

**METALLURGICAL  
CALCULATIONS.  
PART I**

Published @ 2017 Trieste Publishing Pty Ltd

ISBN 9780649105878

Metallurgical calculations. Part I by Joseph W. Richards

Except for use in any review, the reproduction or utilisation of this work in whole or in part in any form by any electronic, mechanical or other means, now known or hereafter invented, including xerography, photocopying and recording, or in any information storage or retrieval system, is forbidden without the permission of the publisher, Trieste Publishing Pty Ltd, PO Box 1576 Collingwood, Victoria 3066 Australia.

All rights reserved.

Edited by Trieste Publishing Pty Ltd.  
Cover @ 2017

This book is sold subject to the condition that it shall not, by way of trade or otherwise, be lent, re-sold, hired out, or otherwise circulated without the publisher's prior consent in any form or binding or cover other than that in which it is published and without a similar condition including this condition being imposed on the subsequent purchaser.

[www.triestepublishing.com](http://www.triestepublishing.com)

**JOSEPH W. RICHARDS**

**METALLURGICAL  
CALCULATIONS.  
PART I**



UNIVERSITY OF TORONTO  
APR 12  
DEPT. OF  
METALLURGICAL ENGINEERING

# METALLURGICAL CALCULATIONS



*McGraw-Hill Book Co. Inc*

PUBLISHERS OF BOOKS FOR

Coal Age ∇ Electric Railway Journal  
Electrical World ∇ Engineering News-Record  
Railway Age Gazette ∇ American Machinist  
Electrical Merchandising ∇ The Contractor  
Engineering & Mining Journal ∇ Power  
Metallurgical & Chemical Engineering

TEMP  
R

# METALLURGICAL CALCULATIONS

BY

JOSEPH W. RICHARDS, A.C., Ph.D.

*Professor of Metallurgy in Lehigh University  
Secretary (and Past-President) of the American Electrochemical Society  
Vice-President, American Institute of Mining Engineers, Member  
of the U. S. Naval Consulting Board, Author of  
"Aluminium, Its Metallurgy, etc."*

---

## PART I.

Introduction, Chemical and Thermal Principles  
Problems in Combustion, and  
Radiation and Conduction of Heat.

FOURTH EDITION  
REVISED AND ENLARGED

McGRAW-HILL BOOK COMPANY, INC.  
239 WEST 39TH STREET. NEW YORK

LONDON: HILL PUBLISHING CO., LTD.  
6 & 8 BOUVERIE ST., E. C.

1917

436333  
9.6.45

## PREFACE TO FOURTH EDITION.

The writer has endeavored to correct all the mistakes, large and small, which crept into the former editions, and to add such new and useful physical and chemical data as have appeared to date. The Thermochemical Tables have been re-cast in more useful form; the Thermophysics of the Elements have been largely extended, and now include the vapor tensions of the solid and liquid elements; the Thermophysics of Chemical Compounds have been tabulated in more usable form; the Radiation Constants of various substances have been put into a different shape, for use with Langmuir's radiation formula.

The author is grateful to those friends whose kindly criticism has pointed out mistakes or suggested improvements.

He also wishes to thank Mr. Leonard Buck and Mr. Y. Takikawa, students in Metallurgy, for considerable assistance given in completing and calculating the tabular data.

J. W. R.

LEHIGH UNIVERSITY,  
Oct. 1, 1917.

---

## PREFACE TO FIRST EDITION.

The larger part of the contents of this book is a reprint of a serial running in the "ELECTROCHEMICAL AND METALLURGICAL INDUSTRY" from March, 1905, to March, 1906. To these has been added the statements of a number of problems for practice, which it is hoped will still further increase the usefulness of the work. It is intended that the serial which is now appearing during 1906 shall appear as Part II, and that which shall appear during 1907 as Part III, completing the work.

To those who are practically conversant with metallurgical operations, no argument need be offered as to the value of properly made calculations concerning the running of a process. To those who are engaged in teaching, it need only be said that if the value of metallurgical problems as a means of teaching



metallurgy is doubted, try the plan and see how wonderfully it succeeds. To artisans or students working alone, it may be said that the mastery of such problems and their working principles constitutes the practical mastery of metallurgy as a science, and leads inevitably to a strong and commanding grasp of the subject.

If ever rule-of-thumb is to be replaced in a metallurgical process by scientific operation, the change must be based on experiments, classification of results, and calculations therefrom. The principles involved are physical, chemical and mechanical; the scientific metallurgist must master these, use them as tools, and overcome brute nature by their skilful employment.

Every metallurgical problem is an exercise in pure logic and mathematical reasoning; the premises are observed facts—all that can be learned of the process by direct observation and measurement; the conclusions desired are everything which can be deduced from the premises by hook or by crook, by direct logical process or by inference. In this way data and information are obtained which cannot be directly observed or measured, and which are of the most essential value for thoroughly understanding the process.

To the study of this hitherto somewhat neglected and yet amazingly fruitful side of metallurgical work the author invites the reader, and hopes that the work here presented may in itself reward everyone who spends time in reading and effort in mastering its contents.

JOSEPH W. RICHARDS.

LEHIGH UNIVERSITY,  
March 12, 1906.

# CONTENTS.

	PAGE
INTRODUCTION.—Scope of the Treatise.....	iii-xi
CHAPTER I.—THE CHEMICAL EQUATION.....	1-12
Atomic Weights.....	1
Relative Weights.....	2
Relative Volumes of Gases.....	2
Exact Weights and Exact Volumes.....	3
Weights and Volumes of Gases.....	4
Corrections for Temperature.....	5
Corrections for Pressure.....	7
Corrections for Temperature and Pressure.....	7
Problem 1.—Combustion of Coal.....	8
Problem 2.—Combustion of Natural Gas.....	10
Problem 3.—Oxidation in a Bessemer Converter..	11
CHAPTER II.—THE APPLICATIONS OF THERMOCHEMISTRY.	13-40
Thermochemical Nomenclature.....	13
Thermochemical Data.....	18-40
Oxides.....	18
Hydrates.....	19
Sulfides.....	21
Selenides, Tellurides.....	22
Arsenides, Antimonides, Phosphides, Nitrides...	23
Hydrides, Hydrocarbons.....	24
Carbides.....	25
Silicides, Fluorides.....	26
Chlorides.....	27
Carbonates.....	28
Bi-Carbonates.....	29
Nitrates.....	30
Silicates.....	31
Sulphates.....	32
Bi-sulphates, Phosphates, Arsenates, Tungstates.	33
Borates, Molybdates, Titanates.....	34
Manganates, Aluminates, Cyanides.....	35
Cyanates, Metallo-cyanides.....	36

Amalgams, Alloys.....	37
Thermochemical Constants of Bases and Acids.....	38
CHAPTER III.—THE USE OF THE THERMOCHEMICAL DATA.....	41-60
Simple Combinations—Complex Combinations.....	41
Double Decompositions.....	43
Calorific Power of Fuels.....	46
Problem 4.—Combustion of Natural Gas.....	47
Dulong's Formula.....	48
The Theoretical Temperature of Combustion.....	50
Specific Heats of Gases Produced.....	51
Combustion with Heated Fuel or Air.....	52
Problem 5.—Calorific Intensity of Natural Gas.....	54
The Eldred Process of Combustion.....	55
Temperatures in the "Thermit Process".....	58
CHAPTER IV.—THE THERMOCHEMISTRY OF HIGH TEMPERATURES.....	61-117
Reduction of Zinc Oxide by Carbon.....	63
General Remarks.....	68
Reduction of Iron Oxide by Hydrogen.....	69
Specific Heats of the Elements.....	70
Latent Heats of Fusion of the Elements.....	71
Latent Heats of Vaporization of the Elements.....	73
Thermophysics of the Elements.....	74
Tables of Thermophysics of the Elements.....	75-103
Efficiency of Furnaces.....	104
Problem 6.—Efficiency of a Rockwell Furnace..	106
Problem 7.—Efficiency of an Amalgam Retort..	107
Problem 8.—Efficiency of a Zinc Distilling Furnace.....	108
Thermophysics of Alloys.....	109
Tables of Thermophysics of Alloys.....	109-113
Problem 9.—Efficiency of a Steel Melting Furnace.....	114
Problem 10.—Efficiency of a Siemen's Furnace..	114
Problem 11.—Efficiency of a Foundry Air-furnace.....	114
Problem 12.—Efficiency of a Foundry Cupola..	115
CHAPTER V.—THERMOPHYSICS OF CHEMICAL COMPOUNDS.....	118-144
Oxides.....	118