

# ROGERS'

# INDUSTRIAL CHEMISTRY

A MANUAL FOR THE STUDENT AND MANUFACTURER

SIXTH EDITION—IN TWO VOLUMES

EDITED BY

C. C. FURNAS

Associate Professor of Chemical Engineering, Yale University

INTI-CID  
BIBLIOTECA DELEGADA  
LABORATORIO - MIGUELETE

IN COLLABORATION WITH

ALLEN ABRAMS  
JEROME ALEXANDER  
ARTHUR A. BACKUS  
GEORGE BARSKY  
M. F. BEHAR  
JOHN F. CORWIN  
TOD G. DIXON  
B. F. DODGE  
F. E. DODGE  
GUSTAV EGLOFF  
CARLETON ELLIS  
G. J. ESSELEN  
W. H. FULWEILER  
W. M. GROSVENOR  
M. H. GURLEY, JR.  
C. A. HAMPEL

W. B. HARPER  
J. W. HASSLER  
WILLIAMS HAYNES  
CARLE R. HAYWARD  
W. C. HOLMES  
T. P. HOU  
MARTIN H. ITTNER  
J. A. JOHNSTON  
W. V. KEEGAN  
W. A. KOEHLER  
WALTER S. LANDIS  
L. F. LIVINGSTON  
ALEXANDER LOWY  
R. B. MAC MULLIN  
C. L. MANTELL  
GEORGE W. MOREY  
W. M. NAGLE

LOUIS A. OLNEY  
G. W. MAC PHERSON PHILLIPS  
A. M. PRENTISS  
ALLEN E. ROGERS  
JAMES W. SCHADE  
HORACE A. SHONLE  
R. NORRIS SHREVE  
ALEX. STEWART  
A. G. STILLWELL  
BRADLEY STOUGHTON  
G. G. SWARD  
EDWIN R. THEIS  
W. D. TURNER  
JAMES F. WALSH  
VICTOR E. WELLMAN  
DONALD G. ZINK

VOLUME ONE



NEW YORK

D. VAN NOSTRAND COMPANY, Inc.

250 FOURTH AVENUE

COPYRIGHT, 1912, 1915, 1920, 1925 BY  
D. VAN NOSTRAND COMPANY

---

COPYRIGHT, 1931, 1942 BY  
D. VAN NOSTRAND COMPANY, INC.

---

*All Rights Reserved*

*This book, or any part thereof, may not  
be reproduced in any form without  
written permission from the publishers.*

**Sixth Edition, Published November, 1942**  
*Reprinted January 1943, December 1948*



*Printed in the U. S. A.*

# CONTENTS—VOLUME I

## SECTION I

### BACKGROUND OF THE CHEMICAL INDUSTRY

CHAPTER		PAGE
1.	THE ECONOMIC PATTERN . . . . . WILLIAMS HAYNES Chemical production — The role of research — Chemical distribution — The structure of chemical industry.	3
2.	THE UNIT OPERATIONS . . . . . C. C. FURNAS AND ALLEN E. ROGERS Fluid flow — The film concept — Heat transfer — Evaporation — Crystallization — Distillation — Drying — Air conditioning — Gas absorption and desorption — Extraction — Filtration — Crushing and grinding — Separation of solid materials — Miscellaneous considerations of the unit operations.	31
3.	THE ORGANIC UNIT PROCESSES . . . . . J. A. JOHNSTON Introduction — Equilibrium — Reaction rate — The organic unit processes.	95
4.	HIGH PRESSURE PROCESSES . . . . . B. F. DODGE Reasons for use of pressure — Catalysts — Survey of pressure processes used in industry — Methanol synthesis — Equipment.	147
5.	INDUSTRIAL INSTRUMENTATION . . . . . M. F. BEHAR Measurable conditions — Properties — Composition — Principal parts of industrial instruments — Principal properties of measuring instruments — Measuring properties of recorders and meters — Performance of automatic controllers — Fundamental electrical elements — Relay or "servo" systems.	168
6.	WATER FOR MUNICIPAL AND INDUSTRIAL USE . . . . . W. D. TURNER Introduction — Sources and nature of water supply — Natural water impurities — Modern requirements of water supply — Purification of water supply — Dissolved solids — Methods of lime-soda softening — Zeolite or Permutit softeners — Distillation — Internal boiler feed-water treatment — Examination of water supply — Sanitary analysis of water — Mineral analysis of water — Expression of results — Interpretation of results.	194

## SECTION II

### HEAVY CHEMICALS AND ALLIED PRODUCTS

7.	SULFURIC ACID . . . . . WILLIAM M. GROSVENOR AND G. W. MACPHERSON PHILLIPS Processes of manufacture — Properties of sulfuric acid — Economic aspects — Sources of raw material — Sulfur burning. <b>Contact Process of Manufacture</b> — Catalysts — General theory of the contact reaction — Types of contact plant. <b>Chamber</b>	239
----	---	-----

- Process of Manufacture** — General description of a chamber plant — Construction and function of the apparatus for chamber process — Concentrating sulfuric acid — Handling sulfuric acid — Kinetics of the contact reaction.
8. THE NITROGEN COMPOUNDS . . . . . W. M. NAGLE AND W. S. LANDIS 322  
**Fixation of Nitrogen** — Ammonia synthesis — The Haber process. **Nitric Acid** — Methods of manufacture — The soda process and the arc process — The ammonia oxidation process.
9. NATURAL SALTS AND BY-PRODUCTS . . . . . ROBERT B. MACMULLIN 346  
 Geology of the salt beds — Common salt, sodium chloride — Methods of evaporation — Uses for salt — Sodium chloride products — Sodium sulfate — Uses for sodium sulfate — Hydrochloric acid — Recovery of other natural soluble salts — Natural soda — Natural sodium nitrate — Potash and potassium compounds — Potash mining — Potash from lake brines — Miscellaneous potassium compounds — Magnesium compounds — Bromine — Iodine — Calcium chloride — Boron compounds.
10. ALKALI AND CHLORINE PRODUCTION . . . . . T. P. HOU 402  
 Use of chlorine. **The Manufacture of Soda** — Outline of the ammonia-soda process — Extent of lime use — Caustic soda — Miscellaneous products.
11. CHLORINE PRODUCTS . . . . . R. B. MACMULLIN AND C. A. HAMPPEL 451  
 Hypochlorites, chlorites, chlorates and perchlorates — Chlorites — Chlorates — Perchlorates — Inorganic chlorination products — Chlorine in organic chemistry — Methane derivatives — Acetylene derivatives — Ethylene derivatives — Propylene derivatives — Butyl and amyl derivatives — Higher hydrocarbon derivatives — Benzene derivatives — Toluene derivatives.
12. ELECTROCHEMICAL INDUSTRIES . . . . . WALTER S. LANDIS 479  
 The electrochemical revolution — Classification of electrochemical industries — Industrial applications of electrochemistry — Artificial abrasives — Miscellaneous products — The storage battery — Pigments — Oxidation and reduction of organic compounds.
13. FERTILIZERS . . . . . A. G. STILLWELL 501  
 Fertilizer materials and their composition — Factors affecting availability — Nitrogenous fertilizers — Potash in the fertilizer industry — Phosphate fertilizers — The manufacture of fertilizers from wastes — Special synthetic fertilizer materials — Methods of growing plants in solution and sand cultures — The economics of the fertilizer industry.

## SECTION III

## FUELS AND THEIR BY-PRODUCTS

14. THE PETROLEUM INDUSTRY . . . . . GUSTAV EGLOFF 529  
 Introduction — Motor fuel from crude oil — Thermal cracking — Motor fuel from cracked gases — Isooctane motor fuel — Production of motor fuels by alkylation, cyclization and polymerization methods — Lubricating oils — By-products.

CHAPTER

PAGE

15.	MANUFACTURED CITY GAS . . . . .	W. H. FULWEILER	578
	Recent developments — Constituents of manufactured gas — General methods of manufacture of coal gas — Carbonizing equipment — Low temperature carbonization — Handling the vaporized products — Carbureted water gas — Oil gas — General processes and operations — By-products.		
16.	COAL TAR AND ITS DISTILLATION PRODUCTS . . . . .	F. E. DODGE	648
	Sources of tar — Effect of carbonization temperature on tar composition — Uses of tar — Purification of tars — Light oil recovery from gas — Properties of the products from the light oil fraction — Other tar products — Future of coal tar products.		
17.	WOOD DISTILLATION INDUSTRY . . . . .	W. B. HARPER	667
	The economic picture behind the wood distillation industry — Hardwood distillation — Refining of products — Naval stores — Refined products — Refining of rosin — Gum naval stores.		
18.	INDUSTRIAL CARBON, BLACKS, AND CHARS . . . . .	C. L. MANTELL	701
	Description of the materials — Diamonds — Graphite — Carbon black — Lampblack — Miscellaneous blacks — Printing inks — Black pigments — Activated carbon — Miscellaneous uses of adsorptive carbons — Other uses of carbon — Carbon in chemical construction.		
19.	INDUSTRIAL GASES . . . . .	W. H. FULWEILER	736
	Producer gas — Blue gas — Compressed petroleum gas — Hydrogen — Acetylene — Oxygen — Miscellaneous gases — Furnace atmospheres.		

SECTION IV

REFRACTORIES AND ALLIED MATERIALS

20.	GLASS . . . . .	GEORGE W. MOREY	775
	Historical — Definition and structure of glass — Composition of glass — Properties of glass — Physical properties. <b>Manufacture of Glass</b> — The raw materials — Miscellaneous ingredients — Equipment and handling in glass manufacture — Glass products — The economics of the glass industry.		
21.	THE CLAY PRODUCTS INDUSTRIES . . . . .	W. A. KOEHLER	814
	Clay, the basic raw material — Domestic production, imports and exports of clays — Clay preparation — Firing — Stages during firing — Manufacture of heavy clay products — Fire clay refractories — Chemical stoneware — Pottery — Porcelain.		
22.	CEMENT, LIME, AND PLASTER . . . . .	TOD G. DIXON	851
	History — Classification of the products — Methods of manufacture — Concrete — Puzzolan cements — Lime — Gypsum products.		

## CONTENTS—VOLUME II

### SECTION V

#### METALLURGICAL PRODUCTS

- | CHAPTER |  | PAGE |
|---------|--|------|
| 23.     | THE METALLURGY OF IRON AND STEEL . . . . . BRADLEY STOUGHTON   | 881  |
|         | Economic trends in iron and steel — Ores — The blast furnace — Chemistry of the blast furnace — The making of steel — Electrometallurgy in the iron and steel industry — Heat treatment of steels — Slowly-cooled steel — Cast iron — Alloy steels.  |      |
| 24.     | NONFERROUS METALLURGY . . . . . CARLE R. HAYWARD   | 914  |
|         | Economic considerations — Basic principles of smelting and refining — Preliminary treatment of ores — Metallurgy of copper — Metallurgy of lead — Metallurgy of zinc — Metallurgy of nickel — Miscellaneous recovery operations — Nonferrous alloys — Electrometallurgy of nonferrous metals — Magnesium — Miscellaneous metals — Electrolytic production of copper — Zinc — Electrolytic refining of impure metals. |      |

### SECTION VI

#### SURFACE COATINGS

- |     |   |      |
|-----|---|------|
| 25. | SURFACE COATINGS . . . . . G. G. SWARD  | 963  |
|     | Introduction — Materials of paint — The individual pigments — White zinc pigments — Titanium pigments — Antimony pigments — White lead pigments — Linseed oil — Miscellaneous materials — Manufacture of paint — Preparation of various types of paint — Varnishes — Cellulose lacquers — Painting methods — Some economic aspects of the paint industry. |      |
| 26. | WHITE LEAD . . . . . ALEX. STEWART  | 1013 |
|     | Economic aspects — The raw materials for white lead — Reactions in making white lead — The Dutch process — The Carter process — Euston process — Sperry process — Thompson-Stewart process — Properties of white lead — Industrial uses of white lead — White basic lead sulfate — Industrial hazards.  |      |

### SECTION VII

#### PRODUCTS OF ORGANIC SYNTHESIS

- |     |  |      |
|-----|--|------|
| 27. | INDUSTRIAL ORGANIC CHEMICALS . . . . . ALEXANDER LOWY  | 1033 |
|     | Organic type formulas — The organic unit processes — Organic type reactions — Industrial products.                       |      |
| 28. | MANUFACTURE OF INTERMEDIATES AND DYES . . . . . R. NORRIS SHREVE   | 1100 |
|     | Economic aspects — Raw materials — Intermediates — Manufacture of aniline — Manufacture of amino-naphthol-sulfonic acids |      |

CHAPTER		PAGE
	— Dyes — Manufacture of typical dyes — Miscellaneous dye notes.	
29.	APPLICATION OF DYESTUFFS . . . . . LOUIS A. OLNEY	1136
	Compounds used by the textile colorist — Classification of dyestuffs — Natural organic dyestuffs — Manufactured organic dyestuffs — Properties of vat dyes — The mechanism of dyeing.	
30.	INDUSTRIAL SOLVENTS . . . . . ARTHUR A. BACKUS AND DONALD G. ZINK	1165
	Introduction — Monobasic alcohols — Hydrocarbons — Recovery of solvent vapors by activated carbon.	
31.	SYNTHETIC PLASTICS . . . . . GEORGE BARSKY	1189
	Historical — Production and use — General chemistry of synthetic plastics — Properties of plastics and methods of fabrication — Methods of manufacture — Phenol-formaldehyde resins — Urea-formaldehyde resins — Melamine resins — Alkyd resins — Polyamide resins — Vinyl resins — Vinylidene chloride resins — Acrylate resins — Polystyrene resins — Coumarone resins — Hydrocarbon resins from petroleum distillates — Sulfur dioxide-olefin resins.	
32.	EXPLOSIVES . . . . . L. F. LIVINGSTON AND W. C. HOLMES	1226
	Introduction — Potential energy of explosives — Properties of explosives — Manufacture of explosives — The role of nitration — Explosives made by nitration — Dynamite — Commercial high explosives containing no nitroglycerine — Initiating devices — Sporting and military explosives — Disruptive explosives for military use — Handling and storage of explosives — Economic trend of commercial explosives.	
33.	MILITARY GASES . . . . . A. M. PRENTISS	1258
	Definition of military gases — Function of military gases in warfare — Types of military gases — Requirements for military gases — Technical requirements — Tactical requirements — Requirements for ideal military gas — World War experience — Future development of chemical warfare — Manufacture of military gases — Methods of disseminating military gases.	
34.	THE MANUFACTURE OF PHARMACEUTICALS . . . . . HORACE A. SHONLE	1278
	Outlining the field — The economic picture — Plant products — Alkaloids — Glucosides — Hormones — Biological agents — Vitamins — Synthetic organic medicinals — Anesthetics — Antiseptics — Sulfanilamide and derivatives — Metallic and organometallic compounds — Iodine derivatives — Phenylethylamine derivatives — Purgatives — Sedatives — Barbituric acids — Trade-mark explanation — Acknowledgments.	

## SECTION VIII

## NATURAL ORGANIC MATERIALS

35.	SUGAR . . . . . J. W. HASSLER	1335
	Sources of sugar — Mechanization of beet and cane agriculture — Steps in sugar manufacture — Evaporation — The boiling operation — Purging and curing — Refining — Miscellaneous factors in operation — Fuel — Economic aspects — By-products — Possibil-	

# CONTENTS

vii

CHAPTER

PAGE

- ity of increased consumption — Increasing yields — Acknowledgment.
36. STARCH: ITS SOURCES, MANUFACTURE AND PRODUCTS . . . . . JAMES F. WALSH 1378  
 Historical — Occurrence and physical characteristics — Chemical characteristics — Starch consumption — Processes of manufacture — general — Process of manufacture of corn starch — Commercial glucose, dextrose and other conversion products — The crop and the industry — Potato starch industry — Sweet potato starch — Tapioca, arrowroot and sago — Wheat starch — Rice starch — Dextrines and gums — Modified starches — Industrial uses.
37. THE PULP AND PAPER INDUSTRY . . . . . ALLEN ABRAMS 1407  
 History — Raw materials — Manufacture of pulp — Sulfite process — Sulfate process — Miscellaneous processes — Processing of pulp — Manufacture of paper and paperboard — Conversion of paper — Grades of paper — Economics of the industry.
38. CELLULOSE INDUSTRIES . . . . . GUSTAVUS J. ESSELEN AND MARTIN H. GURLEY, JR. 1441  
 Properties of cellulose — Cellulose nitrate preparation — Cellulose acetate — Other cellulose esters and ethers — Rayon — Miscellaneous cellulose applications.
39. RUBBER AND RUBBER-LIKE PRODUCTS . . . . . JAMES W. SCHADE AND VICTOR E. WELLMAN 1457  
 Plantation industry — Development of manufacture of rubber goods — Materials of the industry — Processing methods — Rubber products — Chemistry of natural rubber — Chemistry of synthetic rubbers.
40. THE NATURAL RESINS, GUMS, AND GUM RESINS . . . . . C. L. MANTELL 1490  
 Natural resins — The classification, origin, and properties of natural resins — Origin of resins — The physical and chemical properties of natural resins — Sizing and cleaning — Solubility — Thermal processing or running of natural resins — Compatibilities of natural resins — Gums and gum resins — Classification and properties.
41. NATURAL OILS, FATS AND WAXES . . . . . CARLETON ELLIS AND W. V. KEEGAN 1508  
 The economic picture — Chemistry of natural oils, fats, and waxes — Summary of recovery methods and uses of certain oils, fats and waxes — Oil recovery and refinement — Bleaching, deodorizing, and wintering the oils — Hydrogenation — Products of hydrogenation processes.
42. SOAP AND GLYCERINE . . . . . MARTIN H. ITTNER 1535  
 Historical aspects — The soap materials — Determination of fat properties — Constitution of the fats — Production of soap and fatty acids — Animal fats — Plant sources — Handling and treatment of fats — Classification of soaps — Soap manufacture — Finishing the soap — Other processes of soap manufacture — Miscellaneous soap products — Special detergents and wetting agents — Other sulfated detergents — The economics of the soap industry. **Laundering** — The effect of soils on the laundering



CHAPTER		PAGE
	process — Washing supplies — Alkalies and soil. <b>Glycerine</b> — Glycerine from saponification operations — Refining of glycerine — The modern process — Synthetic glycerine — Glycerine from fermentation processes — Economic aspects of glycerine produc- tion.	
43.	GLUE AND GELATINE . . . . .	1581
	JEROME ALEXANDER	
	Physical and chemical properties of glue and gelatine — Raw materials — Manufacture — Preparing the stock — Liquid glues and glue substitutes — Testing the products — Uses of glue and gelatine — Food gelatine — Economic aspects of glue and gelatine.	
44.	CASEIN AND ALLIED MATERIALS . . . . .	1599
	JOHN F. CORWIN	
	Introduction — Historical — The raw material — Manufacturing procedure — Testing and analysis — Technical applications — Vegetable proteins — Production and use trends.	
45.	LEATHER . . . . .	1626
	EDWIN R. THEIS	
	Curing of hides and skins — Classification of hides and skins — Structure of animal skin — Hide damages — Pre-tannage proc- esses — Unhairing — Bating — Pickling. <b>The Tanning Proc- esses</b> — Chrome tanning — Vegetable tanning — Vegetable tan- ning materials — Commercial preparation of tanning extracts — Miscellaneous tannages — Finishing processes — Commercial as- pects of the leather industry — The fur industry — Research in the leather industry.	
	INDEX . . . . .	1687