536.7 WEB 2nd ed.

Absolute entropy, 405
  prediction of, 409
  table of values, for compounds, 493–495
    for elements, 408
Activity, 324
  change, with pressure, 331
    with temperature, 331
  in chemical reactions, 376
  in solutions, 350
  standard states for, 351
Activity coefficients, 347
  and Gibbs-Duhem equation, 458, 459
  and Margules equation, 460
  and Porter equation, 348, 459
  and Scatchard equation, 461
  and van Laar equation, 461
  practical, 353
  rational, 353
  significance of, 353
Adiabatic changes, 3, 54
Aerothermopressor, 276
Amagat's rule, 139, 442, 454
  density, 54
Analysis, air standard, 261
Anemometer, 246
  hot wire, 245
Approximation formulas, 55
Arbeit function, 175
Available energy, 181
Availability, 181
  closed system, 185

Bartlett's rule, 137
Beattie-Bridgeman equation, 55
  for mixtures, 137
Bernoulli's equation, 204
Binary mixtures, 335
  of CO_2 and SO_2, 335
Boltzmann, 88
Boltzmann cell, 144
Boundaries of a thermodynamic system, 2
Boyle's law, 107
British thermal unit, 7
Bubble point, 335

Cailletet and Mathias, 45, 466
Calorimeter, bomb, 84
  flow, 84
  mixing, 84
  Peabody, 72
Calorimetry, 84
Carbon dioxide, *Pvt* relations, table, 53
  pressure enthalpy diagram, 48
Carnot, Sadi, 143
Carnot cycle, 149
Cathode, 481
Cells, concentration, without transport, 484
    with transport, 484
  liquid junctions in, 482
  reversibility in, 485
  types of, 483
Centipoise, 207
Cetane number, 293
Changes, macroscopic, 33
  microscopic, 33
  molecular, 33
  possible, 36
Characterization factor, Watson and Nelson, 137
Charles's law, 137

Chemical reaction, completion of, 383
effect of pressure on, 380
free-energy change of, 364
heterogeneous equilibrium, 376
homogeneous equilibrium, 360
in solution, 384
simultaneous reactions, 385
standard free-energy change of, 367
Clapeyron equation, 153
Clausius, 153
inequality of, 160
Clearance, 79, 118
Components, 38
Compressibility factor, chart, for gases, 132
for liquids, 136
for gases, 131
for liquids, 134
Compression ratio, 118, 268
Compressor, 118
clearance, 118
compression ratio, 118
free piston, 273
intercoolers, 118
staging, 118
work expressions, 76
Conservation of energy, 21
Conservation of mass, law of, 200
Continuity equation, 200
Conversion factors, 492
Cox chart, 57, 58
Critical constants for pure materials, prediction of, 60
table of values, 129
Critical flow pressure, nozzle, 232
Critical mixing temperature, 466
Critical phenomena, 336
first critical point, 338
second critical point, 338
true critical point, 338
Critical point, 43
phenomena, 336
pressure, 43, 61
table of values, 129
temperature, 43, 61
volume, 60
Cycle, air, 261
Carnot, 149
Diesel, 266
air-standard analysis, 268
Cycle, Diesel, efficiency, 268
semi-, 266
efficiencies, 277
Ericsson, 261
internal combustion, 263
irreversible, 147
isothermal, 147
Joule, 263
mercury-water, 259
multiple fluid, 259
Otto, efficiency, 268
injection, 267
Rankine, 255
reheating, 260
reversible, 147
Cylinder, double acting, 282
admission, 283
compression, 283
cutoff, 282
release, 283

Dalton's law, 117, 136
Dead state, 185
Dew point, 335
Diagrams, 42
Dimensions, 24, 28
Distance, 8
Divariant systems, 49
Drag, 199
Duhem, 340, 456
Dühring rule, 57, 59
Dulong and Petit, 88
Dyne, 24

Efficiency, Carnot cycle, 149
Diesel cycle, 268
of engine cycles, 277
of heat engines, 149
Otto cycle, 268
Rankine cycle, 256
thermodynamic, 175
volumetric, 269
Einstein, 404
Ejector, 247
Electrochemical effects, 480
thermodynamics of, 486
Electrodes, calomel, 486
hydrogen, 486
potentials, table of, 487
reproducibility in, 485

Electrodes, standard, 485
Electrometric determination of *p*H; 488
Electromotive force, processes responsible for, 482
  series, 486
  sign of, 482
Energy, 1
  conservation of, 200
  internal, 22
  intrinsic, 22
  kinetic, 2, 22, 27
  potential, 22, 26
  surface, 22
  total, 19, 21
  types of, 22
Energy balance, *see* First Law
Engines, analysis, 286
  Brayton, 263
  Carnot, 149
  compound, 285
  generalised efficiency of, 149
  governing, 284
  heat, 144
  hot air, 261
  isothermal, 146
  Lenoir, 263
  multiple expansion, 258
  nonisothermal, 148
  Philips air, 262
  steam, 281, 286
  two-cycle, 266
  uniflow, 285
  work expressions, 76, 79
Enthalpy, 28
  change with pressure, 431
    graphical presentation, 432
  generalized changes for gases, 433
Enthalpy-concentration charts for ammonia–water, 314
Enthalpy of chemical reaction, 99
  effect of pressure at constant temperature, 102
  effect of temperature on, 99
  standard enthalpy changes, 102, 493
Enthalpy of vaporization, 61, 64, 154
Entropy, 159
  absolute, 405
  an intensive variable, 165
  a point function, 163
  change on mixing, 448
Entropy, generalised relations for, 426, 430
  in irreversible changes, 166
  in isentropic processes, 165
  isothermal change in, 423, 426
  isothermal paths, graphical presentation, 428, 430
  of surroundings, 161
  statistical interpretation of, 168
  units of, 160
Equations of state, algebraic, 55
  diagrammatic, 42
  reduced, 129, 131
  tabular, 50
Equilibrium, 32, 34
  between liquid layers, 467
  box, 363
  chemical reaction, heterogeneous, 360
    homogeneous, 360
  constant, 365
  criteria of, 35, 169, 187, 188, 354, 371
  gaseous reactions, 360
  in gravitational field, 191
  metastable, 37
  neutral, 37
  stable, 37
  types of, 36
  unstable, 37
  vapor–liquid, 454
Equilibrium constant, and reversibility, 37
  effect of pressure on, 366, 380, 381
  effect of temperature on, 395, 399, 400
  gaseous reactions, 360
  heterogeneous reactions, 376
  in terms of activities, 377
  prediction of, chemical, 407
  values for selected reactions, 403
Ethane, properties of, 51
Euler's theorem, 422
Expansion, free, 232
  Joule-Thomson, 109
Expansion ratio, 268
Extensive properties, 39

Feed-water heating, regenerative, 258
First law, 18
  closed systems, 68
  flow equation, multiple streams, 75

First law, flow equation, one stream, 71
open systems, 68, 200
Flame temperature, theoretical, 102
Flow of fluids, general flow systems, 221
laminar, 197
measurement of, 238
patterns, 196
turbulent, 197
velocity profiles, 198
Fluids, flow of, 196
viscosity of, 207
Force, 8
viscous, 199
Force balance, 201, 202
Free energy, 178
change for chemical reactions, 369
change upon mixing, 446
effect of pressure and temperature, 328
for nonisothermal changes, 327
interpretation of, 328
standard change of, 366
Freon, 307
Friction, 11
contraction loss, 228
expansion loss, 229
fluid in pipes, 206
in ducts of changing cross section, 228
pipe fittings, 214
Friction factor, 207
chart, for flow in pipes, 213
Froude number, 211
Fuel cells, 254, 269
Fugacity, 318
change with pressure, 329
change with temperature, 330
from compressibility charts, 320
gas mixtures, 322
liquids, 323
relations for gases, graphs, 321, 322
solids, 323
Function, point, 21

Gas, diatomic, 90
monatomic, 90
triatomic, 90
Gas compressor, 118
bore, 118
Gas compressor, compression ratio of, 118
free air, 118
indicator diagram for, 119
intercooler for, 118
staging in, 118
stroke, 118
Gas constant, 107
Gas laws, *see* Perfect gas
Gas thermometer, 5
Generalized relations between state properties, 435
Gibbs, Willard, 35, 40, 169, 388, 455, 456
Gibbs-Duhem equation, 456, 457
Gibbs-Helmholz equation, 398
Gilliland's method for mixtures, 137

Heat, 7, 152
latent, 47
measurement of, 7
mechanical equivalent of, 19
of combustion, 95
of formation, 95
of mixing, 445
of solution, 346
of vaporization, 61
sensible, 47
Heat balance, 103
Heat capacity, at constant pressure, 85
at constant volume, 86
at low temperature, 404
atomic, versus temperature, 89
Boltzmann, 88
effect of pressure on, 433
Kopp's law, 88
of aqueous solutions, 90
of gases, 90, 92, 93, 493
effect of temperature on, 92
of liquids, 90
of solids, 90, 91
effect of temperature on, 91
relations between c_p and c_v, 87, 110, 111
Heat engines, 144
Heat exchanger, 223
Heat of reaction, 94, 493
bond energies, table of, 98
effect of pressure on, 102
effect of temperature on, 101

Heat of reaction, in van't Hoff box, 362
  prediction of, 97
Heat pump, 152, 315
Helmholz, 398
Henry's law, 347, 471
Heterogeneous reactions, 376
  completion of, 383
  equilibrium in, 376
  systems containing solutions, 384
Hildebrand function, 62, 63
Hilsh tube, 316
Homogeneous reactions, 360
Horsepower, indicated, 284
Humphrey gas pump, 299
Hydrogen electrode, 481, 488
Hydrogen ion concentration, 488

Ideal gases, *see* Perfect gases
Ideal solution, *see* Perfect solution
Impact pressure, 239
Indicated work, 119
Indicators, 283
  cards, 119, 283
  diagrams, 283
  engine, 117, 283
Intensive properties, 39
Internal-combustion engines, control of power, 297
  cooling, 295
  fuel-feeding methods, 294
  fuels, 292
  ignition, 297
  lubrication, 291
  mechanical arrangement, 291
  starting, 297
Internal energy, 22
Intrinsic energy, 22
Irreversible changes, 10
  entropy changes in, 165, 166
  in electrochemical processes, 490
  in fluid flow, 199
Isentropic changes, 54, 113, 165
Isobaric processes, 3
Isometric changes, 3
Isometrics, reduced, 130
Isopiestic processes, 3
Isothermal processes, 3, 111, 318

Jets, 300
Joule (def.), 15
Joule-Thomson effect, 109, 419
  coefficient, 110

K charts, 350
  tables of values for, 496, 497
Kappa, 90
Kay's rule, 137
Kelvin, 315
Kistiakowsky, 62
Klein's equation, 64
Knocking, 292
Kopp's law, 88
Kuenen, 340

Laminar flow, 197, 209
Latent heats, 47
Lewis, G. N., 318, 330
Lewis and Randall rule, 349
Liquefaction of gases, 312
Liquid junctions, 482
Liquids, heat capacities of, 90
  Pvt relations for, 134
Loop curve, 336
Loss, pumping, 269

Mach number, 211
Margules, 454, 460
Mass, 24
Maxwell, 235
Maxwell demon, 144
Maxwell relations, 422, 424, 434, 449
Mean effective pressure, 284
Mechanical equivalent of heat, 7, 15, 19
Membrane, semipermeable, 179
Molality, 334
Molarity, 334
Molecular weight, 107
Momentum flux, 202
Monovariant systems, 46

Nernst, 404
Newton, Isaac, 24
  second law of motion, 202
Newton, R. H., pseudocritical constants, 322
Nozzles, 227, 241
  convergent, 231
  convergent-divergent, 236
Nuclear reactions, 19

Octane rating, 292
Orifice, 243

Orifice, formula for compressible fluids, 245
formula for incompressible fluids, 244
taps, 244
Overvoltage, 490

Parachor, 60
Partial molal free energy, 445
for perfect solutions, 453
for real solutions, 343, 454
relation to ΔF°, 372
Partial molal quantities, 343, 440
change with concentration, 443, 449
change with pressure, 452
change with temperature, 452
graphical method of determining, 443
method of intercepts, 449
partial molal enthalpy, 442
partial molal entropy, 448
partial molal free energy, 343, 445
partial molal volume, 440
Path, 3
Perfect gas, energy relations, 108, 424
entropy changes, 164
gas constant, 111
isothermal changes, 111
law, 107, 420
mixtures, 116
polytropic changes, 115
reversible adiabatic changes, 113
summary of formulas, 121, 122, 123
Perfect solution, 345
heat of mixing, 453
volume changes on formation, 453
*p*H, 488
Phase, 2, 38
Phase equilibria, 440, 450
Phase rule, 40, 388
with chemical reaction, 389
Pipe, pressure drop in, 224
Piston and cylinder processes, 75
Pitot tube, 239
Point function, 21
Poise, 207
Poiseuille's equation, 211
Polytropic changes, 115
Porter equation, 348, 459
Potentials, 4, 34
chemical, 35
Potentiometric titrations, 490
Power cycles, 253
Poynting, 327
Pressure, critical, 43, 61
critical flow, 232
critical throat, 232
impact, 238, 240
mean effective, 268, 284
reduced, 128
stagnation, 246
static, 238
Pressure-enthalpy diagram for carbon dioxide, 48
Prime movers, comparison of, 298
Process, 3
adiabatic, 54
cyclic, 3
irreversible, 10, 190
isentropic, 54, 113, 165
isobaric, 3
isometric, 3, 130
isopiestic, 3
isothermal, 3, 111, 318
polytropic, 115
spontaneous, 170
Properties, 2
of pure materials, 42
tables of, 50
Pseudocritical constants, 134
Pseudocritical volume, 133, 429
Pseudoreduced quantities, 133
Pumps, 221
PvT relations, 44
compressibility factor, 131
for gas mixtures, 136
for liquids, 135
generalized, 128

Quality, 47

Rangue, 316
Rankine cycle, 255
efficiency of, 256
Raoult's law, 345
Reaction, endothermal, 94
exothermal, 94
heat of, 94
theoretical reaction temperature, 388
Real gases, 128, 422
Reduced quantities, 128
Refrigerants, properties of, 306

Refrigeration, 304
capacity, 306
coefficient of performance, 306
efficiency of, 305
fundamentals of, 305
jet, 315
vortex tube, 316
Refrigeration cycles, 308
absorption, 313
vapor compression, 308
Regular solutions, 454
Retrograde condensation, 339
Reversible, 10, 38
Reversible cells, 485
Reversible cycles, 10
Reversible processes, 10
Reynolds number, 197, 211
significance of, 215
Richards, 404
Rockets, 301
Rotameter, 246

Saturated vapor, 44, 49
Saturated liquid, 44, 49
Saturated solid, 44
Scatchard, George, 461
Scavenging, 295
Second law, 143, 205
and first law, combined, 168
in fluid flow, 205
Semipermeable membranes, 179
Sensible heat, 47
Shock waves, 238
Solubility, 464
critical mixing temperature, 469
effect of pressure on, 474
effect of temperature on, 473
in two-phase liquid systems, 471
of liquids, 467, 468
of solids, 472
Solutions, 334
activity of components in, 350
at elevated temperatures and pressures, 348
chemical reaction in, 384
critical phenomena in, 336
gaseous, 344
ideal liquid, 345
methods of preparation, 340
nonideal liquid, 347
Sound, velocity of, 233
Specific heats, 87
Specific properties, 24, 47
Stagnation pressure, 246
Stagnation temperature, 246
Standard enthalpy change, 395
table of values, 493–495
Standard entropy change, 395
table of values, 493–495
variation with temperature, 396
Standard free-energy change, derivation of, 367
effect of pressure on, 368, 379, 380
effect of temperature on, 397, 398
heterogeneous reactions, 376
homogeneous reactions, 367
interpretation of, 369
prediction of, 408
table of values of, 493-495
State, 2
change of, 20
properties, 419
Static pressure, 238
Steady-flow operation, 71
Steady state, 31, 71
Steam, 261
saturated, 51
superheated, 52
value of, 261
Steam turbines, blade-speed ratio, 289
condition curve, 290
cumulative enthalpy drop, 290
diagram efficiency, 289
efficiency, 290
extraction, 289
impulse, 287
reaction, 287
reheat factor, 290
staging, 287
types, 287
Subcooled liquid, 44
Supercharging, 295
Superheated vapor, 44, 267
Surroundings, 2
System, 1
closed, 2
divariant, 49
heterogeneous, 2
homogeneous, 2
monovariant, 46

System, multicomponent, 440
of one component, 40, 42
open, 2

Tables, properties of, 50
ethane, 51
steam, 51, 52
Temperature, 3
absolute, 6
centigrade, 5
critical, 43
Fahrenheit, 5
flame, 102
Kelvin, 6
measurement of, 5
Rankine, 6
reaction, theoretical, 103
reduced, 128
stagnation, 246
thermodynamic, 155
Thermal data, enthalpy of formation, 493, 494, 495
heats of reaction, 94
Thermocouple, 145
Thermodynamics, 1
Thermometer, 5
gas, 5
liquid-in-glass, 5
Third law, 404
Thomas hot-wire flowmeter, 245
Throat, nozzle, 228
Tobolsky, A., 436
Tracers, radioactive, 245
Transference number, 484
Triple point, 44
Trouton's rule, 61
Turbine, bleeder or extraction, 288, 289
engine efficiency, 277
gas, 270, 277
air rate, 276
closed cycle, 273
compressor efficiency, 277
open system, 272
performance, 276
semiclosed, 273
with intercooling, 272
with regeneration, 272
machine efficiency, 277
pressure ratio, 277
steam, 287
Turbine, thermal efficiency, 277
work ratio, 277
Turbocharger, 298
Turbulent flow, 197, 212

Unavailable energy, 182
Uniflow engine, 285
Unit, 24
absolute cgs system, 24
absolute English system, 24
English engineering system, 25
English gravitational system, 25
foot, 25
force-pound, 25
mass-pound, 25
poundal, 25
second, 25
slug, 25
tables of conversion factors, 492
Universe, thermodynamic, 9

Valve adjustment, 284
Valve gear, 282
Corliss, 282
dee, 282
piston, 282
poppet, 282
van der Waals, 340
Van Laar, 460, 461
van't Hoff, equilibrium box, 363, 376
Vapor–liquid equilibria, 454
Vapor pressure, 46, 57
Clausius-Clapeyron equation for, 153
Cox chart, 58
Dühring chart, 59
effect of pressure on, 325
Klein's equation, 64
Variables, 39
extensive, 39
intensive, 39
Variance, 39
Velocity, average, 210
changes, 227, 230
mass, 200
of sound, 233
profile, 198
ratio, average to maximum in flow, 216
supersonic, 236, 237

Velocity pressure, 239
Vena contracta, 244
Venturi meter, 243
Viscosity, 207
  selected values of, 208
  units, 207
Volume, reduced, 128

Warming engines, 315
Watson, K. M., 62, 63
Watt-hour (def.), 15
Wire drawing, 282
Work, 8
Work, absolute values of work functions, 186
  atmospheric, 78
  electrical, 14
  expansion, 12
  flow, 75
  indicated, 284
  isothermal reversible, 175
  reversible flow, 76, 80
  shaft, 76
Work functions, 175
  engineering importance of, 175
Work acceptors, 13