

Index

- Acid Bessemer process, 156
Acid open-hearth process, 154–155
Activated complex, 102
Activities, in metal-oxide silicates, 70
 in Mg_2SiO_4 — Fe_2SiO_4 system, 69
 in ternary silicates, 68 *ff.*
 of $CaSiO_3$ in liquid silicate mixtures, 70
 of oxides in ternary melts, 72
 of silicates in Ca_2SiO_4 — Fe_2SiO_4 , 71
Activity, of aluminum, in Fe—C—Al—Si, 49
 of carbon, in Fe—C, 3 *ff.*, 13, 38
 in steels, 221
 of copper in Cu—Ag, 17
 of FeO , in CaO—FeO— SiO_2 , 73, 75
 in CaO—MgO— SiO_2 , 60
 in slags, 177
 of MnO in CaO—MnO— SiO_2 , 73, 75
 of MnS in slags, 178
 of SiO_2 , in CaO— Al_2O_3 — SiO_2 , 65 *ff.*
 in CaO— SiO_2 , 63 *ff.*
Activity coefficient, of aluminum, in Fe—Si—C—Al, 48
 in iron, 48
 of carbon, in Fe—C, 11, 39, 42–43
 in Fe—C—Si, 44
 in liquid iron, 10
 of metal oxides, 222
 of oxygen, in Fe—C—Si, 44
 in iron, 39, 45, 221
 of PbO in silicates, 75
 of silicon in Fe—C—Si, 43
Adiabatic dropping calorimeter, 18 *ff.*
Alumina-graphite reaction, 46 *ff.*
Aluminum, activity coefficient, in Fe—Si—C—Al, 48–49
 in iron, 48
 deoxidation, 46 *ff.*
 equilibrium distribution in Fe—Ag, 48
Aluminum-killed ingot, 184
Analysis, of gas, 5, 51 *ff.*
 of gases in iron, 51
 of metal, 6
 vacuum fusion, 52
Anodic process, 245–246
As-cast structure, 210–213

Back reaction, 139
Basic Bessemer process, 173
Basic Bessemer slags, 144 *ff.*
Basic open-hearth process, 156
Basic open-hearth slags, 145
Bimolecular reaction, 247–248
Blast-furnace process, 152
Blast-furnace slags, 113 *ff.*
Blowholes, 188, 192
 subsurface, 186–187
Bomb test, 107
Boundary layer, 238, 240, 242, 244–245
 diffusion, 105–106, 238–239, 242
 laminar, 238
 slag, 106
 turbulent, 238
Bubble, formation of, 104
 growth of, 104
 life of, 107
 nucleation of, 105

Calorimeter, adiabatic dropping, 18 *ff.*
 $Ca_2Si_3O_9$ — CaF_2 , viscosity of, 85
Carbon, activity, in Fe—C, 3 *ff.*, 13, 38
 in steels, 221
 activity coefficient, in Fe—C, 11, 39, 42–43
 in Fe—C—Si, 44
 in liquid iron, 10
 deposition of, 7
 oxidation of, 106
 solubility in iron, 43
Carbon boil, 103, 105–107, 109–110, 130, 155
 kinetics of, 104
Carbon monoxide evolution, 107, 115, 129, 131–134, 247–248
 rate of, 132
Carbon-oxygen equilibrium, 37 *ff.*, 139, 141
 in iron, 40, 42 *ff.*
Carbon-oxygen product in iron, 40
Carbon-oxygen reaction, 185, 192
Castings, segregation in, 216 *ff.*
Cathodic process, 245–246
Channel hole, 185, 188
Chemical kinetics, 105
Chemical potential of nitrogen, 103
Chromium, distribution of, 96–98
 reduction of, 93 *ff.*
 kinetic process of, 95
Chromium carbide formation, 94

- Cobalt, density of, 33
 surface tension of, 27 *f.*
 Coefficient, spreading, 91
 Columnar zone, 185
 Concentration gradient, 238
 "Concentration quotient," 241
 Constant, deoxidation, 49
 parabolic rate, 216
 reaction-rate, 111–112, 114–115, 132, 167, 169–170, 240, 243–244, 247, 249
 Contraction, hindered, 217
 Convection, forced, 116, 238
 Copper, activity in Cu–Ag, 17
 equilibrium distribution in Fe–Ag, 15, 17
 Covalent bond, 103, 112
 Cupric oxide oxidizer, 52
- Decarburation, 140, 153
 Deficit semiconductor, 81
 Degassing of open-hearth bath, 109 *f.*
 Dendrites, 182–183, 188, 217
 growth of, 216
 Density, of cobalt, 33
 of iron, 32
 of nickel, 33
 Deoxidation, 157, 232
 by aluminum, 46 *f.*
 by Mn–Si, 154
 by silicon, 117 *f.*, 157
 diagram for Mn and Si, 156
 process, 117
 products, 120
 transients, 122
 Deoxidation constant, 49
 Deoxidizers, 30
 Dephosphorization, 136 *f.*, 142 *f.*, 174–176, 229
 Desiliconizing, 229
 Desulfurization, 113 *f.*, 136 *f.*, 152, 158, 165, 177, 228–229
 external, 153
 with lime, 153
 Diffusion, 102
 boundary layer, 105–106, 242, 244
 control, 246
 film, 115
 layer, 104, 112
 process, 108, 137
 thermal, 7
 Displacement reaction, 240–241, 243, 245, 250
 Distribution equilibrium, 15 *f.*, 222
 Al in Fe–Ag, 48
 Cu in Fe–Ag, 15, 17
 Mn in Fe–Ag, 16
 S in Fe–Ag, 16
 Distribution of chromium, slag-metal, 96–98
- Electrochemical cell, 244
 Electrochemical mechanism, 132
 Electrochemical process, 245–246, 248–249
 Electrochemical reaction, 131, 247
 Electrode potential, 132, 246
 cells, 79 *f.*
 Electrode reaction, 132
 Ellingham diagrams, 136
 Emulsions, 89 *f.*, 225
 metal, 91
- Enthalpy of silicon, 23–24
 Equilibrium, carbon monoxide, 139, 141
 carbon-oxygen, 37 *f.*
 in iron, 40, 42 *f.*
 local, 102, 105, 130, 241, 245
 of silicon and oxygen, 118
 oxygen gas with iron, 41
 slag-metal, 223
 thermal, 8
 Equilibrium distribution, 15 *f.*, 222
 Al in Fe–Ag, 48
 Cu in Fe–Ag, 15, 17
 Mn in Fe–Ag, 16
 S in Fe–Ag, 16
 Errors, experimental, 33
 Evolution of carbon monoxide, 107, 115, 129, 131–134, 247–248
 rate of, 132
 Exchange reactions, 239, 247
- Fick's law, 104–105
 Foaming, 90, 105, 232
 Foaming slags, 89–90
 Foams, 89 *f.*, 225
 Forced convection, 116
 Free energy of mixing in silicates, 72
 Freezing, columnar, 183
 selective, 182
 Freezing time, 201
 Fusion, heats of, 19
- Gas, analysis, 5, 51 *f.*
 in iron, 51
 evolution, 89, 188–190, 192, 244
 formation of, 186
 in solidification, 185
 purification of, 27
 utilization of, 162–163
 Gas-metal interface, 105
 Geller's theory, 109
 Glass, refractive indexes, 57
 viscosity of, 56
 Grain size, 210
 Graphite-alumina reaction, 46 *f.*
 Growth, 209
- Heat, high-temperature, 103
 metallurgical, 103
 requirement, 103
 Heat content of silicon, 18 *f.*
 Heats of fusion, 19
 of silicon, 24
 "High-temperature chemistry," 102
 High-temperature heat, 103
 Hot top, 184–185, 197
 Hydrogen, adsorption of, 207–208
 effect on mechanical properties, 204
 in steel, 203 *f.*
- Inclusions, 121
 Ingot, aluminum-killed, 184
 big-end-down, 193
 big-end-up, 193

- Ingot, hot-top, 213
 killed-steel, 184, 193
 mechanically capped, 189
 rimming, 189–190, 192
 semikilled-steel, 186, 188, 193
 solidification of steel, 181 *ff.*
 taper, 202
 Interface, gas-metal, 105
 slag-metal, 131
 Ionic bonds, 59
 Iron, density of, 32
 surface tension of, 27 *ff.*
 Iron-carbon eutectic, surface tension of, 34
 Iron ore reduction, 149, 151
 Iron oxide, activity, in $\text{CaO}-\text{FeO}-\text{SiO}_2$, 75
 in $\text{CaO}-\text{MgO}-\text{SiO}_2$, 60
 in slags, 177
 $\text{FeO}-\text{Al}_2\text{O}_3$ spinel, 80
 reduction of, 159 *ff.*
 Isotopes, radioactive, 247
- Jet mixing, 166–167
- Killed steel, 157, 182–183, 185
 Killed-steel ingot, 184, 193
 Kinetics, 109, 125, 223, 229, 237 *ff.*
 chemical, 105
 metallurgical, 101 *ff.*
 of carbon boil, 104
 of open-hearth reactions, 101, 103
 Kinetic studies, 233 *ff.*
 Kirkendall effect, 81
 Kish, 95
 Knudsen cell, 222, 224
- Lead oxide, activity coefficient in silicates, 75
 Lime desulfurization, 153
 Local cell, 250
 action, 131, 133
 Local equilibrium, 102, 105, 130, 241
- Manganese, deoxidation, 156
 equilibrium distribution in $\text{Fe}-\text{Ag}$, 16
 oxidation, 173
 residual, 174, 177
 Manganese oxide, activity in $\text{CaO}-\text{MnO}-\text{SiO}_2$, 75
 Manganese-silicon deoxidation, 156
 diagram for, 154
 Manganese sulfide, activity in slags, 178
 Melting point, of mullite, 78
 of silicon, 24
 Metal analysis, 6
 Metal emulsions, 91
 Metallurgical heat requirement, 103
 Metallurgical kinetics, 101 *ff.*
 Metal oxides, activity coefficients, 222
 Metal-slag reactions, 237
 Metals, liquid, sampling of, 17
 neutral solubility in slags, 61–62
 Mixing, 137
 by bottom blowing, 169–170
 by jet, 166–167
 by jet pouring, 169
 by pouring, 167–168, 170
- Mixing, by rabbling, 168, 170
 of slag and metal, 165 *ff.*
 Mixing experiments, 166
 Model study, 165
 Mold, big-end-down, 185
 big-end-up, 185
 Molecular reaction, 102
 Mullite, melting point of, 78
- Nernst's formula, 132, 247
 Nickel, density of, 33
 surface tension of, 27 *ff.*
 Nitrogen, activity in equilibrium, 103
 chemical potential of, 103
 removal of, 110–111
 Nucleating agents, 212
 Nucleation, 102, 133, 209
 in solidification, 211–214
 of bubbles, 105
 rate of, 209
- Open-hearth bath, degassing of, 109 *ff.*
 Open-hearth furnace, 165
 Open-hearth kinetics, 101, 103
 Open-hearth process, 229
 Overpotential, 247
 Oxidation, of carbon, 106
 of manganese, 173
 of silicon, 119, 154
 Oxides, activities in ternary melts, 72
 Oxide slags, 55 *ff.*
 Oxidizer, cupric oxide, 52
 Oxygen, activity coefficient, in iron, 39, 45, 221
 in $\text{Fe}-\text{C}-\text{Si}$, 44
 solubility of, 176, 178
 in iron, 143
 in liquid iron, 38
 Oxygen gas in equilibrium with iron, 41
- Parabolic rate constant, 216
 Parabolic rate law, 194, 200, 237
 Perrin process, 165, 169
 Phase-boundary reaction, 130, 237, 240, 242, 245, 247, 250
 Phase diagram, $\text{CaO}-\text{CaF}_2-\text{SiO}_2$, 85
 $\text{CaO}-\text{FeO}-\text{P}_2\text{O}_5$, 142
 CaSiO_3 —“ FeSiO_3 ,” 68
 Ca_2SiO_4 — Fe_2SiO_4 , 71
 $\text{Fe}-\text{C}-\text{O}$, 150, 159
 $\text{Fe}-\text{H}-\text{O}$, 150–151, 159
 $\text{FeO}-\text{Al}_2\text{O}_3$, 80
 MgSiO_3 —“ FeSiO_3 ,” 69
 Mg_2SiO_4 — Fe_2SiO_4 , 69
 $\text{SiO}_2-\text{Al}_2\text{O}_3$, 77 *ff.*
 Pig iron, 113 *ff.*
 Plant practice, 226 *ff.*
 Polarization, 247, 249
 Pouring mixing, 167, 170
 Process metallurgy, 149 *ff.*
 Product, carbon-oxygen in iron, 40
 Properties of silicates, 59
- Radioactive isotope, 244
 Radioactive tracer, 239–240
 Rate constant, 104

- Rate-controlled processes, 130
 Rate-controlling step, 104–105, 131
 Rate law, first-order, 240, 242–244
 Reaction, first-order, 237
 second-order, 237
 transport-controlled, 237
 Reaction kinetics, 125
 Reaction rate, 101, 123 *f.*, 136
 Reaction-rate constant, 111–112, 114–115, 132, 167, 169–170, 240, 243–244, 247, 249
 Reduction, of chromium, 93 *f.*
 kinetic process of, 95
 of iron ore, 149, 151
 of iron oxide, 159 *f.*
 of silica, 97, 113, 116, 155
 of silicon, 130, 158, 248
 Refractive indexes of glass, 57
 Removal of nitrogen, 110–111
 Rimmed zone, 192
 Rimming steel, 157, 181, 189
 ingot, 189–192
 Rotating crucible furnace, 94–95
- Sample preparation, 22
 Sampling, 117
 of liquid metals, 17
 Segregate, 185, 188, 192–193
 V, 185, 192–193
 Segregate streak, 193
 Segregation, 119, 182, 190, 217
 in steel casting, 216 *f.*
 positive, 216
 Segregation coefficient, 216
 Segregation rate, 119
 Self-diffusion coefficient, 223
 Semiconductor, deficit, 81
 types, 81
 Semikilled steel, 181
 capped, 187–188
 ingots, 186, 188, 192–193
 Shrinkage, 185
 Silica, activity, in CaO—SiO₂, 63 *f.*
 in CaO—Al₂O₃—SiO₂, 65 *f.*
 reduction of, 97, 113, 116, 155, 248
 vapor pressure of, 64
 Silicates, activities, in Ca₂SiO₄—Fe₂SiO₄, 71
 in metal-oxide, 70
 in Mg₂SiO₄—Fe₂SiO₄, 69
 of CaSiO₃ in liquid mixtures, 70
 of FeO in CaO—FeO—SiO₂, 73
 of MnO in CaO—MnO—SiO₂, 73
 free energy of mixing in, 72
 glassy, 121
 groupings of, 55–56, 58
 standard free energy of formation of, 59
 structure of, 55, 75
 ternary, 59
 activities in, 68 *f.*
 tetrahedron, 55
 thermodynamic properties of, 59
 viscosity of, 57
 Silicon, activity coefficient in Fe—C—Si, 43
 deoxidation of, 117 *f.*, 156–157
 enthalpy of, 23–24
 heat content of, 18 *f.*
 heat of fusion of, 24
- Silicon, melting point of, 24
 oxidation of, 119, 154
 reduction of, 130, 158
 Silicon monoxide, 67
 Silicon-oxygen equilibrium, 118
 Similitude theory, 171–172
 Skin, chilled, 189–190
 outer, 189
 Slags, basic Bessemer, 144
 basic-open hearth, 145
 blast-furnace, 113 *f.*
 boundary layer, 106
 foaming, 89–90
 lime-saturated, 143–145
 oxide, 55 *f.*
 oxidizing power of, 155
 run-off, 231
 structure of, 223
 water in, 61
 Slag-metal, equilibria, 223
 interface, 131, 245–246
 mixing, 165 *f.*
 reactions, 136, 247
 Solidification, 185, 194 *f.*, 200 *f.*, 229
 nucleation in, 211–214
 of steel ingots, 181 *f.*, 209 *f.*
 shrinkage in, 217
 transverse, 200–201
 vertical, 200–201
 Solubility, of carbon in iron, 43
 of neutral metals in slags, 61–62
 of oxygen, 178
 in iron, 38, 143, 176
 Soret effect, 233
 Specific heat, true, 18
 Spinel, FeO—Al₂O₃, 80
 Standard free energy of formation of silicates, 59
 Steel, capped, 190
 semikilled, 187–188
 hydrogen content of, 205–206
 killed, 182–183, 185
 quality of, 227
 rimming, 181, 189, 191
 semikilled, 181, 192
 stainless, 210–211
 Steel ingots, solidification of, 209 *f.*
 Steelworks intermediaries, 226, 229
 Stirring rate, 115
 Stokes' law, 106
 Structure of silicates, 55
 Subsurface blowholes, 186–187
 Subsurface zone, 186, 188
 Sulfide capacity, 60
 Sulfur, distribution ratio of, 152
 equilibrium distribution in Fe—Ag, 16
 print, 191
 ratio, 98
 transfer, 92, 113, 116, 125 *f.*
 -transfer reaction, 131
 transport, 130
 Surface activity, 90
 Surface energy, 102
 Surface tension, of cobalt, 27 *f.*
 of iron, 33–34
 of iron-carbon eutectic, 34
 of liquid iron, 27 *f.*
 of nickel, 27 *f.*

- Tapping, 157
Teeming, 181
Temperature gradient, 182
Temperature measurement, 5, 21, 46, 95
Ternary silicates, 59
Thermal diffusion, 7
Thermal equilibrium, 8
Thermal gradients, 183, 185
Transfer, of sulfur, 113, 116, 125 *ff.*
 control, 130, 242–243, 245
 -controlled reaction, 241, 247
 process of, 126–129, 237, 241, 247, 250
Transfer, rate of, 130
True specific heat, 18
Two-phase film theory, 239
Vacuum-fusion analysis, 52
Vapor pressure of silica, 64
Viscosity, of $\text{Ca}_3\text{Si}_3\text{O}_8$ — CaF_2 , 85
 of glasses, 56
 of silicates, 57
Wiberg-Söderfors process, 149