X_m mole fraction of functional group m in UNIFAC method

x mole fraction in liquid phase; mole fraction in any phase; distance; mass fraction in raffinate; mass fraction in underflow; mass fraction of particles

x' normalized mole fraction $= x_i / \sum_{j=1}^{C} x_j$ 1

$\boldsymbol{x}$ vector of mole fractions in liquid phase

x_n fraction of crystals of size smaller than L

Y mole or mass ratio; mass ratio of soluble material to solvent in overflow; pressure-drop factor for packed columns defined by (6-102); concentration of solute in solvent; parameter in (9-34)

y mole fraction in vapor phase; distance; mass fraction in extract; mass fraction in overflow

$\boldsymbol{y}$ vector of mole fractions in vapor phase

Z compressibility factor $= Pv/RT$; total mass; height

Z_f froth height on a tray

Z_L length of liquid flow path across a tray

$\bar{Z}$ lattice coordination number in UNIQUAC and UNIFAC equations

z mole fraction in any phase; overall mole fraction in combined phases; distance; overall mole fraction in feed; dimensionless crystal size; length of liquid flow path across tray

$\boldsymbol{z}$ vector of mole fractions in overall mixture

Greek Letters

α thermal diffusivity, $k/\rho C_P$; relative volatility; surface area per adsorbed molecule

α^* ideal separation factor for a membrane

α_{ij} relative volatility of component i with respect to component j for vapor-liquid equilibria; parameter in NRTL equation

α_j, $\beta_j \gamma_j$ energy-balance parameters defined by (10-23) to (10-26)

β_{ij} relative selectivity of component i with respect to component j for liquid–liquid equilibria

Γ film flow rate/unit width of film; thermodynamic function defined by (12-37)

Γ_k residual activity coefficient of functional group k in UNIFAC equation

γ specific heat ratio; activity coefficient

Δ change (final − initial)

δ solubility parameter; film thickness; velocity boundary layer thickness; thickness of the laminar sublayer in the Prandtl analogy

δ_c concentration boundary layer thickness

δ_{ij} Kronecker delta

ϵ exponent parameter in (3-40); fractional porosity; allowable error; tolerance in (10-31)

ϵ_b bed porosity (external void fraction)

ϵ_D eddy diffusivity for diffusion (mass transfer)

ϵ_H eddy diffusivity for heat transfer

ϵ_M eddy diffusivity for momentum transfer

ϵ_p particle porosity (internal void fraction)

η Murphree vapor-phase plate efficiency in (10-73)

θ area fraction in UNIQUAC and UNIFAC equations; dimensionless concentration change defined in (3-80); correction factor in Edmister group method; cut equal to permeate flow rate to feed flow rate for a membrane; contact angle; fractional coverage in Langmuir equation; solids residence time in a dryer; root of the Underwood equation, (9-28)

θ_L average liquid residence time on a tray

κ Maxwell-Stefan mass-transfer coefficient in a binary mixture

Λ_{ij} binary interaction parameter in Wilson equation

λ mV/L; radiation wavelength

λ_+, λ_- limiting ionic conductances of cation and anion, respectively

λ_{ij} energy of interaction in Wilson equation

μ chemical potential or partial molar Gibbs free energy; viscosity

ν momentum diffusivity (kinematic viscosity), μ/ρ; wave frequency; stoichiometric coefficient

$\nu_k^{(i)}$ number of functional groups of kind k in molecule i in UNIFAC method

ξ fractional current efficiency; dimensionless distance in adsorption defined by (15-115); dimensionless warped time in (11-2)

π osmotic pressure; product of ionic concentrations

ρ mass density

ρ_b bulk density

ρ_M crystal density

ρ_p particle density

ρ_s true (crystalline) solid density

σ surface tension; interfacial tension; Stefan-Boltzmann constant $= 5.671 \times 10^{-8}$ W/m$^2 \cdot$ K^4

σ_I interfacial tension

$\sigma_{s,L}$ interfacial tension between crystal and solution

τ tortuosity; shear stress; dimensionless time in adsorption defined by (15-116); retention time of mother liquor in crystallizer; convergence criterion in (10-32)

τ_{ij} binary interaction parameter in NRTL equation

τ_w shear stress at wall

υ number of ions per molecule

Φ, Φ' volume fraction; parameter in Underwood equations (9-24) and (9-25)

$\bar{\Phi}$ local volume fraction in the Wilson equation

$\phi\{t\}$ probability function in the surface renewal theory

ϕ pure-species fugacity coefficient; association factor in the Wilke-Chang equation; recovery

	factor in absorption and stripping; volume fraction; concentration ratio defined by (15-125)
$\bar{\phi}$	partial fugacity coefficient
ϕ_{df}	froth density
ϕ_e	effective relative density of froth defined by (6-48)
ϕ_s	particle sphericity
Ψ	segment fraction in UNIQUAC equation; V/F in flash calculations; E/F in liquid–liquid equilibria calculations for single-stage extraction; sphericity defined before Example 15.7
Ψ_o	dry-packing resistance coefficient given by (6-113)
ψ	fractional entrainment; loading ratio defined by (15-126); sphericity
ω	acentric factor defined by (2-45); segment fraction in UNIFAC method

Subscripts

A	solute
a,ads	adsorption
avg	average
B	bottoms
b	bulk conditions; buoyancy
bubble	bubble-point condition
C	condenser; carrier; continuous phase
c	critical; convection; constant-rate period
cum	cumulative
D	distillate, dispersed phase; displacement
d	drag; desorption
d,*db*	dry bulb
des	desorption
dew	dew-point condition
ds	dry solid
E	enriching (absorption) section
e	effective; element
eff	effective
F	feed
f	flooding; feed; falling-rate period
G	gas phase
GM	geometric mean of two values, A and B = square root of A times B
g	gravity
gi	gas in
go	gas out
H,*h*	heat transfer
I, I	interface condition
i	particular species or component
in	entering
irr	irreversible
j	stage number
k	particular separator; key component
L	liquid phase; leaching stage
LM	log mean of two values, A and B = (A − B)/ln(A/B)
LP	low pressure
M	mass transfer; mixing-point condition; mixture
m	mixture; maximum
max	maximum
min	minimum
N	stage
n	stage
O	overall
o,0	reference condition; initial condition
out	leaving
OV	overhead vapor
P	permeate
R	reboiler; rectification section; retentate
r	reduced; reference component; radiation
res	residence time
S	solid; stripping section; sidestream; solvent; stage; salt
s	source or sink; surface condition; solute; saturation
T	total
t	turbulent contribution
V	vapor
W	batch still
w	wet solid-gas interface
w,*wb*	wet bulb
ws	wet solid
X	exhausting (stripping) section
x,*y*,*z*	directions
δ	at the edge of the laminar sublayer
0	surroundings; initial
∞	infinite dilution; pinch-point zone

Superscripts

E	excess; extract phase
F	feed
ID	ideal mixture
(*k*)	iteration index
LF	liquid feed
o	pure species; standard state; reference condition
p	particular phase