

## Index

### a

- abrasion of particles 466
- acetamide 185
- acetic acid 375
- Acetobacter* 359, 375
- acetogenic bacteria 384
- acetone cyanohydrin 193
- N*-acetyl L-tyrosine 199
- N*-acetyl L-valine 199
- Acinetobacter calcoaceticus* 154
- acrylamide 142, 314, 347
  - commercial production 184
- activation energy 53, 54, 66, 71, 284
- activator 34, 37, 68, 73, 74, 259
- active site of enzyme 42
- activity-based approach, limitations 113
- N*-acylamino acid racemases 198, 199
- N*-acylamino acids 199
- acylases 13, 146, 176, 177, 277, 314, 347
- acylation 42, 48, 49, 53, 54, 166, 167, 170
- adherent mammalian cells, for
  - biopharmaceuticals production 383, 384
- adhesion 361, 362, 376, 377, 378, 393, 466
- adipoyl-7-ADCA 528
- adipoyl-6-APA 527
- adsorption, 378. *See also* enzyme adsorption
  - microorganisms 376
- aerosols 21, 22
- agarose 322, 323, 326, 363, 364, 368
- agglomeration 280, 331
- aggregates 366
  - microbial 382, 388
- aggregation 367
- agricultural residues 509, 511
- Agrobacterium tumefaciens* 344
- alanine racemase 198
- alcohol
  - polyvinyl alcohol (PVA) 368, 374
  - production, by fermentation (*See also* fermentation)
  - secondary alcohols resolved using lipases 169
  - as solvent 83
  - synthesis of 144, 145
  - tertiary alcohols 169, 170
- alcohol dehydrogenase (ADH) 19, 39, 71, 143–146, 154, 171, 300, 486
- alcoholic fermentation. *See* fermentation
- alcohol oxidase (AOX) 221
- aldolases 39, 193–197
  - biocatalytic route 541
  - classes 193, 194
  - retro-aldol reaction 131, 197
  - type I and type II, mechanism of 194
  - *in vivo* aldol reaction catalyzed by NeuAc aldolase 197
- alginate 369, 370, 372
- alginic acid 370
- 3-alkyl-substituted 2-cyclohexenones 159
- amidases 40, 58, 146, 176, 177, 238, 240, 258, 287, 529, 530
- amide bonds 176
  - synthesis using proteases and amidases 176
- amino acid dehydrogenases (AADHs) 146, 147
  - catalytic mechanism 146
  - synthesis of optically active L-amino acids using 147
- amino acids 51, 52
  - average content, as activesite residues in enzymes 41
  - condensation 50
  - C-terminal, hydrolysis of 45
  - racemic 177
  - sequence alignment 336
  - substitutions 122, 125, 126, 129, 191

- synthesis of 145, 346
  - amino acylases 315, 347
  - (*R*)-amino-adipic acid 539
  - 7-aminocephalosporanic acid (7-ACA) 16, 177, 346, 433, 451, 525, 526, 532
    - chemical and enzyme technological 532
    - flowsheet for production 531
    - hydrolysis cycle 535
    - immobilized enzyme and minimal abrasion 538
    - pH and temperature dependence 535
    - process for production 531–533
    - production 25, 327
    - product isolation 539
    - space–time yield 539
    - suitable reactors and 537, 538
  - 7-amino-deacetoxy-cephalosporinic acid (7-ADCA) 16, 346, 436, 522, 525, 526, 527, 528, 530
  - 6-aminopenicillanic acid (6-APA) 177, 346, 525, 528
  - ammonia 102, 304, 322, 346, 391, 392, 463, 487, 511
  - ammonium chloride 12
  - amorphous cellulose 514
  - amylases, thermostable 279
  - $\alpha$ -amylase 3, 9, 40, 46, 50, 226, 279, 284, 285, 286, 287, 289, 292–294, 462, 493, 494, 496, 504, 505
  - $\beta$ -amylase 42, 127, 293
  - amyloglucosidases 9, 45, 279
    - thermostable, stabilization 306
  - amylopectin 291, 292
  - amylose 291, 292
    - crystalline structure 493
  - anaerobic 385, 390
  - anaerobic bacteria growth kinetics 387
  - anaerobic cultures 361
  - anaerobic fluidized bed reactors 390
  - anaerobic mixed cultures 380–384, 387, 465
  - anaerobic systems, kinetics 384, 387
  - anaerobic wastewater treatment 384–390
  - antibiotic resistance 122, 527
  - antibiotic-resistant bacterial strains 527, 528
  - applied biocatalysis 8
    - basic principles 8
    - early developments 8–10
  - Arabidopsis thaliana* 149
  - arabinoxylanases 504, 505
  - L-arginine 146
  - 2-arylpropionic acids 172
  - L-ascorbic acid synthesis 219
  - asparagine 132, 146, 279, 485, 513
  - L-asparagine 146, 485
  - aspartame 57, 347, 348
    - thermolysin-catalyzed synthesis of 177, 348
  - Aspergillus niger* 43
  - asymmetric synthesis 20, 65, 67, 77, 114, 143, 161–164
  - atorvastatin 541, 542
    - calcium salt, structure 540
  - attachment 334
- b**
- Bacillus erodians* 12
  - Bacillus licheniformis* 284
  - Bacillus subtilis* 126, 159
  - bacterial hyperthermophilic amylases 494
  - Baeyer-Villiger monooxygenases (BVMO) 114, 153–155
    - acetophenone-converting 155
    - conversion of mono- and bicyclic ketones 156
    - converting  $\beta$ -hydroxyketones into monoacetate 156
    - proposed mechanism 155
  - $\beta$ -amylase 42, 127, 293
  - baking process 289
  - beer, maturation 375
  - bentonite 321
  - benzylic hydroxylations 157
  - binding, glutaraldehyde 331
  - biocatalysts 2
    - market for enzymes used as 15
    - productivities 500
    - lifetimes 314
  - biocatalytic processes
    - classification 18
    - economics 23
    - environmental sustainability goals 23
    - steps to be considered in designing 26
    - vs. chemical catalysts 21
  - biochemical engineering 450
  - biodiesel 166, 215, 314, 348, 349
    - enzymatic transesterification 349, 521
    - synthesis of 215
  - bioenergy 361
  - bioethanol 501, 503, 504, 506, 509, 521
    - manufacture, whole dry grind process 504
  - biofilms 361–365, 378, 379, 381, 393–395
    - catalysis 393–396
    - electrotransfer 398
    - formation 381, 396
    - growth 378
  - biofilter 392, 393
  - bioflocs 365
  - biofuels 28, 215, 276, 451

- alternative biocatalyst-based biofuels 520, 521
  - from biomass 501
  - enzymes 512–517
  - general 507, 508
  - lignocellulose-based biofuels 507
  - pilot studies 519, 520
  - pretreatment 509, 512
  - processing 503, 517
  - and reaction engineering 517–519
  - raw materials 508, 509
  - starch-based ethanol production 502–507
  - biofuel cells, performance 397
  - biogas 384
  - bioinformatics 213
  - biological trickling filter, with water reservoir 393
  - biomass 4, 5, 392, 501, 508, 509
    - biotechnological production process 5
    - consumption of 5
  - biomass-based diesel 501
  - biomass support particles (BSPs) 349
  - biopharmaceuticals 362
  - bioreactors 213, 369, 449, 451, 454
  - bioscrubber 392
  - biotechnological processes 5, 15, 17
  - biotransformations 154, 210, 218, 220, 335, 361, 369, 394, 449, 485
    - β-lactam antibiotics 122, 177, 451
    - 7-ACA production 531–533
    - cephalosporin acylase (CA) 535, 536
    - cephalosporin C, hydrolysis 533–535
    - enzyme processes 521–531
    - process options evaluation
      - minimum space-time yield 539
      - pH-controlling buffers 537, 538
      - process window 536, 537
      - product isolation 539, 540
      - reaction end point 539
    - β-lactamase 39, 129
  - BLAST 112, 114, 118, 119
  - β-methyl-D-glucoside 10
  - bovine serum albumin (BSA) 123
  - bread manufacture 289
  - BRENDA database 39, 46, 284
  - Browning products 500
  - Burkholderia cepacia* 168
  - 1,4-butanediol (1,4-BD) 215, 222
  - 1-butyl-3-methylimidazolium tetrafluoroborate (BMIM-BF<sub>4</sub>) 87
  - butyrate ester 165
- C**
- Candida antarctica* 168, 333
  - Candida boidinii* 147, 302
  - carbamoylase 107, 126, 187, 188, 210, 288
  - Carbohydrate Active Enzyme database 36
  - carbohydrate binding module (CBM) 513
  - carbon dioxide 11, 147, 162, 218, 504, 521
  - carbon–oxygen demand (COD) 519
  - carboxyl esterases 165, 172, 175
  - carboxylic acid 81, 145, 152, 153, 158, 168, 174, 182, 197, 391
  - carboxypeptidase A 39, 43, 46, 50, 53, 64, 437
  - carrageenan 369, 371
  - carriers 314, 317, 319, 321–323, 324, 325, 327, 331, 346, 376, 381, 388
    - cell immobilization 376
    - epoxide function 327
    - fluidized bed reactors 388
    - functional groups, 324
    - macroporous structure 327
    - synthetic 326
    - types 321
  - catalyst productivity 281
  - celite 321
  - cells
    - adherent 197, 383
    - biomass 533
    - human animal 383
  - cell–cell interactions 197
  - cell–cell transfer 398
  - cellobiohydrolases (CBH) 512, 515, 516
  - cellobiose 329, 512–514, 517
  - cell surfaces composition 377
  - cellular redox metabolism 216
  - cellulase components, synergism 515
  - cellulases 45, 113, 276–278, 287, 289, 291, 294–296, 512, 513, 515, 516
    - kinetics 514
    - synergism 515
  - cellulose
    - based ethanols 501
    - crystallinity 510
    - derivatives 321
    - elementary fibrils 510
    - ethanol 501
  - cephalosporin
    - hydrolysis 345
    - short history of 523–525
  - cephalosporin acylase 535, 536
  - cephalosporin C 23, 25, 57, 78, 122, 177, 522, 524, 526, 527, 529, 532, 537
    - to 7-ACA, conversion 533
    - amidase 16, 327, 333, 529
    - immobilization 327
    - biosynthesis 522, 525, 527, 530, 531
    - hydrolysis 533–535
    - synthesis 345

- chemical oxygen demand (COD) 366, 380, 384, 386, 387, 389, 401, 519
  - chemocatalysts 2, 3
  - chemoenzymatic syntheses 142
    - of (+)-crispine 161
  - chiral cyanohydrins
    - chemical synthesis from 190
    - hydroxynitrile lyase-catalyzed synthesis of 192
  - N-chloroacetyl L-valine 199
  - p*-chloroethyl acetate 171
  - chitosan 369, 370
  - chloroperoxidase (CPO) 157
  - 2-chloropropionate 171
  - chromatographic protein purification 249
    - chromatographic adsorbents, properties of 249
    - dynamic properties 252–254
    - mechanical stability 251, 252
    - static properties 249–251
    - and conditioning of technical and therapeutic enzymes 257
    - enzymes for therapy and diagnostics 259, 260
    - technical enzymes 257–259
    - problems 255
    - procedures 255–257
  - chromatographic separation procedure 532
  - cis*Δ9 fatty acids 166
  - cis*–*trans* isomerases 197
  - ClustalW 112, 119
  - COD. *See* chemical oxygen demand (COD)
  - CO<sub>2</sub> emissions 501
  - cofactors 15, 39, 40, 52, 111, 210, 238, 302, 304, 360, 361, 374, 484
    - regeneration 302
  - combinatorial active-site saturation test (CAST) 128, 129
  - companies 286, 315
  - competitive inhibitor 73
  - competitive product inhibition 78
  - computational design of enzymes 131, 132
  - conformational changes 314
  - continuous stirred tank reactor (CSTR) 423, 455, 458
    - catalyst productivity 463
    - membrane systems 297
    - offer constant reaction conditions 460
    - ratio of enzyme activities 460
    - reaction carried out 303
    - reaction rate 458
    - reactor configurations with 462
    - residence time
      - distribution 466, 468, 470
      - required 459
      - using mass balance 458
    - for starch hydrolysis 462
    - substrate concentration 456, 457
  - continuous tubular reactor 455, 457, 458
  - conversion rates 282
    - calculation of 282, 283
  - Corynebacterium ammoniagenes* 221
  - Corynebacterium glutamicum* 146
  - covalent binding 331–335
  - cross-linking 319, 334
  - cross-linking enzyme aggregates (CLEAs) 319, 334
  - crotonamide 185
  - crystallization 484, 485
  - CSTR. *See* continuous stirred tank reactor (CSTR)
  - cyanohydrins 171, 189, 191–194
    - (*S*)-cyanohydrins 193
    - (*R*)-4-cyano-3-hydroxy-butyric acid
      - route 540
  - 3-cyanopyridine 185
  - cyclodextrins 285, 293, 340, 343
  - cyclomaltodextrin 293
  - CYP4A1 gene 149
  - cysteine hydrolases 177, 183
- d**
- D-alanine 198
  - D-amino acid oxidase 327
  - deacetoxy-cephalosporin C (d-CephC) 531
  - deacylation 42, 46, 48, 54, 55
  - decoloring 497
  - degradation 9, 10
    - 7-ACA 539
    - anaerobic COD degradation 401
    - anaerobic degradation
      - of biomass 384, 385
      - of organic compounds 391
    - bacterial degradation to fatty acids 389
    - butyric acid 386
    - complementary mRNA 234
    - enzymatic degradation of
      - hemicelluloses 504
      - hydrocarbons 391
      - nitriles 184
      - organic matter 396
      - oxidative 391
      - progesterone 154
  - degree of polymerization (DP) 494
  - dehalogenases 182
  - dehydrogenases 39, 65, 71, 97, 100, 114, 127, 128, 130, 143, 144, 146, 155, 162, 171, 198, 214, 219, 221, 300, 302, 348, 486, 541

- cofactor regeneration 302
  - synthesis of alcohols 144, 145
  - D-enantiomers 146
  - denaturation
    - irreversible, rate constant for 94
  - denitrification 391, 538
  - 5-deoxy-5-ethyl-D-xylulose 196
  - deoxynucleotides (dNTPs) 121
  - deoxyribose-5-phosphate aldolase (DERA) 541
  - deracemization 160
    - of  $\alpha$ -MBA 160
    - via nucleophilic displacement 171
  - desymmetrizations 171
    - prochiral hydroxyglutaronitrile 187
    - prostereogenic compounds 143, 175
  - detergent enzymes 296, 294
    - formulation 280
  - detergents 280, 294–296
  - dextran 58, 280, 323
  - dextrin 8, 351
    - conversion to glucose 504
    - production, process 9, 494
  - D-fructose diphosphate (FDP) 195
  - D-glyceraldehyde-3-phosphate 195
  - DHAP-dependent aldolases 195, 196
  - diastase 9
  - diastereomers 159, 197
  - Diels–Alder reaction 132
  - diffusion coefficients 363
  - diglycerides 349
  - trans*-dihydroperillaldehyde 159
  - dihydroxyacetone phosphate (DHAP) 194–196, 214, 215
  - diisopropyl ether 193
  - dimensionless numbers 466
  - dimethylformamide (DMF) 86, 126
  - discontinuous stirred tank reactor 455, 457
  - DKR. *See* dynamic kinetic resolution (DKR)
  - DNA repair 121
  - DNase 121
  - DNA shuffling 122
  - downstream operations 478
  - downstream processing, of enzymes 245–249
  - dry mill ethanol process, enzymes for 505
  - dynamic kinetic resolution (DKR) 143, 170–172
    - of allylic alcohol using Pd(0) 172
    - improvement 172
    - principle 171
    - requirements 171
    - secondary alcohols using ruthenium catalyst 172
- e**
- Eadie–Hofstee plots 75
  - EGSB 366, 383, 389, 390
  - electron transfer system 150, 398
  - electrophiles 52
  - enantioselectivity 3, 72, 87, 94, 95, 115, 124, 126, 130, 152, 154, 159, 160, 167–170, 172, 175–177, 180, 181, 183, 187, 188
  - endoglucanases 513, 514, 516
  - endohydrolases 43
  - endopeptidase 43
  - end points 76–79
    - for kinetic resolutions of racemates 82
    - optimal yields 79
    - pH dependence of yield at 79–82
  - engineered monoamine oxidase (MAO-N-5) 160
  - enoate reductase-catalyzed reductions 158
  - enoate reductases 157
  - enol esters 166, 171
  - entrapment 368, 372, 399
  - environmental impact assessment 452, 453
    - E-factor 453
    - environmental hazardous quotients 453
    - indicators 452, 454
    - mass, or intensity, index (MI) 453
    - quantitative assessment 453
    - total environmental impact (EI) 453
  - enzymatic biodiesel transesterification 521
  - enzymatic hydrolysis 509, 510, 520
  - enzymatic isomerization 500
  - enzymatic processes, industrial process realization 529
  - enzyme activity 457
  - enzyme adsorption 245, 249, 250, 251, 253, 254, 255, 319, 321, 329, 330, 431, 437, 514, 515
    - to cellulose. 515
    - isotherms 254, 256, 314, 320, 431, 482
    - Langmuir adsorption isotherm 252
    - maximal adsorption capacity 251
    - rate 528
    - time dependence 253
    - unwanted irreversible 319
  - enzyme application 277
    - in organic chemistry 141
  - enzyme-based production processes 19–22
  - enzyme-catalyzed processes
    - in aqueous suspensions 84–85
    - changes in rates, *k<sub>cat</sub>*, *K<sub>m</sub>*, and selectivities 85
    - concentration gradients at phase boundaries 83

- kinetically controlled 22, 24, 25, 33, 50, 54–60, 68, 76, 79, 88, 90, 95, 100, 177, 178, 238, 435, 440, 444, 529, 530
- in nonconventional solvents 87
- changes in rates,  $k_{cat}$ ,  $K_m$ , and selectivities 89, 90
- with slightly soluble products and substrates 83
- in two-phase system 86
- enzyme-catalyzed resolution 55
- enzyme classification 33, 35
  - CATH Protein Structure Classification 36
  - EC classification system 35, 36
- enzyme deactivation 304, 429, 514, 515, 539
- enzyme discovery 111
- enzyme-encoding gene, identification 112
- enzyme engineering 115, 295
- enzyme function 33, 41
  - mechanism 41–43
- enzyme immobilization 13, 317, 319–323, 326, 327, 330, 341, 351, 360, 397
- enzyme modification 99, 280
- enzyme-producing organism 226
- enzyme-product complex 48
- enzyme productivity
  - in animal and plant tissues and microorganisms 228
  - calculation 285
  - decreases with increasing yield 346
  - reasons for development 142
- enzyme sources 227
  - GRAS microorganisms 227
  - pancreatic tissue 227
  - for rennet 227
- enzymes structure-function relationships 514
- enzyme technological process, patent on 530, 531
- enzyme yield 37, 231, 234, 236, 244, 276
  - improvement 231–233
  - periplasmic and extracellular enzymes 236
  - lipases 243–245
  - penicillin amidase 238–243
  - processes influencing 233–236
- epimerases 197
- epoxidations 157, 178, 394
- epoxide groups 333
- epoxide hydrolases (EHs) 114, 129, 143, 178–182
  - mechanism 179
- equilibrium-controlled hydrolysis 24, 25, 69, 433, 528
- equilibrium-controlled processes 22
  - yield, factors for enzymes 94, 95
- equilibrium-controlled reactions 55, 56, 66
- Erodine 12
- errorprone polymerase chain reaction (epPCR) 120, 122, 125
- Escherichia coli* 52, 121, 151, 174, 189, 210, 214, 238, 239, 242, 258, 346, 361, 368, 440, 486, 525, 536
  - engineered pathways for 216
  - enzymatic reactions and direct carbon flow 215
  - mutant 220
  - producing 1,3-PD in aerobic fermentation 215
  - recombinant 221
  - screening, to produce penicillin amidase 230
  - whole-cell biotransformation system
    - conversion of D-fructose to D-mannitol 218
- EGSB 389
- electron transfer 398
  - biofilm 398
  - cytochromes 398, 399
- entrapment 368, 374
  - alginate 372
  - yeast 399
- enzyme
  - adsorption 330
  - aggregates 319
  - applications 277
  - engineering 295
  - inactivation 306
  - market share 277
  - productivity 285, 346
  - technical 287
- epoxide groups, binding 333
- esterases 63, 87, 113, 119, 122, 123, 126, 165, 166, 169, 172, 277, 287, 329
  - amidases 287
  - from *Arthrobacter globiformis* 174
  - esterase-catalyzed resolutions 174
  - from *P. fluorescens* (PFE) 130
  - pig liver esterase 175, 176
  - recombinant 173
- esters
  - enol esters 166, 167, 171
  - fatty acid alkyl esters (FAAE) 216
  - fatty acid esters (FAEs) 349
  - fatty acid ethyl esters (FAEE) 215
  - fatty acid methyl esters 166
  - methyl/ethyl esters 199, 349
  - nitrate esters 158
  - (S)-*p*-nitrophenyl esters 124, 125
  - trifluoroethyl esters 167

- of umbelliferone 123
- for use in cosmetic applications 142
- vinyl esters 167
- ethanol 215, 501
- acid-catalyzed steam, schematic flowsheet 518
- fermentation technologies 503
- ethyl (*S*)-4-chloro-3-hydroxybutanoate 114
- Eupergit® 327
- E*-value 143
- exhaust gas purification 391
- exoglycosidases 50
- exohydrolases 43
- exopeptidases 43, 50

## f

- fatty acid alkyl esters (FAAE) 216
- fatty acid esters (FAEs) 349
- fatty acid ethyl esters (FAEE) 215, 216
- fatty acid methyl esters 166, 215
- fatty alcohols 215, 216
- fjh* gene 218
- FDP aldolases 195
- fermentation 9–11, 10, 11, 15, 17, 153, 215–217, 216, 236, 241, 245, 248, 279, 360, 384, 396, 503, 504, 505, 507, 509, 517, 518, 521, 525
- fixed bed reactors 463
  - advantages 463
- flocculation 366, 378
- fluidized bed reactors 464, 465, 466
  - for anaerobic wastewater treatment 390, 465
- fluorescence-activated cell sorting (FACS) 123
- fluorogenic assay, based on umbelliferone derivatives 123
- food processing 14
- formaldehyde dehydrogenase (FLD) 221, 222, 302, 303
- formate dehydrogenase (FDH) 147, 162, 198, 218, 219, 221, 300, 302, 303
- fossil fuel 519
- free energy 52–54, 92, 521
- Fru-aldolases 195
- fructo-oligosaccharides (FOS) 340, 342, 345
- fructose 335
- fructosyltransferases 342, 344
- fruit, processing 289
- fuel ethanol 501–503
- functional groups 25, 33, 40–42, 54, 75, 280, 313, 318, 324, 325, 326, 328, 330, 331

## g

- galacto-oligosaccharides (OS) 340
- $\alpha$ -galactosidase 340
- $\beta$ -galactosidases 16, 39, 58, 113, 259, 279, 285, 315, 333, 339, 340, 444
- GDP-fucose 221
- GDP-mannose 221
- gel formation, mechanisms of 369, 371
- gene shuffling 14
- genetic engineering 166, 261, 294, 296, 340
  - impact 276, 278
- genome 213
- Geobacter* sp 398
- Geotrichum candidum* 166
- global warming 5
- Glu-7-ACA hydrolysis 527
- glucanases 113, 277, 289, 504, 505, 512
- glucanotransferases 293
- glucoamylases 14, 16, 45, 46, 50, 292, 293, 375, 493, 496, 497, 500, 504, 505
  - genetic modification 293
  - stabilization 293
- Gluconobacter oxydans* 361
- glucose-1-dehydrogenase 130
- glucose dehydrogenase (GDH) 541, 542
- glucose–fructose isomerase 197
- glucose–fructose syrups 493, 497
  - manufacture of 497–500
  - quality requirements 500
- glucose isomerases 50, 293, 314, 335, 336
  - commercial immobilized 338, 500
  - immobilized 13, 14, 337, 338, 464, 497, 498–500
- glucose isomerization 281, 335, 336, 463, 498
  - mechanism 335
  - process, flow scheme 499
- glucose oxidase (GOD) 367
- $\beta$ -glucosidases 24, 93, 217, 512, 516
- L-glutamate 146
- glutamate racemase 198
- glutamine 102, 132, 187, 279
- glutaryl-7-ACA 529, 533
- glutaryl amidases 529, 530
- glycerol-3-phosphatase 214, 215
- glycerol-3-phosphate 196, 214
- L-glycerol-3-phosphate 196
- glycerol phosphate oxidase (GPO) 196
- glycerol trinitrate (GTN) 158
- glycine-dependent enzymes 194
- glycoamylase 42, 45, 46, 50
- Glycochips 345
- glycoconjugates 197
- glycosidases 277, 287
- glycosidation 285, 344

- glycosides 10
- glycosylation 46, 47, 482
- glycosyl fluorides 344
- glycosyl hydrolase family 61 (GH61) 516
- glycosyltransferases 161, 290, 293, 338, 340–343, 341, 343
  - immobilized 340
- glycosynthases 344
- granulation 366, 378
- granulated formulations 280
- GRAS organisms 229
- green chemistry 466
  
- h**
- haloalcohol dehalogenase
  - catalyzed ring opening of *p*-nitrostyrene oxide 183
  - mechanism for reversible epoxide ring opening catalyzed by 182
- haloalkane dehalogenase 182
  - feature 182
- halohydrin dehalogenase (HHDH) 129, 541, 542
- heme peroxidase 126
- hemiacetals 152, 171, 541
- hemicellulases 16, 289, 291, 504, 512
- hemithioacetals 171
- heterogeneous biocatalyst 314
- Hevea brasiliensis* 112, 189
- hexokinase 40, 41, 58
- high fructose corn syrup (HFCS) 14, 25, 293, 335, 451, 497
- His–Asp dyad 132
- HisA variants 122
- histidine 69, 122, 132, 179, 191, 250, 318, 330
- Hit mutants 124
- HMG-CoA reductase inhibitors 540
- homogeneous aqueous solutions 89
- homologous enzymes 112, 120, 130
- hydantoinases 126, 146, 187–189, 188, 197, 235, 288, 315
- hydantoins 171, 187, 189, 210, 346
- trans*-hydrogenation 158
- hydrogen peroxide 151, 157, 196, 288
- hydrogen sulfide 392
- hydrolases 27, 55, 57, 58, 63, 113, 165, 277
- hydrolysis
  - biopolymers 43
  - and biotransformation of carbohydrates 335–345
  - cellulose 217
  - cephalosporin C 25, 122, 345
  - with  $\alpha$ -chymotrypsin 65
  - diethyl ester 168
  - epoxides 179
  - lactose 24
  - nitriles 183, 185
  - penicillins 13, 14, 17, 19, 78, 80, 81, 102, 283, 345, 528
  - with proteinase K 65
  - starch 276
  - stereoselectivity 65
  - styrene oxide 181
- hydrolytic carbohydrate reactions 339
- 4-hydroxybenzaldehyde 191
- p*-hydroxycinnamic acid 361
- 3-hydroxy ester 122
- hydroxylated carboxylic acids 151–153
- 6-hydroxy-L-norleucine 148
- hydroxynitrile lyase (HNL) 112, 141, 143, 189–193, 485
- $\alpha$ -hydroxynitriles 189
- p*-hydroxystyrene 361
- L- $\beta$ -hydroxyvaline 148
  
- i**
- immobilization, by entrapment 368
  - entrapment in ionotropic gels 369
  - principle 369–372
- entrapment, in polymeric networks 368, 369
- entrapment of cells in alginate 372–375
- immobilization techniques 126, 298, 349
  - binding methods 330
  - adsorption 330, 331
  - covalent binding 331–335
  - common carriers for 319, 320, 322
  - crosslinking 319
  - functional groups 318
  - via glutaraldehyde 332
  - hydantoinase 210
  - inorganic carriers 321
  - of microorganisms (*See* immobilized microorganisms)
  - organic synthetic carriers 326–330
  - parameters of 317–319
  - polysaccharides and derivatives, used for 321
  - principles 317
  - procedures for glucose isomerase 337
  - properties of matrices 319, 320
  - reason 314
- immobilized biocatalysts 411
  - calculated and experimental data 437–439
  - concentration gradients, problems caused by 442
  - continuous stirred tank reactor 423–425
  - distribution and conformation 429

- effectiveness factors 414–416
- and concentration profiles of particle 418–422
- effectiveness factors, determinations of 436
- essential properties, determination of 425, 428
- improving performance 441
- intrinsic properties 431–434
- kinetic characterization 430, 431
- packed bed reactor/stirred batch reactor 424, 425
- physicochemical properties 428, 429
- productivity 436, 437
- reaction rate, function of particle radius 416–418
- selectivities 435, 436
- space–time yield
- and effectiveness factors for different reactors 422, 423
- factors influencing 413, 414
- stability 436, 437
- stationary charge density 429, 430
- immobilized cell
  - mass transport 362
  - physiology 364
- immobilized enzymes 314
  - advantages 278
  - applications 335–346
  - commercial processes 315, 316
  - disadvantages 278
  - limitations 317
  - productivities 314, 336
  - stabilization 314
  - standard method 319
- immobilized microorganisms 360
  - advantages 360
  - aggregation/flocculation 364–367
    - characteristics of life 367
    - conditions for 366
  - biocompatible matrices 369
  - bioflocs 363
  - cell immobilization carriers, requirements for 376
  - in different supports 375
  - diffusion–reaction–growth correlations 364
  - disadvantages and problems 361
  - immobilized cell physiology 364
  - industrial applications 362
  - influenced by mass transport and 362
  - interaction 377
  - mass transport 362
  - methods 365
  - modifications in microenvironment 362
  - physiology 364
  - principles 362
  - PVA as matrices 368
- immobilized mixed cultures 391, 392
- immobilized yeast cells 375
- impeller 474, 475
- inactivation 283–285, 306
  - kinetics 284, 285
  - rates 284
- industrial applications, of enzymes 14, 27, 170, 217, 277, 290, 317, 340, 362
- industrial starch hydrolysis, enzymes for 495
- infusorium 10
- inhibition, 282, 283
  - competitive 73
  - Eadie–Hofstee plots 75
  - mixed 74
  - noncompetitive 74
- insoluble enzymes 313
- insulin 57, 177
- integration of process
  - chemical and enzyme processes 28
  - chromosomal integration of genes 217
  - enzymatic steps into starch processing 451
  - racemization reaction 484
  - steps and external constraints 450
- intramolecular autolysis 93
- inulin 339
- inulinase 339
- invertase 339
  - sucrose by hydrolysis 305
- in vitro* evolution 3, 27, 94, 99, 100, 118, 121
- ion-exchange resins 326
- ion exchangers 331
- ionic liquids (ILs) 89
- ionic polysaccharides 369
  - structures of 370
- ionotropic gel 368
  - formation 399
- isoamylases 293, 497
- isobutyramide 185
- isolated enzymes, as biocatalysts 226
- isomalto-oligosaccharides 46, 293, 342
- isomaltose 11, 46, 50, 293, 482, 497
  - thermodynamic data 80
- isomaltulose ( $\alpha$ -D-glucosyl-1,6-D-fructose) 16, 23, 315, 340, 341, 342
  - production 342
- isomerases 197, 198, 277
- isomerization 20, 280
  - glucose 20
  - of glucose (Glu) 78
- isopenicillin N 521, 526, 527

- isopropanol 145, 146, 531, 533  
 isopropenyl acetate 166, 171  
 ISPR. *See* process technology
- k**
- $\alpha$ -carrageenan 370  
 Kemp eliminase 131  
 keto–enol tautomerization 167  
 $\alpha$ -ketoglutarate 215  
 ketone 114, 143, 154, 156, 158, 161, 162, 164, 190, 193, 486, 542  
 ketoreductase 142, 143, 541, 542  
 3-ketosucrose ( $\alpha$ -D-ribo-hexopyranosyl-3-  
 ulose- $\beta$ -D-fructofuranoside) 344  
 kinetically controlled processes 22, 24, 55, 77, 78, 176  
 – maximum product concentration 78  
 – of soluble *N*-acetyl-(*S*)-Tyr-(*S*)-Arg-NH<sub>2</sub> 84  
 kinetic resolution 143  
 – of aryl aliphatic tertiary alcohol acetates using  
 double mutant 170  
 – lipase-catalyzed kinetic resolution  
 -- by acylation 167  
 -- acyl donors used in 167  
 -- by hydrolysis 167  
 – yield 143  
 kinetic resolution, of racemic amino  
 acids 463  
 kinetics 282  
 – of enzyme-catalyzed reactions 59–68, 281  
 K<sup>+</sup> ions 371
- l**
- lactase 289  
*Lactobacillus brevis* 146  
*Lactobacillus bulgaricus* 483  
*Lactobacillus fermenti* 198  
 lactose, hydrolysis 289, 339  
 L-amino acids, production 347  
 L-leucine 146, 303, 304  
 L-*tert*-leucine 148, 302  
 leucine dehydrogenase (LeuDH) 146, 302, 303  
 – reaction mechanism 147  
*Leuconostoc oenos* 368  
 levansucrases 57  
 Lewis acid 194  
 life cycle analysis 519  
 lignocellulose 215, 276, 508, 512, 517, 521  
 – biomass 451, 509  
 – hydrolase activities 521  
 – pretreatment 509  
*Linum usitatissimum* 189  
 Lipase Database 36  
 lipases 50, 58, 69, 83, 93, 108, 113, 124, 165, 167, 170, 243–245, 295, 296, 316, 331, 333, 334, 483  
 – applications 348, 349  
 -- immobilized 348  
 -- in organic chemistry, reasons for 166  
 – from *B. subtilis* 130  
 – catalyzed ester hydrolysis of butyrate  
 ester 165  
 – changes in enantioselectivity 126  
 – classification 166  
 – enantiopreference, empirical rule 168  
 – eukaryotic 244  
 – exhibit high enantioselectivity and  
 stability 168  
 – food applications 289  
 – immobilized 329, 348  
 – industrial applications 170  
 – for kinetic resolution of carboxylic  
 acids 168  
 – posttranslational processing 244  
 – primary alcohols resolved using 169  
 – secondary alcohols resolved using 169  
 – vs. esterases 166  
 Lipitor<sup>®</sup> 129  
 lipitor side chain synthesis, biocatalytic  
 process 540–542  
 liquid hot water pretreatment (LHW) 512  
 living modified organisms (LMOs) 1  
 loop reactors 461  
 lyases 27, 36, 59, 112, 173, 182, 189  
 – aldolases (*See* aldolases)  
 – hydroxynitrile lyases 189–193  
 lysine 102, 131, 146, 187, 194, 318, 332  
 L-lysine 146
- m**
- maceration products 290  
 magnetic adsorbent particles 483  
 Maillard reaction 335  
 malt extract 12  
 maltodextrins 293  
 maltose 50, 78, 292, 293, 342, 344, 494, 497  
 – thermodynamic data 80  
 maltotriose 494, 496  
 mammalian cells, immobilized 361  
*Manihot esculenta* 189  
 mass balances 430, 455, 462  
 – for cascade 462  
 – CSTR in steady state 457  
 – mass indices 453  
 – of reactor 457  
 mass transfer 3, 25, 83, 90, 236, 254, 314, 361, 362, 373, 392, 416, 420, 441, 457, 468

- external 460, 468, 476
  - limitations
  - due to adsorption of molecules 437
  - due to growing cells in the catalyst matrix 361
  - in heterogeneous biocatalysts, 314
  - and operational effectiveness factor 457
  - in reactors 476, 477
  - material, support 382
  - matrix, secondary 388
  - mdh* gene 218
  - medium design 279
  - membrane processes 300, 304, 305
  - membrane systems 297
    - advantages 305
    - configurations 299
    - disadvantages 305
    - industrial processes with 300, 301
    - principles 297
    - processes 300, 305
    - production of L-leucine 302, 303
    - scheme of production system 298
    - separation 481
  - metabolic engineering 210–214
    - application, cells requirement 212, 213
    - problems solved by 211
    - productivity, and product yield 211, 212
    - quantitative relations for fluxes  $J_i$  212
    - strategies to improve xylose fermentation 216, 217
  - metabolic flux 210, 213, 214
  - metabolomics 213
  - metagenome libraries 113
  - metagenomes 96, 231
  - metal ions, elimination 497
  - metallopeptidases 39, 43, 177
  - methacrylamide 185
  - methanogenic bacteria 384
  - Methanotherx soehngeni* 366
  - L-methionine 126, 188, 481, 484
  - $\alpha$ -methyl-D-glucoside 10
  - methyl esters 349
  - MFC. *See* microbial fuel cells (MFC)
  - Michaelis–Menten-based model 516
  - Michaelis–Menten constant 53, 59–62, 64
    - hydrolases 64
    - influence of ionic strength 75, 76
    - pH dependence 69–71
    - temperature dependence 71–73
  - Michaelis–Menten kinetics 212, 386, 401, 418, 421–423, 457, 459, 460, 462
  - microbial aggregates 382
    - carriers 388
  - microbial fuel cells (MFC) 396–399
    - efficient use of bacterium 399
    - electrodes 397
    - electron transfer mechanisms 398
    - integration 397
  - microcarriers 383
  - microchannel reactors 329
  - microorganisms
    - immobilization, microenvironment 362
    - immobilized 360, 361, 369, 374, 375
  - microsomes 369
  - microstructured flow reactors 466
  - microtiter plate (MTP)-based formats 123
  - mixed culture 466
  - mixed inhibition 74
  - mixing 471
  - mixing time 468, 471
  - monoamine oxidases 159, 160
  - monooxygenases 114, 148, 149, 156
    - P450 monooxygenases 149–151
    - reactions catalyzed by 149
  - moxalactam 122
  - multipoint 334
  - mutagenesis screen 344
  - mutants. *See also* mutations
    - double 117, 170
    - of esterase 122
    - Hit mutants 124
    - homology between mutants of cephalosporinase gene 122
    - immobilized 536
    - libraries, methods to create 118
    - obtained by epPCR and site-directed mutagenesis 125
  - mutarotation 45
  - mutations 95, 118
    - neutral (or silent) 95
    - point 118, 121
    - random 119
    - of single amino acids 293
    - spontaneous 50
  - mutazyme 121
  - Mycobacterium tuberculosis* 154
- n**
- N-acetylmannosamine (ManNAc) 196
  - N-acetylneuraminic acid (NeuAc) aldolase 196, 197
  - NADH 15, 145, 147, 161, 163, 218, 221, 297, 302
  - NADH-dependent 1,4-butanediol dehydrogenase 222
  - NAD(P)H 111, 142, 144, 145, 146, 149, 156, 157, 158, 159
  - nanoparticles 330

- nanostructured magnetic materials 330
  - naproxen 172
  - National Environmental Policy Act (NEPA) 520
  - native enzymes 279
  - natural evolution 94
    - changes in enzyme properties by 96–99
    - enzyme stability 99, 100
    - kinetic constants and selectivities of penicillin amidases 98
    - selectivity in kinetically controlled synthesis 100, 101
    - stereoselectivity 100
  - NDT codon 130
  - L-neopentylglycine 148
  - NHase/amidase system 185
  - NHase genes 184
  - nicotinamide 142, 185
    - commercial production 184
  - nitrate 363, 391, 392
  - nitrification 391
  - nitrilases 182, 185, 315
    - engineered 187
    - optically active arylactic acid derivatives 186
      - regioselective hydrolyses using 185
  - nitrile hydratases 182–187, 185, 347
    - crystal structure 184
    - groups requiring Fe(III) or Co(III) ions 183
    - mechanism of nitrile hydration catalyzed by 184
    - regioselective hydrolyses using 185
  - nitrite 391, 392
  - nitroaromatics (TNT) 158
  - p*-nitrobenzyl ester 126
  - nitrogen elimination, from wastewater 391
  - NNK approach 130
  - noncompetitive substrate inhibition 74, 78
  - nonpathogenic microorganisms 280
  - nonpretreated Avicel, conversion-time behavior 516
  - nonsteroidal anti-inflammatory drugs 185
  - nucleophiles 52, 55
  - nucleotide-activated monosaccharides 57
  - nucleotide-activated sugars 221, 340
- o**
- odor elimination 392
  - old yellow enzyme (OYE) family 157
  - oleic acid 166
  - olfactometric measurement 392
  - oligosaccharides (OS) 10, 24, 25, 29, 45, 50, 74, 292, 293, 338, 340, 343, 344, 496, 497
    - enzyme-catalyzed hydrolysis of
      - synthesis 343
    - optimization of enzyme production 226
  - OS. *See* oligosaccharides (OS)
  - oxidative biotransformations 361
  - oxidative degradation 392. *See also* degradation
  - oxidoreductases 27, 65, 144, 277, 278, 288, 302
  - 2-oxo-4-phenylbutyric acid 303
  - oxyanion 146, 169
  - oxygenases 148, 149
- p**
- pancreatic proteases 13
  - paper and pulp processing 290
  - Paracoccus denitrificans* 50
  - patent(s) 529–531
  - Pd catalyst 142
  - pectic enzymes, in fruit processing 289
  - pectinases 226, 289
    - preparations 290
  - pellet 366, 367
    - microbial 365
    - morphology 367
  - penicillin 57, 177, 451, 521, 523–525
    - biosynthesis 522
    - hydrolysis 307
    - production 530, 531
    - short history of 523–525
    - synthesis 345
  - penicillin acylase (PGA) 314
    - catalyzed coupling of 6-aminopenicillanic acid 178
  - penicillin amidases 13, 16, 17, 40, 42, 50, 51, 56, 65, 73, 80, 88, 99, 100, 177, 178, 228, 238–241, 244, 249, 257, 258, 277, 307, 321, 334, 346, 432, 435, 439, 463, 524, 531, 536
    - half-life 536
    - immobilized, productivity 346
    - pH stability 92
  - penicillin G 77, 528
    - hydrolysis 19, 346, 528
  - Penicillium notatum* 523
  - pentaerythritol tetranitrate (PETN) 158
  - pentose phosphate pathway 216, 217
  - peptidase-catalyzed peptide synthesis 177
  - Peptidase Database 36
  - peptidases 49, 148, 176, 177
  - peptides 49
    - bonds 177
    - mechanism of enzyme-catalyzed hydrolysis 47
    - synthesis 347
  - peroxidases 157

- pharming 229
- (*S*)-*m*-phenoxybenzaldehyde
  - cyanohydrin 194
- phenylacetone monooxygenase (PAMO) 154
- phenylacetyl-7-ADCA 528
- L-phenylalanine 121
- phenylalanine dehydrogenases 147
- 2-phenylethanol 361
- pH-independent dissociation constant 533
- phosphodiesterase 74
- phospholipases 348
- phosphorylation 214
  - of glycerol 196
- pH-T process 536, 537
- Pichia pastoris* 175, 222
  - engineered whole cells 221
- Pichia stipitis* 216
- pK-values 46, 70, 71, 76, 81, 198, 431, 434, 534, 538
- plant biomass-derived hemicelluloses 215
  - Plasmodium falciparum* 344
- PLP-dependent alanine racemase 198
- PLP-independent racemases 198
- P450 monooxygenases 128, 149–151
- POET's conventional ethanol plant 520
- polyanions 369
- polycations 369
- polyethylene 393
- polyethylene glycol (PEG) 148, 299
- polymeric networks 368
- polymers 280
- polyols 279, 280
  - protective effect 279
- polypropylene 393
- polysaccharides 280, 343, 493
  - carriers 323
  - enzymatic hydrolysis 509
  - ionic 369
  - used as carriers for enzymes 323
- polystyrene 327
- polyunsaturated fatty acids (PUFAs) 349
- polyurethane 393
- polyvinyl alcohol 280, 368
- polyvinylpyrrolidone 280
- polyvinylsaccharides 280
- porcine pancreatic lipase (PPL) 168
- pores diameter 320
- posttranslational modification 113
- power consumption 474
- pressure drop 477
- Proactinomyces erythropilis* 153
- process sustainability 451, 452
- process technology 478
  - aims 479
  - commercial 315
  - elements 480
  - external configurations for ISPR with cooling crystallization 485
  - integration 479–486
    - biphasic systems 481
    - combining continuous chromatography 484
    - industrial applications 480
    - integrated downstream operations 479
    - potential of crystallization 484
    - potential of magnetic adsorbent particles 483
    - product adsorption to solid particles 482
    - production of 6R-dihydro-oxoisophorone (DOIP) 484
    - rhamnolipid production process management 483
    - two-phase systems with ionic liquids 481
  - perspectives of ISPR in biotransformations and 481
  - reactor instrumentation 486
  - steps 479
- prochiral substrate 3-hydroxy glutaronitrile 540
- products, 315
  - adsorption 482
  - biotechnologically produced 6, 7
  - Browning products 500
  - BT products 502
  - cephalosporins derived from 525
  - environmental impact of bio-based products 453
  - of high added value 375
  - to meet human needs 6
  - with minimal waste and 5
  - produced in quantities larger than 16, 17
  - with selected types of fatty acids 348
  - with sucrose analogues as substrates 345
- productivity 281, 285
  - GI 336
- product yield 15, 20, 55, 58, 67, 76, 81, 82, 95, 103, 212, 217, 281, 451
  - condensation 58
  - to overcome limitation 486
  - pH dependence 79
  - temperature dependence 79
- progesterone 154
- 1,3-propanediol (1,3-PD) 214
- propionamide 185
- propylene glycol 280
- ProSAR (protein sequence–activity relationships) strategy 129

- Protaminobacter rubrum* 341  
 proteases 113, 115, 285, 287  
 – alkaline 294, 295  
 protein engineering 25, 37, 94, 95, 96, 115, 124, 213  
 – enzymes optimized by 127, 128  
 – strategies for 115–117  
 protein functional groups 324, 325  
 proteins, surface 331  
 protein stability 130  
 proteomics 213  
*Pseudomonas aeruginosa* 125, 174, 244, 364, 483  
*Pseudomonas diminuta* 535  
*Pseudomonas putida* 153, 156, 361  
*Pseudomonas* sp 395  
 – biofilm forming 394, 396  
 pullulanases 293, 497, 500  
 purification, of waste gas 393  
 pyranose oxidases 345  
 pyridoxal-5'-phosphate-dependent enzyme 114  
*Pyrococcus furiosus* 114, 285  
 pyruvate 143, 161, 162, 194, 196, 197, 216, 318  
 pyruvate decarboxylase 163, 216, 318  
 pyruvate/phosphoenolpyruvate-dependent aldolases 196, 197
- r**
- racemase 65, 126, 143, 171, 188, 197, 198, 210, 481, 485  
 racemization 66, 100, 143, 171, 188, 199, 484, 485  
 random mutagenesis 118  
 rate constant 94  
 rational enzyme engineering 94  
 rational protein design 117, 118  
 raw starch hydrolysis (RSH) 506  
 (*R*)-3-chloro-2-methyl propionate 170  
 (*R*)-cyanohydrins 193  
 reaction conditions 281, 385  
 – in technical processes 281  
 reactors, 390  
 – basic (ideal) 454  
 – cascade 455, 462  
 – instrumentation 486  
 – mass transfer in 476, 477  
 – for penicillin hydrolysis 463  
 – residence time distribution 468–471  
 – scale-up, dimensionless numbers 466–468  
 – three-phase 464  
 “real” reactors 455  
 recombinant DNA technology 112, 210  
 recombinant enzymes 280  
 recombinant microorganisms 231  
 recombinant pig liver esterase isoenzymes (1–5) 175, 176  
 recombinant production of enzymes 27  
 reductase 114, 148, 150, 157, 158, 216, 540  
 regiospecificity 34, 45, 54, 166, 348  
 regulations governing 260  
 – good laboratory practice 265  
 – good manufacturing practice 265  
 – by international and national authorities 266  
 – use of enzymes produced in wild-type/recombinant organisms 265  
 – use of genetically modified microorganisms 260, 261  
 –– biological containment 264–265  
 –– physical containment 261, 264  
 renaturation 91  
 residence time 457  
 – distribution 466, 468  
 rhamnolipids 483  
 rhamnose-inducible promoter 210  
*Rhizomucor miehei* 168, 348  
*Rhodococcus jostii* 154  
*Rhodococcus rhodochrous* 183, 347, 362  
 risk classes 264  
 (*R,S*)-5-(2-methylthioethyl)hydantoin 126  
 (*R,S*)-naproxen methyl ester 172  
 (*R,S*)-1-phenyl-2-butyl acetate 175
- s**
- saccharification 293  
*Saccharomyces cerevisiae* 216, 364, 484, 506  
*Saccharomyces rouxii* 484  
 safety aspects 280  
 scale up 466  
 Schiff base 131, 167, 279  
 screening-based systems 123  
 selection-based systems 121  
 selectivity 46, 56, 71, 73, 90, 95, 114, 116, 124, 160, 166, 169, 187, 291, 343, 414, 435, 436, 470, 484  
 – condensation products synthesis 100  
 – in kinetically controlled processes 90, 435  
 – substrate selectivity 173  
 semisynthetic penicillins 524, 525  
 – enzymatic and chemical production of 525  
 sensors 466  
 Sepabeads® 322, 327, 351  
 – functional groups 328  
 Sephadex® 323  
 Sepharose™ 323  
 serine 132

- serine carboxypeptidases 50
  - serine hydrolases 177
  - serine peptidases 165
  - S-ethyl thioesters 167
  - sexual mutagenesis 121
  - shear stress 476
  - Shewanella oneidensis* 398
  - sialic acid 196
  - silica carrier 321, 350
    - activation 332
  - simultaneous saccharification and fermentation (SSF) 504, 518
  - Sitagliptin 276
  - site-directed mutagenesis 14, 51
  - social assessment 452, 454
  - solubilities 23, 27, 34, 55, 86, 90, 172, 471, 485, 539
  - soluble enzymes 276, 464
    - advantages 278
    - applications 286–288
      - food applications 289, 290
      - industrial 277, 290, 291
      - disadvantages 278
  - soluble starch 292
  - sorbitol 279, 284
    - protective effect 280
  - spacers 319
  - space–time yield (STY) 77, 281, 412
    - factors influencing 413, 414
    - limitation 413
  - stability 14, 25, 87, 91, 99, 100, 284, 293, 314, 318, 319, 323, 334, 536, 541
    - biological 379
    - chemical 99, 326
    - enzymes, immobilization 314
    - operational 366, 369, 378
    - thermal 22
  - stabilization 284
  - staggered extension process (StEP) 121
  - Staphylococcus aureus* 524
  - starch 289
    - hydrolysis 9, 20, 292, 496, 498, 503
      - enzymes 494
      - modeling 493
    - liquefaction process, reactor configuration 494
    - processing 291–294, 493–497
  - steam explosion 511
  - stereoselectivities 63, 65–68, 72, 73, 90, 123, 146, 148, 159, 166, 175, 187, 191, 343, 435, 436
    - for equilibrium-controlled processes 72
    - temperature dependence 73
  - stereospecificities 55
    - binding interactions determine 66
  - steroid 9 $\alpha$ -hydroxylation 220
  - steroid  $\Delta^1$ -dehydrogenation 220
  - steroid pathway intermediates 220
  - sterol/steroid bioconversions 221
  - stirred tank reactor (STR) 455, 459
    - deviations from ideal flow in stirred vessels 467
    - mixing in 471–476
  - strain optimization 216, 217
  - Streptomyces murinus* 336
  - Streptomyces rubiginosus* 336
  - Streptomyces* sp.
    - biofilm cultures, alcaligenes eutrophus 395
  - structure–activity relationships 118
  - substrate specificity of enzymes 54
  - subtilisin 177
  - succinate 215
  - sucrose 340, 344
    - analogues 344, 345
    - hydrolysis 305
    - isomerization 341
  - sucrose ( $\alpha$ -D-glucosyl-1,2- $\beta$ -D fructose) 341
  - sucrose phosphorylase 340
  - sugar transport 216
  - surface charge 377
  - suspended cells 300
  - sustainable new enzyme processes, to meet human needs 28, 451
  - synthetic polymers 326–330
    - carrier 328
  - synthetic resins 329
- t**
- tailor-made biocatalysts 344
  - Taq* polymerase 121
  - textile industries 290
  - Thermobifida fusca* 154
  - thermodynamic data, for enzyme-catalyzed reactions 80
  - thermolysin 347, 348
  - Thermomyces aquaticus* 121
  - Thermomyces lanuginosus* 168
  - thermostable  $\alpha$ -amylase 284, 504
  - thioesterases 216
  - thioesters 167, 481
  - thiols 167
  - threonine 132
  - time dependence, of equilibrium 24
  - transaminases 65, 161–164
  - transcriptomics 213
  - transcyanation 193
  - transferases 39, 50, 55, 57, 58, 65, 100, 161, 277, 278, 288

transglycosidations 341  
transhydrocyanation 193  
transition metal catalysis 142  
triacylglycerol hydrolases. *See* lipases  
*Trichoderma reesei* 512  
– enzymes, schematic view 513  
– industrial strains 516  
trickle bed reactors 392, 464  
trickling filter 393  
trifluoroethyl esters 167  
triglycerides 348  
trinucleotides 57  
triphenylphosphonium chloride 171  
tryptophan 121, 122, 131, 318, 368, 395  
tubular reactor (TR) 455, 457, 463, 477  
– configurations 464  
– pressure drop and fluidization in 477, 478  
turnover number 53, 59–63, 132, 151, 297,  
418, 431, 432, 434  
– hydrolases 64  
– influence of ionic strength 75, 76  
– pH dependence 69–71  
– temperature dependence 71, 72  
L-tyrosine 88, 121, 132, 146, 157, 158,  
182, 199

**u**

UASB 389  
UDP-galactose 221  
UDP-glucose 221  
unit operations 478  
unorganized soluble fermenters 10

**v**

vegetable processing 289  
vinyl acetate 73, 166, 167, 169

**w**

washing performance 296  
wastewater treatment 361, 382, 465  
– anaerobic 383  
water-insoluble solid (WIS) 519  
water-soluble polyelectrolytes 369  
wax esters 215, 216  
wax ester synthase 216  
whole-cell biotransformation 154, 210  
– biocatalyst for D-mannitol formation from  
fructose in 219  
– conversion of D-fructose to D-mannitol  
218  
– D-glucose to 2,5-diketo-D-gluconic acid  
and 220  
wild-type glutaryl amidase, half-life 536  
wild-type microorganisms 229  
– classification 262, 263  
– fluorescence-activated cell sorter for  
HTS 230  
– screen for enzymes 229

**x**

XAD adsorbents 329  
XAD resins, derivatization 333  
x-ray crystallography 117  
xylanases 113, 216, 277, 289, 291  
xylose pathway enzymes 216

**y**

yeast cells, immobilized 375, 399

**z**

zinc ion 194  
zymase 11  
*Zymomonas mobilis* 163, 217, 375  
Zymotechnica 15