour, Dr. T. Gompf, Dr. R. L. Griffith, Dr. F. Hamm, Dr. G. Happ, Dr. A. Herz, Dr. W. J. Knox, Jr., Dr. W. Moffitt, Dr. O. H. Muller, Mr. D. Pearlman, Dr. R. Pontius, Dr. B. W. Rossitter, Dr. W. R. Ruby, Dr. H. Seeman, Dr. D. R. Simonsen, Dr. W. R. Vaughan, and to my wife, Dr. Louise H. Weissberger. Last, but not least, I want to express my gratitude to the publishers and their staff, not only for their expert handling of technical matters, but for their willingness to undertake a new edition instead of a less onerous, more remunerative, but for the user less satisfactory, reprinting of the second edition.

A. W.

*Research Laboratories
Eastman Kodak Company
Rochester, New York*

R
54.5
W 432(3)
:1-2

TECHNIQUE OF ORGANIC CHEMISTRY

Volume I—Part II

PHYSICAL METHODS of Organic Chemistry

Third Completely Revised and Augmented Edition

Editor:

ARNOLD WEISSBERGER

Authors of Part II:

E. D. BAILEY

N. BAUER

E. R. BLOUT

L. O. BROCKWAY

L. M. CORLISS

G. DONNAY

J. D. H. DONNAY

K. FAJANS

A. L. GEDDES

F. A. HAMM

J. M. HASTINGS

E. E. JELLEY

S. Z. LEWIN

W. N. LIPSCOMB

J. B. NICHOLS

W. C. NIXON

M. A. PEACOCK

R. B. PONTIUS

PART TWO

1960 215
INTERSCIENCE PUBLISHERS, INC., NEW YORK
INTERSCIENCE PUBLISHERS LTD., LONDON

7-26 /A2

TECHNIQUE OF ORGANIC CHEMISTRY
ARNOLD WEISSBERGER, *Editor*

Volume I

PHYSICAL METHODS OF ORGANIC CHEMISTRY

Third Completely Revised and Augmented Edition

Part Two

TECHNIQUE OF ORGANIC CHEMISTRY

ARNOLD WEISSBERGER, *Editor*

- Volume I:* Physical Methods of Organic Chemistry
Third Edition
Parts I to IV
- Volume II:* Catalytic, Photochemical, and Electrolytic
Reactions
Second Edition
- Volume III:* *Second Edition*
Part I. Separation and Purification
Part II. Laboratory Engineering
- Volume IV:* Distillation
- Volume V:* Adsorption and Chromatography
- Volume VI:* Micro and Semimicro Methods
- Volume VII:* Organic Solvents
Second Edition
- Volume VIII:* Investigation of Rates and Mechanisms of
Reactions
- Volume IX:* Chemical Applications of Spectroscopy
- Volume X:* Fundamentals of Chromatography



TECHNIQUE OF ORGANIC CHEMISTRY

INTRODUCTION

Organic chemistry, from its very beginning, has used specific tools and techniques for the synthesis, isolation, and purification of compounds, and physical methods for the determination of their properties. Much of the success of the organic chemist depends upon a wise selection and a skillful application of these methods, tools, and techniques, which, with the progress of the science, have become numerous and often intricate.

The present series is devoted to a comprehensive presentation of the techniques which are used in the organic laboratory and which are available for the investigation of organic compounds. The authors give the theoretical background for an understanding of the various methods and operations and describe the techniques and tools, their modifications, their merits and limitations, and their handling. It is hoped that the series will contribute to a better understanding and a more rational and effective application of the respective techniques. Reference is made to some investigations in the field of chemical engineering, so that the results may be of assistance in the laboratory and help the laboratory chemist to understand the problems which arise when his work is stepped up to a larger scale.

The field is broad and some of it is difficult to survey. Authors and editor hope that the volumes will be found useful and that many of the readers will let them have the benefit of their criticism and of suggestions for improvements.

A. W.

*Research Laboratories
Eastman Kodak Company
Rochester, New York*

TECHNIQUE OF ORGANIC CHEMISTRY

GENERAL PLAN OF THE SERIES

Volume I (Third Edition—in four parts). **Physical Methods of Organic Chemistry.**

Authors: A. E. Alexander, D. H. Anderson, J. R. Anderson, J. C. Arthur, Jr., E. D. Bailey, N. Bauer, G. L. Beyer, E. R. Blout, L. O. Brockway, L. M. Corliss, A. H. Corwin, R. L. Custer, B. P. Dailey, G. Donnay, J. D. H. Donnay, K. Fajans, D. D. Fitts, G. K. Fraenkel, A. L. Geddes, H. S. Gutowsky, F. A. Hamm, W. D. Harkins, J. M. Hastings, W. Heller, E. E. Jelley, W. Klyne, C. G. Le Fevre, R. J. W. Le Fevre, S. Z. Lewin, W. N. Lipscomb, W. J. Mader, H. Mark, L. Meites, D. H. Moore, L. D. Moore, Jr., O. H. Müller, J. B. Nichols, W. C. Nixon, G. Oster, A. C. Parker, M. A. Peacock, R. B. Pontius, J. G. Powles, H. A. Scheraga, P. W. Selwood, T. Shedlowsky, R. Signer, D. R. Simonson, W. M. Siri, E. L. Skau, C. P. Smyth, M. Spiro, D. W. Stewart, J. M. Sturtevant, W. Swietoslowski, J. F. Swindells, C. Tanford, G. W. Thomson, B. M. Tolbert, R. Ullman, M. J. Vold, R. D. Vold, R. H. Wagner, H. Wakeham, C. E. Waring, S. Wawzonek, W. West, N. B. Woodall, and N. Wotherspoon

Volume II (Second Edition). **Catalytic Reactions**, V. I. Komarewsky, C. H. Riesz, and F. L. Morritz; **Photochemical Reactions**, C. R. Masson, V. Boekelheide, and W. A. Noyes, Jr.; **Electrolytic Reactions**, S. Swann, Jr.

Volume III (Second Edition).

Part I. Separation and Purification. C. M. Ambler, G. Broughton, D. Craig, L. C. Craig, A. B. Cummins, F. B. Hutto, Jr., A. L. Jones, K. Kammermeyer, F. W. Keith, Jr., E. MacWilliam, E. G. Scheibel, R. E. Stauffer, and R. S. Tipson.
Part II. Laboratory Engineering. J. W. Axelson, R. S. Egly, R. F. Eisenberg, M. P. Hofmann, R. R. Kraybill, G. H. Miller, J. H. Rushton, W. C. Streib

Volume IV. Distillation. J. R. Bowman, C. S. Carlson, A. L. Glasebrook, J. C. Hecker, E. S. Perry, A. Rose, E. Rose, R. S. Tipson, and F. E. Williams

Volume V. Adsorption and Chromatography. H. G. Cassidy

Volume VI. Micro and Semimicro Methods. N. D. Cheronis. With contributions by A. R. Ronzio and T. S. Ma

Volume VII. Organic Solvents. A. Weissberger and E. S. Proskauer. *Second Edition* by J. A. Riddick and E. E. Toops, Jr.

Volume VIII. Investigation of Rates and Mechanisms of Reactions. *Editors:* S. L. Friess and A. Weissberger. *Authors:* G. M. Burnett, B. Chance, L. Grunwald, S. L. Friess, F. M. Huennekens, T. H. James, T. S. Lee, J. E. Leffler, R. Livingston, H. W. Melville, B. K. Mores, P. R. O'Connor, W. J. Priest, F. J. W. Roughton, and W. D. Walters

Volume IX. Chemical Applications of Spectroscopy. *Editor:* W. West. *Authors:* A. B. F. Duncan, W. Gordy, R. N. Jones, F. A. Matsen, C. Sandorfy, and W. West

Volume X. Fundamentals of Chromatography. H. G. Cassidy

TECHNIQUE OF ORGANIC CHEMISTRY

Volume I

From the Prefaces to the First and Second Editions

In recent years, the science of physics has become increasingly important to the organic chemist. Physics has given much greater precision to the concepts of atoms, bonds, and structural formulas, and it has made possible the development of new, and the improvement of older, methods for the examination of chemical systems. With the increasing number and complexity of physical methods for the treatment of organic chemical problems there has resulted a specialization of research workers in the methods which they employ, and the selection of a research problem is frequently governed more by the physical method to be used than by the chemical nature of the problem. Some workers have made themselves familiar with several methods in order to deal with their individual problems. In other cases, however, physical methods have been used without adequate preparation.

The chemist, in order to acquaint himself with a certain physical method, has in the past been compelled to search through periodicals and specialized books. The present work has been compiled with the hope of relieving him of much of this burden. It has been the object of the authors to provide a description of tested methods, the theoretical background for understanding and handling them, and the information necessary for a critical evaluation of the experimental results.

Because of the diversity of the methods discussed, no attempt has been made to secure a uniformity of presentation which might have been desirable for formal reasons. In some chapters a discussion of theory was unnecessary, in some a relatively brief theoretical treatment sufficed, and in other chapters a rather complete exposition of the theory appeared necessary. Some methods have been treated in monographs, while for others no comprehensive modern presentation is available. Therefore, a rather severe selection and delimitation of material was exercised in some chapters and a more complete treatment given in others.

The book is also calculated to appeal to the student who seeks to increase his understanding of the methods described, although he may not practice them himself. For him, chapters like those on x-ray and electron diffraction should be adequate, but the practical application of these techniques will require the use of the supplemental literature to which reference is made.

The title, *Physical Methods of Organic Chemistry*, has been called too narrow. "Organic Chemistry" distinguishes the methods described from

those physicochemical methods which, though essential in other fields, are less important for, or not applicable to, organic chemistry—for example, methods employing very high temperatures. We do not, of course, suggest that the methods described are applicable to organic problems only. Though it is gratifying that workers in other fields have found the book useful, it is our chief object to provide information on the physical methods used by chemists, physicochemists, physicists, biologists, and other research workers in dealing with organic chemical problems.

Preface to the Third Edition

The Second Edition of this treatise was published in 1949 and brought up to date by Part III in 1954. Since then the continued high demand for Parts I and II has indicated the need for either a reprinting or a new edition, and a survey has shown that only a new edition would cope with the changes in, and the additions to, the rapidly developing field.

In the Third Edition of *Physical Methods* new topics have been added, as chapters on "Automatic Control" by J. M. Sturtevant, "Automatic Recording" by D. R. Simonsen, "Weighing" by A. H. Corwin, "Determination of Particle Size and Molecular Weight" by G. L. Beyer, "X-Ray Microscopy" by W. C. Nixon, "The Kerr Effect" by C. G. and R. J. W. Le Fevre, "Determination of the Faraday Effect" by C. E. Waring and R. L. Custer, "Nuclear Magnetic Resonance" by H. S. Gutowsky, "Paramagnetic Resonance Absorption" by G. K. Fraenkel, "Determination of Transference Numbers" by M. Spiro, and "Controlled-Potential Electrolysis" by L. Meites.

Automatic control and automatic recording are applicable to many of the methods described in the treatise, and the systematic discussions of Chapters I and II obviate repetitious references. Weighing, likewise, is of general importance. Particle size is influential on, and determined by means of, measurements with so many different methods that a unifying survey appeared desirable. Other new chapters take care of omissions in the earlier editions and of recent additions to the arsenal of methods which are applicable to organic compounds.

The two chapters on "Spectroscopy and Spectrophotometry" and on "Colorimetry, Photometric Analysis, Fluorimetry, and Turbidimetry" by W. West have been divided into five chapters: "Spectroscopy and Spectrophotometry in the Visible and Ultraviolet" by W. West, "Infrared Spectrophotometry" by D. Anderson, W. West, and N. B. Woodall, "Colorimetry and Photometric Analysis" by W. West, "Determination of Fluorescence and Phosphorescence" by G. Oster and N. Wotherspoon, and "Light Scattering" by G. Oster. The importance of "Optical Rotatory Dis-