Index

absorber, 33
  multistage, cascade, 272–277
absorbers, 32–35
dimensional analysis, 457–459
exercises, 53–54, 158, 166, 329–350
mass transfer in, 528–531
multistage, 272–277
  single stage, 267–272
absorption, 267, 562
acetanilide
  synthesis of, 72
acetone, thermodynamic properties, 86, 200, 498
acetonitrile–methylpyridine mixtures, 307, 363
acetonitrile–nitromethane mixtures, 328
acetonitrile–water mixtures, 362, 409
acetylene
  reaction with hydrogen chloride, 69, 174
  thermodynamic properties, 86
Addams, Morticia, 435
adsorbents, 300
adsorbers, 34, 300, 343
adsorption, 170, 300, 342, 524, 562
AIChE, 3
air
  cooling by water evaporation, 191
  thermodynamic properties, 125
air conditioning, 132, 161, 376
air drying, 160
air pollution, 4
Alaskan pipeline, 448
alkylation, 67, 161
aluminum
  impurity in silicon, 26
  reaction with hydrogen chloride, 27
  reaction with propanol, 22
  thermodynamic properties, 59, 86
ammonia
  adiabatic reactor for, 143
  as a refrigerant, 128
  as fuel, 195
  chemical equilibrium, 140
  from manure, 83
  mixtures with water, 266, 325–326
reaction to aniline, 72
  reaction to hydrazine, 70
  reaction to hydrogen cyanide, 197
  reaction to nitric acid, 61
  reaction to urea, 197
  synthesis of, 8–16
  thermodynamic properties, 87, 200
  aniline–heptane–methylcyclohexane mixtures, 322, 396
  aniline–hexane–methylcyclopentane mixtures, 318, 395
  aniline
    synthesis of, 72
  antibiotics, 5, 72
  artificial kidney, 157, 483
  astronauts, protection of, 81
  atmospheric chemistry, 512–517
  automobile catalytic converter, 523
  azeotrope, 562
bacteria
  for ethanol to acetic acid, 541
  in drinking water, 82
  in sewage treatment, 508–512
Baekeland, Leo, 423
Bakelite, 4
Basaran, Osman, 475
base dimensions, 426
base units, 426
batch process, 9, 517
batch reactor, 512
battleship waves, 481
beeswax, 192
benzene
  absorption from air, 158, 267
  condensation from air, 294
  isomerization of allyl to propenyl, 99
  mixtures with toluene, 253
  pressure–volume phase diagram, 291
reaction to acetanilide, 73
reaction to aniline, 72
reaction to phenol, 55
Index

benzene (cont.)
reaction to styrene, 67, 161
thermodynamic properties, 86
biotechnology, 6, 562
body mass
relation to bone diameter, 495–496
relation to wing area, 463
Bond number, 474
bottoms product, distillation, 283
brine, 91
bubble point
mixture, 253
pure substance, 292
bubbler, 267
bubbles, rising in liquids, 473
Buckingham Pi theorem, 433
buoyancy, 437
butane, dehydrogenation, 517
butanol
as an absorber fluid, 528
thermodynamic properties, 498
butanol–water mixtures, 315
butene, dehydrogenation, 517
calcium carbonate
in the Solvay process, 60
thermodynamic properties, 86
calcium chloride
in the Solvay process, 60
thermodynamic properties, 86
Capillary number, 475
capital costs, 147
carbon cycle for Earth, 165
carbon dioxide
in Earth’s carbon cycle, 165
in fuel cell cycle, 30
in hydrogen fuel cycle, 39
in synthesis of urea, 197
supercritical fluid for extractions, 319
thermodynamic properties, 86
transfer from lungs to air, 331
carbon monoxide
from carbon dioxide, 198
in automobile catalytic converters, 523
in syngas, 135
oxidation of, 523
reaction with nitric oxide, 524
thermodynamic properties, 86
carbon tetrachloride
synthesis of, 54
thermodynamic properties, 86
carbonates, in fuel cells, 30
catalytic cracking, 4
charcoal, as benzene adsorbent, 342
chemical engineering
achievements, 3
definition, 2
opportunities, 5
chemical kinetics
definition, 563
in reactor design, 136, 527
chlorine
in synthesis of acetaldehyde, 72
reaction to carbon tetrachloride, 54
reaction to hydrazine, 70
reaction with ethylene, 68
thermodynamic properties, 87
chlorobenzene
in acetaldehyde synthesis, 72
mixtures with hexane, 313
mixtures with tetrachloromethane, 306
chlorofluorocarbons, 128, 190
chlorosilanes
in silicon processing, 28
removal from air, 84
citric acid, synthesis of, 500
Clausius–Clapeyron equation, 468
closed system, 91, 563
clothes, process to wash, 58
coal
conversion to diesel fuel, 48
conversion to methanol, 173
in hydrogen synthesis, 35
in silicon synthesis, 26
sulfur emissions, 202
underground gasification, 35
cocurrent flow, 126
coffee
mug design, 192
process for instant, 168
combiner, 10
compressibility, gas, 461
compressor, 18
condensation, 289
for separating benzene from air, 294
descenser, in distillation columns, 282
conservation
of assets, 145, 148
of energy, 118–119, 126
of mass, 91, 95, 104
conservation law, 155, 563
constitutive equation, 155
continuous process, 9
continuous reactor, 523
continuous, stirred-tank reactor (CSTR), 524
conversion factors, 549
cooling
by evaporation, 191
lake source, 190
core variable, 433
guidelines for selecting, 438
rules for a valid set of, 449
countercurrent flow, 126
in multistage separators, 278
critical point, 293
in dimensional analysis of gases, 460
Index

crude oil, in Alaskan pipeline, 449
CSTR, 524
cyclohexane
    partial oxidation to adipic acid, 74
    thermodynamic properties, 86, 200
Dalton’s law, 140
dehydorgenation
    of butane to butene, 517
    of ethylbenzene to styrene, 67
depreciation, 148
derived units, 427
desalination of seawater, 90, 95–99
    analysis of energy flow, 118
    by freezing, 95
design tools
    for transient-state processes, 499
    from dimensional analysis, 447
    from graphical analysis, 301
    from mathematical modeling, 156
desulfurization of natural gas, 32
dew point, 563
    of a mixture, 258
    on enthalpy–composition diagrams, 264
    pure substance, 292
dichloroethane
    by-product in vinyl chloride synthesis, 174
    condensation from air, 386–387
    mixtures with propanol, 408
    thermodynamic properties, 86
diesel fuel, 48
differential equation, 499
    boundary conditions for, 503
    initial conditions for, 503
    numerical integration of, 521, 542
dimensional analysis
    advantages of, 466
    design tools from, 447
    general method for, 436
dimensional consistency, 427
dimensionless groups, 547
    method for deriving, 448
    selecting core variables, 438, 449
    dimensions, base, 426
dinosaurs, 425
    bone diameters and mass, 497
    speed of, 436
dioxin, 81
distillate, 564
distillate product, distillation, 283
distillation
    by flashing, 254
    multistage, 277
    distillation columns, 283–289
    dimensional analysis of, 457
    exercises, 350–374
    schematic with sieve plates, 458
dough, recipe for, 58
dust in air, terminal velocity, 444
dynamic similarity, 448, 451, 467, 564
earthware, cooling by evaporation, 191
Einstein, Albert, on problem solving, 23
Einstein’s equation for the molar heat capacity of a solid, 468
Einstein’s mass–energy equation, 468
elasticity number, 486
electric arc furnace, 26
elevators, delays of, 83
energy flow rates, rules of thumb, 122
engineering, description of, 2
English units, 427
enthalpy–composition diagrams, 262–267
    exercises, 324–328
equilibrium line
    for absorbers and strippers, 269
    for distillation columns, 280
ethanol
    in spirit vinegar, 541
    measured by a breathalyzer, 332
    mixtures with methanol, 158
    mixtures with water, 364, 408
    mixtures with water and methanol, 316
    reaction to acetic acid, 541
    synthesis from grain, 182
ethylene
    chlorination of, 68
    pressure–enthalpy diagram, 389
    reaction to styrene, 67, 161
    thermodynamic properties, 86
ethylene oxide
    synthesis from ethylene, 49
    thermodynamic properties, 86
Euler method of numerical integration, 543
Euler number, 450
explosion, dimensional analysis of, 470
Fanning friction factor, 453
feed tray, distillation, 283
fermentor, 500
fertilizer, 8
fibers, optical, 241
Fick’s second law of diffusion, 473
flash drum, 254, 259
mass balance on, 158
multistage cascading, 277
flash drums
    exercises, 306–312
flooding in vapor–liquid columns, 457
flow
    from a draining tank, 504
    in a rough pipe, 452
    in a smooth pipe, 447
    over a spillway, 534
    through a notch, 536
    through an orifice plate, 476

© in this web service Cambridge University Press

www.cambridge.org

Cambridge University Press
978-1-108-42147-8 — Chemical Engineering Design and Analysis
2nd Edition
Index
More Information
Index

flowsheets, 9
conventions, 17, 23
general practices, 57
tips for analyzing, 40
fluid flow in a pipe, 447
heat transfer, 454–457
roughness, 453
fraud, scientific, 495
friction factor
Fanning, 453
for a sphere in a fluid, 554
Froude number
for a sphere moving through a fluid, 440
in walking, 434
relation to the Galileo number, 441
fuel cells, 29
Galileo, 431
Galileo number for a sphere moving through a fluid, 441
galloping
and bone strength, 497
Froude number, 436
geometric scaling, 423
glucose, oxidation of, 172
graph paper, 554–558
groundwater pollution, 342
Hagen–Poiseuille law, 469
half-life, 515
heat exchanger, 15, 565
energy balance on, 123–128
in series with adiabatic reactors, 136
heat pump, 128
coefficient of performance, 151
heat transfer
by forced convection, 471
fluid in a pipe, 455
in fan-assisted ovens, 471
Péclet number, 472, 484
Prandtl number, Pr, 472
solid sphere in a fluid, 478
temperature control in a reactor, 531–534
heat-transfer coefficient, 456
in a chemical reactor, 531
vertical tube, 469
Henry’s law, 155
heptane
mixtures with aniline and methycyclohexane, 322
process to purify, 19–23
process to purify, recycle, 115
hexane
mixtures with aniline and methycyclopentane, 318
mixtures with chlorobenzene, 313
mixtures with pentane and heptane, 212
home heating, energy analysis of, 192
humidity, 161, 376, 378
hydrazine
synthesis of, 70
thermodynamic properties, 87
hydrochlorination
of acetylene, 69
of ethylene, 68
hydrogen
storage as a metal hydride, 44–47
storage options, 42–44
synthesis from coal, 35–36
synthesis from methane, 29–32
synthesis from natural gas, 32–35
synthesis from water, 36–40
thermodynamic properties, 87
hydrogen chloride
reaction to chlorine, 69
reaction with acetylene, 69, 174
reaction with silicon, 27
thermodynamic properties, 87
hydrogen cyanide
in processing steel, 61
synthesis by BMS process, 197
synthesis from ammonia and methane, 53
synthesis of, 197
thermodynamic properties, 87
hydrogen peroxide
in synthesis of hydrazine, 70
synthesis of, 71
thermodynamic properties, 87
hydrogen sulfide
absorption from hydrogen, 164
from manure digestion, 82
in natural gas, 32
thermodynamic properties, 87
ideal gas law, 155, 243, 423, 459–463, 469, 561
ideal solutions, 155, 295
immiscible liquids, phase diagrams, 318, 321, 474
instant coffee, 168
integrals, table of, 560
iron
impurity in silicon, 26
steel processing, 60
thermodynamic properties, 27
iron oxide
catalyst, 32
in cycle to convert carbon dioxide to methane, 73
in steel processing, 61
just-in-time strategy for repairs, 214
Keynes, John Maynard, 145
kidney, artificial, 5, 157, 470
lake-source cooling, 190
laws, universal vs. constrained, 155
lead, contamination in water, 82
least squares, method of, 493

© in this web service Cambridge University Press  www.cambridge.org
Index

Leibniz, Gottfried, on conservation of energy, 118
Levenspiel, Octave, 463
lever rule, 244–247
applied to tie lines, 259
derivation of, 159
for energy balances, 247–253
for enthalpy–composition diagrams, 265
Lewis number, 473
limestone
as sulfate scrubber, 202
in Solvay process, 60
linear regression, 493
lions, strategy for, 80
log–log graph paper, 555
lungs, modeled as an absorber, 330
magnesium hydroxide, as sulfate scrubber, 62
magnesium sulfate
mixtures with water, phase diagram, 394
make-up stream, 34
map, thermodynamic, 255
mass transfer
across liquid–liquid interfaces, 528
across vapor–liquid interfaces, 267, 457, 481
Fick’s law, 473, 529
for concentration gradients, 466
Péclet number, 484
McCabe–Thiele method, 283–289
membrane separation of air, 158
meteor crater, dimensional analysis of, 482
methane
in natural gas, 32
in synthesis of ammonia, 12
in synthesis of hydrogen, 29–32, 64
in synthesis of hydrogen cyanide, 197
in synthesis of nitric acid, 62
oxidation, adiabatic temperature rise, 134
oxidation, heat of reaction, 134
partial oxidation to methanol, 65
synthesis from carbon dioxide and water, 73
synthesis from syngas, 35, 135–139
thermodynamic properties, 86
methane burner, 13
methanol
from partial oxidation of methane, 65
mixtures with ethanol, 158
mixtures with water, 309, 358
mixtures with water and ethanol, 316
oxidation, adiabatic temperature rise, 196
synthesis from coal, 173
synthesis from methane, 66
synthesis from syngas, 36, 136, 140, 198
thermodynamic properties, 86
methylcyclohexane
mixtures with aniline and heptane, 322, 396
methyleclopentane
mixtures with aniline and hexane, 318, 395
miscible liquids, ternary diagrams, 399
mixer, 17
mixing lines, 246–247, 272
mixing lines, 246–247, 272
on enthalpy–composition diagrams, 266
on ternary diagrams, 316
monoethanolamine, for hydrogen sulfide absorption, 34
myricyl palmitate
in coffee mug design, 192
thermodynamic properties, 200
natural gas
in synthesis of hydrogen, 32
removal of hydrogen sulfide, 32
Newton, Isaac, on mathematical modeling, 155
Newton, unit of force, 427, 548
Newton’s
law of gravitation, 468
law of resistance, 444
law of viscosity, 437
second law, 89, 155
nitric acid
mixtures with water, 350
synthesis of, 61
thermodynamic properties, 87
nitric oxide
reaction with carbon monoxide, 524
thermodynamic properties, 87
nitrogen
heat capacity, 125
in synthesis of ammonia, 8–16
thermodynamic properties, 87
nitrogen dioxide
pollutant in air, 62
thermodynamic properties, 87
nitrous oxides, pollutants in air, 513
numerical integration, 542
Nusselt number, 478
Ohnesorge number, 475
operating costs, 146
depreciation, 148
vs. capital costs, 147, 149, 151
operating lines
for absorbers, 267–272
for multistage cascade absorbers, 272–277
for multistage cascade flash drums, 283–289
orange juice, concentration of, 159
orifice
diameter, in a bubble plate, 472
equation, 505
in bottom of draining tank, 504
plate in pipe, Reynolds number, 477
osmotic separation, 345
oxychlorination of ethylene, 69
oxygen
absorption in lungs, 330
atmospheric reactions, 512
in methane burner, 14
in synthesis of adipic acid, 74
Index

oxygen (cont.)
  partial reduction to hydrogen peroxide, 71
  thermodynamic properties, 88
ozone, role in the stratosphere, 512
paintbrush, options for cleaning, 156
partial pressure
  and Dalton’s law, 140
  and Henry’s law, 155
  relation to thermodynamic activity, 140
Pauling, Linus, on good ideas, 89
Péclet number, 466, 472, 481, 485
pendulum, dimensional analysis of, 428
PFR, 522, 566
phase diagrams
  enthalpy–composition, 262–267
  pressure–composition, 253–262
  pure substances, 289–293
  temperature–composition, 253–262
ternary systems, 318
phenol, thermodynamic properties, 303
photolithography, 50
physical constants, 550
Pi group, 432, 566
Pi theorem, 433
pinch point, 276, 287
pipes, cost of insulation, 203
pizza dough, recipe for, 58
plate tectonics, dimensional analysis of, 482
plug flow reactor (PFR), 522, 566
poise, base dimensions of, 437
popcorn, separation from corn kernels, 479
potassium–sodium mixtures, 392
Prandtl number, 456, 472, 478–479, 483
pressure–composition vapor + liquid phase diagrams, 253–262
pressure-swing processes, 288, 409
problem definition, 38, 47, 50
problem solving
defining the real problem, 19
McMaster heuristic, 23
successive, for design evolution, 8
process control, 1, 7, 511
profit, 146, 149
vs. return on investment, 150, 152
propane, phase diagram, 382
propanol
mixtures with dichloroethane, 409
mixtures with dimethylamine, 312
removal from heptane, 19–23
thermodynamic properties, 20
pump, 18
purge stream, 14, 22
pyrolysis reactions, 52, 68
rain
  and runoff pollution, 85, 342
  prediction of, 378
rate constant, in chemical reactions, 515, 533
reactor, 8
and process viability, 17
batch, 513, 517
continuous, stirred-tank (CSTR), 524
flowsheet guidelines for, 19
plug flow, 523
tips for flowsheet analysis, 40
rectifying section, distillation, 283, 567
recycle
economic analysis of, 152
mass balances on, 95–99, 110–114
with purge, 14, 34, 104
with separation, 21, 104
reduced parameters, 434, 439, 459, 567
refrigeration cycle, 130
repairs, just-in-time strategy, 214
residence time, 510–511, 523, 525, 530
return on investment (ROI), 149, 567
vs. profit, 150, 152
ROI, see return on investment
sand
  as a projectile, 464
  in silicon synthesis, 25
scale-up, 4, 423
scrubbers, 202
seawater, composition, 90
semilog graph paper, 555
separator
  and phase lines for analysis, 41
  and process economics, 17
flowsheet conventions, 18
liquid–gas, 10
solid–liquid, 20
sewage treatment, 508–512
Sherwood plot, 244
SI units, 427
Siemens process, 28
sieve plates, 458
significant figures, 551–553
silicon
  process for electronic-grade, 25–29
  thermodynamic properties, 27
silicon wafers
  process to coat for lithography, 50, 85, 241
snow
  mass of, 241
  prediction of, 378
soda ash, Solvay process, 60
sodium carbonate
  in Solvay process, 60
sodium sulfate, mixtures with water, phase diagram, 393
sodium–potassium mixtures, 392
solid–liquid separators, 20, 215
Solvay process for soda ash, 60
Index

soybeans, oil extraction from, 166
sphere, terminal velocity of, 437
splitter, 14
spreadsheets
for data analysis, 487–493
for mass balances, 178–186
for numerical integration, 542–545
stages, equilibrium
in absorbers, 275
in distillation, 283
Stanton number, 456, 478
steady state
definition, 92, 499
multiple states, 523
Stokes’s law, 155, 444, 568
stratosphere, reactions in, 512
stream, process, 9
stripper, 568
model for lungs, 331–332
stripping section, distillation, 283
styrene
synthesis of, 67
thermodynamic properties, 87, 200
sulfur
oxidation of, 51
thermodynamic properties, 88
sulfur dioxide
pollutant in air, 62
thermodynamic properties, 88
sulfuric acid
in a bubbler to dry air, 166
in methanol synthesis, 67
in steel processing, 60
mixtures with water, 327
thermodynamic properties, 87
sulfur–iodine cycle for hydrogen synthesis, 38
surge tank, 500
syngas, 135
from coal, 35
from methane and water, 31, 65
in fuel cells, 29
reaction to methanol, 198
synthesis gas, see syngas
system
borders for mass balances, 92, 96, 114
open vs. closed, 91
steady-state, 92
transient-state, 499

tank
draining, 471, 504
sewage, 508
surge, 500
temperature–composition vapor + liquid phase
diagrams, 253–262
ternary diagrams, 324–328
tetrachloroethylene, synthesis of, 52
tetrachloromethane
mixtures with chlorobenzene, 306
tie line, 249
toluene
mixtures with benzene, 253
trajectory line
for reactors on temperature-conversion maps, 145
for single-stage absorber, 272
trips, see stages
triple point, 293, 460
trucking, 435
uncertainty, in linear regression, 493
unit operations, 2, 17
units, base and derived, 426
units, process, 17
urea, synthesis of, 197
valve, flowsheet symbol, 18
vapor–liquid equilibrium diagram, 280
vapor–liquid phase diagram, 257
vinyl chloride
synthesis of, 68
thermodynamic properties, 86
viscosity, dimensions of, 437
viscous coiling, 470
walking
analysis of, 431–436
universal correlation for, 434
water
and humidity in air, 378
condensation from air, 387
cooling by evaporation, 191
energy–phase line, 250
extraction by osmotic separation, 345
mixtures with ammonia, 325
mixtures with butanol, 315
mixtures with ethanol, 364
mixtures with methanol, 309
mixtures with methanol and ethanol, 316
mixtures with nitric acid, 350
mixtures with sulfuric acid, 327
water cycle for Earth, 165
water–gas shift reaction, 32
waves
blast, from explosions, 470
bow, 434, 481
dimensional analysis of, 470
weather, prediction of rain and snow, 378
Weber number, 475
Wellington, Arthur Mellen, and engineering, 33
zeolites, 170
zinc oxide, catalyst, 32