

monographs of Sir Lowthian Bell, and the manual of Phillips and Bauerman, from which volume a few illustrations have been borrowed. The literature of the subject has been enriched by Howe, of Boston, who has collected a store of facts in his elaborate and recently published volume on steel.

In the preparation of a portion of this little work, I have been aided by my colleague, Mr Bennett Brough, whose help has been specially useful in passing the work through the press.

I hope that the book will be found useful to my own students, for whose progress I feel sincere solicitude.

CHILWORTH, SURREY,  
December 23, 1890.

## CONTENTS.

### CHAPTER I.

#### THE RELATION OF METALLURGY TO CHEMISTRY.

### CHAPTER II.

#### PHYSICAL PROPERTIES OF METALS.

	PAGE
Molecular structure . . . . .	12
Crystalline structure . . . . .	13
Density . . . . .	14
Contraction during solidification and cooling . . . . .	15
Fracture . . . . .	16
Malleability . . . . .	16
Ductility . . . . .	17
Tenacity . . . . .	17
Toughness . . . . .	17
Hardness . . . . .	17
Brittleness . . . . .	19
Elasticity, extensibility, and strength of metals . . . . .	19
Effect of high temperatures on the properties of metals . . . . .	24
" low      "      "      " . . . . .	25
Testing machines . . . . .	26
Impact tests . . . . .	33
Colour . . . . .	36
Fusibility . . . . .	36
Welding . . . . .	37
Acoustic properties . . . . .	38
Properties common to fluids and solid metals . . . . .	38
Occlusion of gases . . . . .	47
Diffusion of metals . . . . .	49
Kernel roasting . . . . .	55
Cementation processes . . . . .	56
Diffusion of amalgams in mercury . . . . .	60
Volatility of metals . . . . .	61
Magnetic properties of metals . . . . .	62



	PAGE
Electrical resistance of metals . . . . .	65
Specific heat of metals . . . . .	66
Table of physical constants of metals . . . . .	67

## CHAPTER III.

## ALLOYS.

Early investigations . . . . .	69
Views as to the constitution of alloys . . . . .	70
Union of metals by fusion . . . . .	73
"    compression . . . . .	73
"    electro-deposition . . . . .	76
Liquation and segregation . . . . .	76
Solution of metals in metals in the fluid condition . . . . .	83
Action of electric currents on molten alloys . . . . .	88
Conduction of electricity by alloys at varying temperatures . . . . .	89
Effect of composition on the conductivity of alloys . . . . .	90
Influence of foreign elements on the properties of metals . . . . .	93
Influence of varying quantities of metals on each other . . . . .	100
Relationship between the atomic volume of an element added to a metal and the effect produced by this addition . . . . .	104
Effect of temperature on strength of alloys . . . . .	105
Effect of low temperatures on the properties of alloys . . . . .	107
The rarer metals and their alloys . . . . .	109
Electrolytic fusion . . . . .	111
The industrial use of the rarer metals . . . . .	114
Colour of alloys . . . . .	117
Alloys of industrial importance . . . . .	121

## CHAPTER IV.

## THE THERMAL TREATMENT OF METALS.

Annealing, hardening, and tempering . . . . .	126
History . . . . .	128
Internal constitution of steel . . . . .	130
Micro-sections of different varieties of steel . . . . .	<i>To face</i> 138
Working of steel . . . . .	150
Classification of steel . . . . .	153
Summary . . . . .	155
Thermal treatment of industrial alloys . . . . .	156
Sand casting and chill casting . . . . .	157
Effect of annealing alloys . . . . .	157
Effect of quenching aluminium bronze at various temperatures . . . . .	158
Effect of annealing Muntz metal . . . . .	158
Effect of mechanical work on the properties of alloys . . . . .	158
Bibliography of work on the thermal treatment of steel . . . . .	159

## CHAPTER V.

## PYROMETRY.

	PAGE
Pyrometry . . . . .	162
Classification of the principles on which pyrometers are constructed . . . . .	163
Types of thermometers in general use . . . . .	164
Seeger cones . . . . .	165
Siemens water pyrometer . . . . .	166
Carnelly and Burton pyrometer . . . . .	168
Siemens resistance pyrometer . . . . .	168
Callendar recorder . . . . .	170
Thermo-electric pyrometer . . . . .	172
Photographic recorder . . . . .	177
Thread recorder . . . . .	178
Differential pyrometer . . . . .	179
Air thermometer . . . . .	181
Uehling pneumatic pyrometer . . . . .	185
Optical pyrometry . . . . .	191
Wanner pyrometer . . . . .	196
General considerations . . . . .	205
Bibliography . . . . .	208

## CHAPTER VI.

## METALLOGRAPHY.

History of microscopic metallography . . . . .	210
Microscopic metallography . . . . .	212
Micro-photographs of alloys, etc. . . . .	<i>To face</i> 212
Preparation of photo-micrographs . . . . .	213
Microscope and its accessories . . . . .	215
Solution theory of alloys . . . . .	220
Constitution of metallic alloys . . . . .	225
(1) Free metals . . . . .	225
(2) Solid solutions . . . . .	226
(3) Intermetallic compounds . . . . .	227
(4) Compounds of metals with non-metals . . . . .	231
(5) Eutectic mixtures . . . . .	232
(6) Solid solutions of compounds . . . . .	234
(7) Allotropic modifications . . . . .	234
Classification of binary alloys . . . . .	235
Bibliography . . . . .	240

## CHAPTER VII.

## FUEL.

Classification of fuel . . . . .	246
Calorific power . . . . .	247
Calorific intensity . . . . .	249



xiv	CONTENTS.	PAGE
I. Natural fuels . . . . .		250
(1) Wood . . . . .		250
(2) Peat . . . . .		251
(3) Lignite . . . . .		252
(4) Coal . . . . .		253
(5) Anthracite . . . . .		255
(6) Liquid fuels . . . . .		255
(7) Natural gas . . . . .		256
II. Prepared fuels . . . . .		257
(1) Compressed fuels . . . . .		257
(2) Dried fuels . . . . .		257
(3) Carbonised fuels . . . . .		257
(a) Charcoal . . . . .		259
(b) Coke . . . . .		281
(4) Liquid fuel . . . . .		281
(5) Gaseous fuel . . . . .		281
Producer gas . . . . .		290
Water gas . . . . .		290
Blast-furnace gases . . . . .		293

### CHAPTER VIII.

#### MATERIALS AND PRODUCTS OF METALLURGICAL PROCESSES.

Ores . . . . .	294
Fluxes . . . . .	294
Metallurgical agents . . . . .	295
Selection of fluxes . . . . .	296
Slags . . . . .	298
Economic application of slags . . . . .	299
Calculation of furnace charges . . . . .	311
Classification of metallurgical processes . . . . .	312
Roasting and calcination . . . . .	313
Oxidising agents . . . . .	315
Reducing agents . . . . .	315
Chemical agents . . . . .	316

### CHAPTER IX.

#### FURNACES.

Materials used in the construction of furnaces . . . . .	317
Acid refractories . . . . .	317
Basic ,, . . . . .	319
Neutral ,, . . . . .	319
Crucibles . . . . .	320

	CONTENTS.	XV
		PAGE
Classification of furnaces . . . . .		321
I. Hearths . . . . .		323
II. Shaft furnaces . . . . .		326
III. Reverberatory furnaces . . . . .		338
IV. Closed-vessel furnaces . . . . .		353
V. Electric furnaces . . . . .		357

### CHAPTER X.

#### THE SUPPLY OF AIR TO FURNACES.

Methods of producing draught . . . . .	365
Blowing-engines . . . . .	369
Hot-blast stoves . . . . .	373
Dry blast . . . . .	378

### CHAPTER XI.

#### THERMO-CHEMISTRY.

Units . . . . .	382
Bomb calorimeter . . . . .	383
Chemical equilibrium . . . . .	387
Thermal equations . . . . .	391
Bibliography . . . . .	403
<i>Folding Table to face</i>	404

### CHAPTER XII.

#### TYPICAL METALLURGICAL PROCESSES.

Classification of processes . . . . .	405
Welsh method of copper-smelting . . . . .	408
Smelting of gold and silver ores in Colorado . . . . .	413
Freiberg process . . . . .	416
Wet processes for treating argentiferous copper ores . . . . .	427
Treatment of gold ores . . . . .	430
Purification of platinum . . . . .	433
Wet process for treating nickel and cobalt ores . . . . .	433
The extraction of nickel from its ores by the Mond process . . . . .	436
Separation of nickel and copper by means of sodium sulphide . . . . .	449
The electrolytic refining of base bullion—Bett's process . . . . .	450

### CHAPTER XIII.

#### ECONOMIC CONSIDERATIONS.

Object of the metallurgist . . . . .	452
Capital and labour . . . . .	452
Modes of payment . . . . .	454
Production of metals . . . . .	460
Price of metals . . . . .	460
INDEX . . . . .	465