TABLE OF CONTENTS

CHAPTER I.	GENERAL INFORMATION	15
Tables		
Table I–1.	Greek alphabet	17
Table I–2.	. Conversion of selected units to International System	
	of Units (SI)	18
Table I-3.	Conversion factors of selected dimensions from U.S./British	
	to SI unit	19
Table I–4.	Decimal multiples and submultiples of SI units	20
Table I–5.	I-5. Periodic table of the elements	
CHAPTER II.	PROPERTIES OF SUBSTANCES	23
Figures		
Fig. II.1.	Pressure correction factor of molar specific heat of gases	38
Fig. II.2.	Pressure correction factor of enthalpy of gases	39
Fig. II.3.	Pressure correction factor of enthalpy of gases	40
Fig. II.4.	Pressure correction factor for dynamic viscosity of gases	41
Fig. II.5.	Generalized compressibility factor	42
Fig. II.6.	Reduced dynamic viscosity of gases	43
Fig. II.7.	Reduced thermal conductivity of gases	45
Fig. II.8.	Thermal conductivity of dry air	50
Tables		
Table II–1.	Physical properties of selected substances	25
Table II–2.	Molar specific heat $(c_{p,M})$, standard enthalpy (ΔH), standard thermodynamic potential (ΔG) and standard entropy	
	of pure substances (S)	27
Table II-3.	Molar specific heat of gases	30
Table II-4.	Mean molar specific heat of gases in the range of temperature	
	from 0°C to t	33
Table II-5.	Dynamic viscosity of gases $\eta \cdot 10^4 \text{ Pa} \cdot \text{s}$ (pressure P = 10 ⁵ Pa)	36
Table II-6.	Thermal conductivity λ W/(m \cdot K) of gasses and vapours	
	at different temperatures (pressure $P = 10^5 Pa$)	37
Table II–7.	Dynamic viscosity of selected substances in the critical	
	conditions	44

3

Table II–8. Table II–9.	Thermal conductivity of substances in the critical state 4 . The dynamic viscosity: η_0 and C constants in Sutherland's	
	formula and $\sqrt{MT_{cr}}$ constant in Herning–Zipperer formula	
	for mixture of gases ($P < 2 MPa$)	
Table II–10.	0. Thermal conductivity of gases: λ_0 and C constants	
	in Sutherland's formula ($P < 1 MPa$)	
Table II–11.	Physical parameters of dry air ^{*)} ($P = 98.1 \text{ kPa}$)	49
Table II–12.	. Physical parameters of steam at the saturation limit	
	(for atmospheric pressure and higher pressures)	51
Table II–13.	Physical parameters of steam at the saturation limit (for lower	r
	than atmospheric pressure)	53
Table II–14.	The density of liquid and aqueous solution	56
Table II–15.	Specific heat of liquid and aqueous solutions	57
Table II–16.	Density and specific volume of pure glycerine	58
Table II–17.	Dynamic viscosity of glycerine and glycerine solutions	
	at different temperatures	59
Table II–18.	Dynamic viscosity of liquid and aqueous solutions	60
Table II–19.	Thermal conductivity of liquid and aqueous solutions	62
Table II–20.	Surface tension of liquid and aqueous solutions	63
Table II–21.	Coefficient of thermal expansion of liquid and aqueous	
	solution for $t_0 = 0^{\circ}C$	64
Table II–22.	Physical parameters of water	65
Table II–23.	3. Physical properties of selected solid and construction	
	materials	67
Table II–24.	Thermal properties of materials	69
Table II–25.	5. Selected properties of bulk solids	
CHAPTER III. H	HYDRODYNAMICS	75
Figures		
Fig. III.1.	Friction factor for fully developed flow in circular pipe	
- 0	(Moody diagram)	77
Fig. III.2.	Inlet shape and loss factor ξ for pipe (fluid enters from	
- 8	large tank)	86
Fig. III.3.	The entrance loss coefficient (ξ) for different entrance	
- 8	conditions (flow leaving a tank)	86
Fig. III.4.	Tube bundle arrangements in shell-and-tube heat exchanger	87
Fig. III.5.	Resistance (loss) coefficient ξ for gradual pipe transition	89
Fig. III.6.	Loss (resistance) coefficient for tee	
Fig. III.7.	Flow regime map for gas-liquid mixture flow in vertical pipe	

		100 0
Fig. III.8.	Gas-liquid mixture flow patterns in vertical pipe 9	
Fig. III.9.	Flow regime map for gas-liquid mixture flow in horizontal	
-	pipe	94
Fig. III.10.	Gas-liquid mixture flow patterns in horizontal pipe	
Fig. III.11.	Flow regime map for liquid-liquid flow in vertical	
0	pipe (upflow)	95
Fig. III.12.	Oil-water flow patterns in vertical pipe (upflow)	96
Fig. III.13.	Operating range of packed columns with $(25 \times 25 \times 2.5)$ mi	m
8	ceramic Raschig rings	102
Fig. III.14.	Operating range of packed columns with $(35 \times 35 \times 42)$ mm	n
1.18	ceramic Raschig rings	103
Fig III 15	Flooding conditions for packing column (scrubber)	105
Fig. III.16	Diagram for velocity calculation of solid particles falling thr	ough
1 lg. 111.10.	a fluid	109
Fig III 17	Drag coefficient ζ and particle sphericity Ψ as a function	
1 ig. 111.17.	of Reynolds number	111
Eig III 18	Viscosity ranges for different impellers	114
Fig. 111.10.	Characteristic of different impellers for generation of turbu	lence
Fig. 111.19.	and liquid numping	114
Eig III 20	Plot of the power number versus impeller Reynolds number	er for
Fig. 111.20.	different types of impellers	115
	different types of impenets	
Tables		
Table III_1	Values of surface roughness for various materials	78
Table III_1.	Resistance coefficients for different fitting types	79
Table III-2.	Representative loss coefficients ξ for various fittings	
Table III-5.	or values	84
Table III 4	Peristance coefficient ξ for tube bundle (flow perpendicu	lar to
Table 111-4.	the tubec)	87
Table III 5	Designed coefficient for single miter hend with variable	cross
Table III-5.	section	88
Table III 6	Equivalent length of straight pipe for fittings and valves	91
Table III -6 .	Equivalent length of straight pipe for intings and varies	92
Table $\Pi = 7$.	Transi and design value sities of fluids in Chemical Process Ind	lustry
1able 111-8.	Typical design velocities of huids in Chemical Process me	93
TT 1 1 TT 0	pipelines	97
1able 111–9.	Correlations for volu fraction and frictional pressure drop	98
Table 111-10.	Commonly used random packings	90
Table III-11.	The initial data for commonly used random packings	100
Table III-12	lechnical data of Kaschig rings	100

Table III–11. Technical data for commonly us Table III–12. Technical data of Raschig rings

Table III-13. Optimal gas velocity, u _{go} at temperature 20°C and atmospheric			
	pressure 104		
Table III–14.	II–14. Value of function $f(w_{lo})$ in equation for determining packing		
	factor ϕ (used to estimate effectively wetted area		
	of packing)	105	
Table III–15.	Filter specific cake resistance relative to dry mass, a	106	
Table III–16.	ble III–16. Compressibility factor s for sludge		
Table III–17.	III-17. Examples of use sands and gravels in filtration		
Table III–18.	ble III–18. Formulas for calculating concentration of suspension		
	components	108	
Table III–19.	Equivalent diameter, sphericity and correction factor		
	to calculate the fall velocity of selected geometries		
	of solid particles	110	
Table III–20.	Type of impellers	112	
Table III–21.	Geometrical parameters of impellers	116	
CHAPTER IV. H	IFAT TRANSFFR	117	
Figures			
Fig. IV.1.	Heat loss of insulated pipes	121	
Fig. IV.2.	Heat loss from insulated flat surfaces	122	
Fig. IV.3.	Fixed-tube heat exchanger	144	
Fig. IV.4.	Shell-and-tube heat exchanger	145	
Fig. IV.5.	Temperature distribution in cross-flow heat exchanger		
0		100	
Tables			
Table IV-1.	Constant values and exponents in the equations describing	g the	
	more important cases of heat transfer	119	
Table IV-2.	Heat loss of pre-insulated pipes	123	
Table IV-3.	Convective heat transfer coefficient h, $W/(m^2 \cdot K)$	124	
Table IV-4.	Convective heat transfer coefficient for different heat transfer coefficient for different heat transfer the transfer the transfer term is a second term in the term in term is a second term in term in term in term in term in term is a second term in t	nsfer	
	processes h, W/($m^2 \cdot °C$)	124	
Table IV-5.	Heat transfer coefficient for natural convection (excluding		
	radiation) for horizontal pipes in a stagnant air at the temp	era-	
	ture of 20°C	125	
Table IV-6.	The multiplier (A) of function for calculating convective	heat	
	transfer coefficient h (natural convection)	126	
Table IV-7.	Critical heat load (q_{cr}) for liquids (P = 100 kPa)	127	
Table IV-8.	Multiplier of function for calculating convective heat transf	er	
	coefficient during condensation, $h = A \varphi r^{1/4} (H \Delta T)^{-1/4}$,		
	$W/(m^2 \cdot K)$	128	

cai
129
ent
29
20
130
20
30
31
.33
34
39
41
42
46
47
18
40
50
58
63
.69
74
.79
83
86
87
98

7

Table IV-31. Table IV-32. Table IV-33.	Thermal efficiency for rectangular fin over circular tube Thermal efficiency for trapezoidal fin over circular tube Thermal efficiency for square fin of rectangular cross-section over circular tube	
1able 1v-34.	 Correction factor for thermal efficiency of circular fin of rectangular cross-section 	
CHAPTER V. M	ASS TRANSFER	201
Fig. V.1.	Diffusion group of component A in solvent B (The molar volume of liquid according to Table V–13)	217
Tables		
Table V–1.	Replacement n for concentrations	203
Table V–2.	Driving force for mass transfer $(Z_{f(i)m})_{og}$	204
Table V–3.	Henry's law constant for aqueous solutions of gases	205
Table V–4.	Solubility of ammonia (NH_3) in water	207
Table V–5.	Solubility of sulphur dioxide (SO_2) in water	208
Table V-6.	Solubility of carbon dioxide (CO_2) in water	209
Table V-7.	Kinematic diffusion coefficient of A in B for gases, $(t = 0^{\circ}C, D = 1012 h D_{2})$	210
Table V 8	P = 1013 HPa Kinematic diffusion coefficient of A in B for gases $(t - 0^{\circ}C)$	210
1able v=0.	$P = 1013 hP_2$	211
Table V-9.	Dynamic diffusion coefficient of A in B for gases ($t = 25^{\circ}$ C.	211
14010	P = 1013 hPa 2	
Table V–10.	-10. Kinematic and dynamic diffusion coefficient for gases	
	and liquids in water (diluted solutions), $(t = 20^{\circ}C,$	
	P = 1013 hPa)	213
Table V–11.	Constant-forces in Lennard-Jones equation	214
Table V–12.	Values of function $\Omega = f\left(\frac{kT}{c}\right)$	
Table V–13.	The molar volume of liquid at saturation and atmospheric	
	pressure 216	
Table V–14.	The values of constants and exponents for the more importa-	int
	mass transfer equations	218
CHAPTER VI. D	DISTILLATION	221
Figures		255
F1g. VI.I.	Gilliand's diagram for calculation of theoretical plates	255

Fig. VI.2.	Boiling point diagram for benzene (A) – toluene (B) binary mixture, P = 101 kPa	256
Fig. VI.3.	Vapour–liquid equilibrium curve for benzene (A) – toluene (B) system, P = 101 kPa	
Tables		
Table VI–1.	Saturation parameters for some organic components	223
Table VI–2.	Relative volatility of ideal binary mixtures for pure compone	ents
	in boiling point at atmospheric pressure	239
Table VI–3.	Relative volatility α_{AB} of selected mixtures for higher	
	pressures	240
Table VI–4.	Constants in van Laar [*]) equation for binary mixtures	
	at atmospheric pressure	241
Table VI–5.	Vapour-liquid equilibrium data for some binary systems	242
Table VI–6.	Azeotropic binary mixtures with a minimum boiling point	
	at atmospheric pressure	253
Table VI–7.	Azeotropic binary mixtures with maximum boiling point	
	at atmospheric pressure	254
CHAPTER VII.	EXTRACTION AND CRYSTALLIZATION	257
CHAPTER VII. Tables	EXTRACTION AND CRYSTALLIZATION	257
CHAPTER VII. Tables Table VII–1.	EXTRACTION AND CRYSTALLIZATION Liquid-liquid equilibrium data for three-component system	257
CHAPTER VII. Tables Table VII–1.	EXTRACTION AND CRYSTALLIZATION Liquid-liquid equilibrium data for three-component system – coexistence curve (data in mass percent)	257 s 259
CHAPTER VII. Tables Table VII–1. Table VII–2.	EXTRACTION AND CRYSTALLIZATION Liquid-liquid equilibrium data for three-component system – coexistence curve (data in mass percent) Selected properties for some crystals of inorganic	257 s 259
CHAPTER VII. Tables Table VII–1. Table VII–2.	EXTRACTION AND CRYSTALLIZATION Liquid-liquid equilibrium data for three-component system – coexistence curve (data in mass percent) Selected properties for some crystals of inorganic components	257 s 259 262
CHAPTER VII. Tables Table VII–1. Table VII–2. Table VII–3.	EXTRACTION AND CRYSTALLIZATION Liquid-liquid equilibrium data for three-component system – coexistence curve (data in mass percent) Selected properties for some crystals of inorganic components Selected properties for some crystals of organic	257 s 259 262
CHAPTER VII. Tables Table VII–1. Table VII–2. Table VII–3.	EXTRACTION AND CRYSTALLIZATION Liquid-liquid equilibrium data for three-component system – coexistence curve (data in mass percent) Selected properties for some crystals of inorganic components Selected properties for some crystals of organic components	257 s 259 262 263
CHAPTER VII. Tables Table VII–1. Table VII–2. Table VII–3. Table VII–4.	EXTRACTION AND CRYSTALLIZATION Liquid-liquid equilibrium data for three-component system – coexistence curve (data in mass percent) Selected properties for some crystals of inorganic components Selected properties for some crystals of organic components Solubility of selected inorganic components in water,	257 s 259 262 263
CHAPTER VII. Tables Table VII–1. Table VII–2. Table VII–3. Table VII–4.	EXTRACTION AND CRYSTALLIZATION Liquid-liquid equilibrium data for three-component system – coexistence curve (data in mass percent) Selected properties for some crystals of inorganic components Selected properties for some crystals of organic components Solubility of selected inorganic components in water, g/100gu o	257 s 259 262 263 264
CHAPTER VII. Tables Table VII–1. Table VII–2. Table VII–3. Table VII–4. Table VII–5.	EXTRACTION AND CRYSTALLIZATION Liquid-liquid equilibrium data for three-component system – coexistence curve (data in mass percent) Selected properties for some crystals of inorganic components Selected properties for some crystals of organic components Solubility of selected inorganic components in water, $g_a/100g_{H_2O}$ Solubility of selected organic components in water,	257 s 259 262 263 264
CHAPTER VII. Tables Table VII–1. Table VII–2. Table VII–3. Table VII–4. Table VII–5.	EXTRACTION AND CRYSTALLIZATION Liquid-liquid equilibrium data for three-component system – coexistence curve (data in mass percent) Selected properties for some crystals of inorganic components Selected properties for some crystals of organic components Solubility of selected inorganic components in water, $g_a/100g_{H_2O}$ Solubility of selected organic components in water, $g_a/100g_{H_2O}$	257 s 259 262 263 264 265
CHAPTER VII. Tables Table VII–1. Table VII–2. Table VII–3. Table VII–4. Table VII–5. Table VII–6.	EXTRACTION AND CRYSTALLIZATION Liquid-liquid equilibrium data for three-component system – coexistence curve (data in mass percent) Selected properties for some crystals of inorganic components Selected properties for some crystals of organic components Solubility of selected inorganic components in water, $g_a/100g_{H_2O}$ Solubility of selected organic components in water, $g_a/100g_{H_2O}$ The supersaturation limit for aqueous solutions mixed with	257 259 262 263 264 265
CHAPTER VII. Tables Table VII–1. Table VII–2. Table VII–3. Table VII–4. Table VII–5. Table VII–5.	EXTRACTION AND CRYSTALLIZATION Liquid-liquid equilibrium data for three-component system – coexistence curve (data in mass percent) Selected properties for some crystals of inorganic components Selected properties for some crystals of organic components Solubility of selected inorganic components in water, $g_a/100g_{H_2O}$ Solubility of selected organic components in water, $g_a/100g_{H_2O}$ The supersaturation limit for aqueous solutions mixed with inorganic salts, a cooling rate of 24 K/h	257 s 259 262 263 264 265 266
CHAPTER VII. Tables Table VII–1. Table VII–2. Table VII–3. Table VII–4. Table VII–5. Table VII–6. Table VII–6.	EXTRACTION AND CRYSTALLIZATION Liquid-liquid equilibrium data for three-component system – coexistence curve (data in mass percent) Selected properties for some crystals of inorganic components Selected properties for some crystals of organic components Solubility of selected inorganic components in water, $g_a/100g_{H_20}$ Solubility of selected organic components in water, $g_a/100g_{H_20}$ The supersaturation limit for aqueous solutions mixed with inorganic salts, a cooling rate of 24 K/h Kinetic constants of crystallization from a solution	257 259 262 263 264 265 266 266 268
CHAPTER VII. Tables Table VII–1. Table VII–2. Table VII–3. Table VII–4. Table VII–5. Table VII–6. Table VII–6.	EXTRACTION AND CRYSTALLIZATION Liquid-liquid equilibrium data for three-component system – coexistence curve (data in mass percent) Selected properties for some crystals of inorganic components Selected properties for some crystals of organic components Solubility of selected inorganic components in water, $g_a/100g_{H_2O}$ Solubility of selected organic components in water, $g_a/100g_{H_2O}$ The supersaturation limit for aqueous solutions mixed with inorganic salts, a cooling rate of 24 K/h Kinetic constants of crystallization from a solution Temperature depression of the aqueous solutions	257 259 262 263 264 265 266 268

Figures

Fig. VII.1.	Water (A) – acetone (B) – trichloroethane (C) equilibrium	
	triangular phase diagram, t = 30°C	262

9

CHAPTER VIII. DRYING				
Table VIII-1	.Physical properties of moist saturated air (pressure 0.1 MPa)	279		
Table VIII-2	Table VIII–2. Enthalpy $i_s kJ/kg_{d.a.}$ and moisture content $W_A g/kg_{d.a.}$ under atmospheric pressure			
Table VIII–3	.Equilibrium moisture content in various materials at 25°C	291		
Figures				
Fig. VIII.1.	Psychometric chart for moist air at atmospheric pressure	275		
Fig. VIII.2.	Mollier diagram	275		
Fig. VIII.3.	Drying diagram for moist air under pressure 0.1 MPa (rang	e 270		
	of low temperatures)	277		
Fig. VIII.4.	Drying diagram for moist air under pressure 0.1 MPa (rang	ge		
	of high temperatures)	278		
rig. v 111.5.	pressure	290		
	produce	270		
CHAPTER IX. R	EFRIGERATION	293		
Figures				
Fig. IX.1.	Mollier-type diagram for R290	299		
Fig. IX.2.	Mollier-type diagram for R717	304		
Fig. IX.3.	Mollier-type diagram for R744	307		
Fig. IX.4.	Mollier-type diagram for R134a	310		
Fig. IX.5.Mollier-type diagram for R2231		313		
Tables		sk.		
Table IX-1.	Classification of some refrigerants	295		
Table IX–2.	Control substances in the Montreal Protocol	295		
Table IX–3.	able IX–3. Ozone Depleting Potential (ODP) of some substances			
Table IX–4.	X-4. Global Warming Potential (GWP) of various refrigerants 2			
Table IX–5.	Physical properties of R290 refrigerant	297		
Table IX–6.	Physical properties for saturated R290 refrigerant	298		
Table IX–7.	Physical properties of R717 refrigerant	300		
Table IX–8.	Physical properties for saturated R717 refrigerant	303		
Table IX-9.Physical properties of R744 refrigerant305				
Table IX–10.	Table IX-10. Physical properties for saturated R744 refrigerant306			

Table IX-11.	Physical properties of R134a refrigerant	
Table $IX = I2$.	Physical properties for saturated R134a retrigerant	
Table $IX = 13$.	Physical properties of R22 refrigerant	
Table $IX - 14$.	Physical properties for saturated R22 refrigerant	
Table $1X - 15$.	Storage temperature for some commodities	
		717
Tables	UPROCESSES	31/
Table X–1.	The content of the basic elements in the biomass	
	of microorganisms	319
Table X–2.	Typical concentrations of mineral components in liquid	
	media	319
Table X–3.	Examples of Chemical Oxygen Demand values (COD)	
	for some wastewater	319
Table X–4.	Inorganic components of different microorganisms	320
Table X–5.	Degree of reduction (γ) for atoms and charge	320
Table X–6.	Degree of reduction (γ) for the nitrogen atom present	
	in the biomass and nitrogen source for microorganism	
m 11 m -	growth	320
Table X–7.	Degree of reduction for biomass (γ_x) with average composition	tion
T 11 X 0	for different N sources	321
lable X-8.	Elemental composition and degree of reduction (γ) for set	221
Table V 0	Organisms	321
Table X 10	Tunical K, values for selected microbial cells	324
Table $X = 10$.	Standard molar Cibbs energy and enthalpy $(T - 208 \text{ K})$ pH	- 7
Table A-11.	P = 1 bar $C = 1$ mol/l) and degree of reduction	- /,
	for the corresponding compound in growth systems	325
Table X-12	The standard thermodynamic properties of combustion	525
1401011 12.	for selected substances referenced to 1 C-mol (at standard	
	conditions $t = 25^{\circ}C$; $P = 10^{5}$ Pa)	326
Table X–13.	The values of y $/\gamma$ for selected substances	327
Table X–14.	Examples of the biomass yield coefficient	327
Table X–15.	The average value of yield coefficients for selected	
	substrates	328
Table X–16.	The yield coefficients for the growth of various microorgani	isms
	on glucose under aerobic conditions	328
Table X–17.	Comparison of different types of fermenters used in aerobic	2
	processes	329

APPE	NDIX MATHEMATICAL RULES	331
A.1.	Logarithms	331
A.2.	Differentiation	332
A.3.	Integration	333
A.4.	Matrices	334

REFERENCES 341

*