

Index

a

- ABM-derived catalytic material 466
- acetaldehyde (AD) 108, 110, 147, 149, 178, 179, 180, 189, 323, 324, 327, 328, 352, 378
- acetone to methyl isobutyl ketone 173–177
- acid catalysts 2, 84, 498, 506
- acid-base catalysts 2, 84, 232
- acrylates 147
- acrylic acid (AA) 86, 147, 149, 150, 311, 418
- activated carbon 2, 6, 211, 243, 383, 446, 448, 464, 468
- activation site and mechanism 227
- adenosine 5'-triphosphate disodium salt hydrate 30
- Aldol reaction 84, 352, 454, 491
- adsorption
of molecules 115, 376, 380
pressure-swing adsorption 312
- aerobic oxidation catalysis 211
- Ag@mHA-Si-(S)) nanocatalyst 418
- Ag/eggshell catalysts 457
- agar-gelatin hybrid hydrogels 39
- AgNP loaded 1,4-diazabicyclo[2.2.2] octane (DABCO) grafted mHA 419
- AgNPs 418, 419
- air treatment 374, 382
- alcohol coupling reaction 327
- alcohol oligomerization probability 181
- aldol condensation 141, 148, 152, 178, 179, 252, 310, 323–325, 350–352, 466
- alginic acid 23
- alkali doped materials 186
- alkali metal oxides 455, 462
- alkali metals 165, 182
- alkaline earth and alkali metal doped HA catalysts 300
- alkaline earth metals 6, 165, 182, 214, 465
- alkaline-earth apatites 96
- alkane oxidative dehydrogenation reactions 201, 217
- (*E*)-2-alkene-4-ynecarboxylic esters 311
- alkenoic acids 209
- alkyl lactates 147
- alkyl phosphates 49, 209
- allylamine hydrochloride 418
- alpha-tricalcium phosphate (α -TCP) 28
- Amberlyst CH28 176
- amino-acids 103, 209, 506, 508
- 2-aminoethanol 29
- 2-amino-2-ethyl phosphate ($\text{H}_2\text{PO}_4(\text{CH}_2)_2\text{NH}_2$) 49

- o*-aminophenol 465
 α -aminophosphonates 506
 3-aminopropyltriethoxysilane
 (APTES) 50, 427, 428
 2-aminopyridine 360
o-aminothiophenol 465
 ammonia 1, 29, 30, 53, 184, 249, 261,
 262, 269, 301, 308, 310, 312,
 318–319, 467
 ammonia temperature-programmed
 desorption (NH₃-TPD) 143,
 147, 251, 310
 ammonia-borane hydrolysis reaction
 318
 ammonium dihydrogen phosphate
 ((NH₄)₂HPO₄) 4, 8, 20, 21, 23,
 24, 31, 38, 53, 153, 328, 329
 amorphous calcium phosphate (ACP)
 75
 amorphous HA 317
 animal bone meal (ABM) 465
 animal bones 440, 450
 and eggshell
 waste animal bone 307, 444, 453,
 462, 466
 anion-exchange membrane (AEM) fuel
 cells 464
 apatite carbonate 442, 444, 445, 448
 apatite carbonate type A
 (Ca₁₀(PO₄)₆(CO₃)₂) 444
 apatite carbonate type B
 (Ca₁₀(PO₄)₃(CO₃)₃(OH)₂) 444
 apatite mineral 443
 apatite structure and model studies 76
 apatite thermodynamics 95
 apatite-based catalysts 75, 203
 apatite/Pd(0) catalysts 211
 apatite/Ru(III) catalysts 204
 apatites 19, 345
 as catalyst supports 346
 as catalysts in C–C bond formation
 347
 apatitic calcium phosphates 74, 88,
 89, 101, 102, 117
 apatitic channels 78, 98, 105
 apatitic crystal morphology 89
 aragonite 442, 444
 aromatic aldehydes 353, 465, 466, 487,
 488, 491, 504
 aromatic nitro compounds 512
 atomic adsorption spectroscopy (AAS)
 87
 Au-Pd bimetallic system 309
 Au/Al₂O₃ 155
 Au/HA catalysts 155, 309, 310
 Au/HA-based catalysts 310
 Au/hydroxalcite 155
 Au/MgO 155
 Au/SiO₂ 155, 310
 Au/TiO₂ 155, 310
 Au/ZnO 155, 310
 β -azido alcohol 424
- b**
- bacterial cellulose (BC) 38
 ball-milling method 32–34
 barbituric acid 353
 benzaldehyde 154, 203, 208, 210, 212,
 214, 230, 328, 353–355, 357, 358,
 360, 423, 424, 466, 487, 491,
 509–511
 benzene to phenol 183–185
 benzimidazoles 465
 benzoic acid (BAcid) 209–210
 benzophenone production 466
 benzothiazoles 465
 benzoxazoles 465
 benzyl alcohol (BA) 29, 154–156, 203,
 205, 207, 210–213, 230, 328,
 509–510

- g-benzyl-L-glutamate N-carboxyanhydride (BLG-NCA) 50
- beta tri-calcium phosphate (β -TCP) 22, 23, 28, 34–36, 41, 44, 86, 98, 100, 452, 465, 482
- bifunctional commercial ion exchange resin 176
- Biginelli condensation reaction 354
- Biginelli reaction 505, 506
- biguanide-functionalized hydroxyapatite-encapsulated- γ -Fe₂O₃ nanoparticles (HA- γ -Fe₂O₃) 303
- bimetallic catalysts 284–286, 290, 309
- bimetallic Ru-Zn/HA 6
- bimetallic supported HA 308
- biofuel additive 352
- 3-benzyl-2-phenylimidazo[1,2-*a*]pyridine 363
- 1,3-butadiène 144, 145, 323
- “biomimetic” apatites 76
- bio-oil 141, 152, 186, 188
- bioceramic composite 441, 461
- biochar 6, 453, 466
- biodegradable packaging 182
- biodiesel 186
- production
- environmental impact 300
 - esterification reaction 307–308
 - other esterification reactions 308–312
 - overall transesterification reaction 300
 - trans-esterification reactions 301–307
- bioethanol 145, 177, 180, 181, 189, 250, 329
- biofilter (adsorbent) biomaterial 446
- biofuels 180, 254, 325
- biogas production technologies 269
- biogasoline 145, 250
- biomedical/biotechnology magnetic fluids 414
- biometric method 416
- biomimetic apatites 76, 81–84, 88, 90, 92–95, 97, 98, 101, 102, 105, 113, 115
- biphasic calcium phosphate (BCP) 23
- bis-coumarin derivatives 426
- α,α' -bis(substituted benzylidene)cycloalkanones 466
- 1-(3,5-bis-(trifluoromethyl)phenyl-3-propyl)thiourea 350
- bone char 441, 446, 447, 467
- bone-derived catalyst 452, 461, 462, 466
- borohydride hydrolysis reaction 316
- borohydrides 316
- p*-bromoacetophenone 348
- Brønsted acid sites (HPO₄²⁻) 3, 108, 144, 149, 151
- Brunauer–Emmett–Teller (BET) method 90, 210, 211, 246, 249, 391, 442, 484
- bulk defective hydrogenphosphate 91, 94
- bundle-like carbonated apatite 39
- butadiene 144, 145, 250, 320, 323, 327
- 1,3-butadiene 144, 145, 250, 323
- butan-2-ol model reaction 223
- butanol 177
- formation of 150
 - preparation 177
- n*-butanol 26, 27, 86, 108, 177, 178, 180, 249, 250, 299, 320–324, 352
- 1-butanol 8, 29, 144, 181, 250–252, 327
- 2-butanol 23, 114, 142–144
- 1-butene 143
- 2-buten-1-ol 149, 251, 324

- butyraldehyde 149, 181
 B-type hydroxyapatite 328
- C**
- CaCO₃ nanoparticles 30
 Ca_{10-x}Co_x(PO₄)₆(OH)₂ 285
 Ca-deficient HA 47, 141, 143, 144,
 146, 152, 154, 272, 281, 282, 317
 supported Co and Ni catalysts 154
 CaHPO₄ 28, 29, 31, 33, 44, 482
 Ca(H₂PO₄)₂ 31, 35
 Ca_{10-x-B}[□]Ca_{x+B}(PO₄)_{6-x-B}(HPO₄)_x
 (CO₃)_{A+B}(OH)_{2-x-2A-B}[□]OH_{x+A+B}
 87
 Ca_{10-x}(HPO₄)_x(PO₄)_{6-x}(OH)_{2-x} 156
 Ca_{10-z}(HPO₄)_z(PO₄)_{6-z}(OH)_{2-z}·nH₂O
 47, 85
 Ca_{8.93}(HPO₄)_{1.56}(PO₄)_{4.44}(PO₄R)_{0.63}
 (OH)_{0.14} 49
 calcination temperature 23, 36, 147,
 148, 186, 273, 303, 305, 442, 444,
 451, 452, 462, 492, 507
 calcined eggshell sorbent membrane
 461
 calcined eggshell-derived catalyst (CaO)
 459
 calcite 442, 444, 448, 482, 484
 calcium acetate ((CH₃COOH)₂Ca) 4
 calcium acetate (Ca(CH₃COO)₂) 22,
 23
 calcium carbonate (CaCO₃) 6–8, 20,
 21, 23, 29–31, 33, 36, 46, 47, 154,
 300, 304, 437, 438, 441–452, 459,
 465, 468
 calcium carbonate/oxide/phosphate
 445
 calcium hydroxyapatite (Ca₁₀(PO₄)₆
 (OH)₂, HA) 270, 299
 calcium hydroxyapatite (HA,
 Ca₁₀(PO₄)₆
 (OH)₂) 270
 calcium looping 459
 calcium nitrate (Ca(NO₃)₂) 4, 22–25,
 36, 39, 40, 49, 53, 171, 281, 304,
 308, 393, 397, 419
 calcium nitrate (Ca(NO₃)₂·4H₂O) 4,
 22–25, 36, 39, 49, 53, 171, 281,
 304, 308, 393, 397, 419
 calcium oxide (CaO) 34, 444, 445, 447,
 449, 451, 455, 457, 458, 460, 461,
 462, 465, 468, 492
 calcium phosphate 20, 23, 25, 50, 73,
 74, 78, 82, 90, 100–102, 104, 116,
 163, 171, 215, 216, 413, 418,
 437–438, 441, 442, 444–446, 448,
 451, 462, 465, 466, 482
 hydrolysis 28
 calcium supplement 445
 calcium-deficient hydroxyapatite 7, 8,
 46, 47, 212, 300, 303, 314, 329
 Ca_{10-y}Ni_y(OH)₂(PO₄)₆ 277
 Ca_{9.5}Ni_{2.5}(PO₄)₆ catalyst 173
 Ca_{10-y}Ni_y(PO₄)₆(OH)₂ 285
 Ca_{3-x}Ni_x(PO₄)₂ 277
 Ca_{9.5}Ni_{2.5}(PO₄)₆ 171–173
 Ca(NO₃)₂ 4, 8, 11, 20, 22–25, 27, 31,
 35, 38, 39, 53, 153, 154, 305, 308,
 327–329, 389
 CaO/biomass ratio 458, 459
 CaO—CeO₂/HA catalysts 305
 Ca(OH)₂ 7, 20, 21, 31, 33, 35, 36, 46,
 47, 49, 101, 143, 152, 300, 386
 capillary microfluidic techniques 24
 Ca/P ratio 29, 34, 38, 44, 46, 47, 83, 85,
 86, 87, 142–148, 152–155, 157,
 178, 189, 204, 212, 241, 242, 250,
 251, 262, 281, 282, 310–312, 314,
 323, 346, 352, 418, 450
 influence of Ca/P ratio 143–152
 Ca₁₀(PO₄)_{6-x}(SiO₄)_x(OH)_{2-x} 48
 Ca₁₀(PO₄)₆X₂ 212
 carbon dioxide
 temperature-programmed

- desorption (CO₂-TPD) 147, 152, 153, 259, 310, 316
- carbon monoxide oxidation 454
- carbon nanofiber 2, 467, 468
- carbon nanotubes (CNT) 2, 8, 284, 388, 467, 468
- carbon-carbon bond formation 347, 494
- carbon-carbon cross-coupling reaction 347
- carbonate hydroxyapatite (CO₃HA) 182
- carbonate substituted synthetic apatites 92
- carbonated biomimetic apatites 93
- carbonated hydroxyapatite 177
- carbonation-calcination reactions 460
- cassiterite (SnO₂) phases 311
- catalysis 1, 414
 - HAP analogs and their catalytic applications 425–426
 - HAP catalysts and green chemistry 426–430
 - magnetic HAP nanoparticles 420–425
 - catalyst additives 2, 492
 - catalytic oxidation 455–458, 467
- catalytic selective hydrogenation 454
- Ca₁₀(VO₄)₆(OH)₂ 289
- Ca₁₀(VO₄)_x(PO₄)_{6-x}(OH)₂ solid solutions 86, 225, 227
- CeO₂-doped HA 353
- CeO₂-supported catalyst 286
- cerium nitrate (Ce(NO₃)₂·6H₂O) 53
- cetyl trimethyl ammonium bromide (CTAB) 27, 222, 303, 308, 357, 386
- chemical doping with nanoparticles 416
- chemical precipitation 44, 154, 182, 241, 305, 315, 328, 417
- chicken eggshells 437, 444, 449, 457, 460, 462
 - derived CaO sorbents 460
- chicken meat 438, 439
- chitosan-doped HA 354
- chlorapatite 76, 100, 104, 112
- C₂-hydrocarbons 164
- Claisen–Schmidt condensation 3, 466, 491–494
- Claisen–Schmidt reaction 454
- clean combustion 269, 319
- Co₁₀(PO₄)₆(OH)₂ 222
- Co(0)HA nanoclusters 317
- co-precipitation method 20–22, 53, 110, 302–304, 327, 416, 425
- Co/α-Al₂O₃ reference catalyst 290
- Co/Al₂O₃ catalyst 12, 254, 280
- Co/CeO₂ catalyst 281
- Co/HA system 289
- CO₂ emissions 180, 253
- CO₂ methanation 253
- CO₂–Fisher–Tropsch (FT) synthesis 253
- cobalt phosphate 3, 401, 402
- cobalt phthalocyanine/apatite 204, 210
- cobalt pyrophosphate 3
- cobalt-hydroxyapatite (Co/HA) catalyst 223, 328
- CoFe₂O₄ magnetic oxide nanoparticles 427
- collagen 437, 443
- concentrated oil-in-water (O/W) emulsion technique 26
- condensation reactions
 - Claisen–Schmidt condensation 491–494
 - Knoevenagel reactions 487–491
 - Michael addition 494–496
- conjugated carboxylic esters 311
- conventional energy 311
- CoO/Sr₁₀(PO₄)₆(OH)₂ 219

- cooked waste fish bone (CWFB) 305
 “core-shell” product 21
 cross-coupling reaction 141, 273,
 347–350, 361, 453, 454, 466, 499,
 500, 502
 crossed-aldol condensation reaction
 466
 crotonaldehyde 110, 149, 178, 179,
 189, 320, 323, 511–512
 Cu/CeO₂ 177
 cyanoacetamide 354
 β-cyanohydrin 424
 3-cyanopyridine 466
 β-cyclodextrin conjugated γ-Fe₂O₃/HA
 solid-liquid phase transfer
 catalyst 424
 cyclooctane 29
 cyclooctanol 29
 cyclophosphates 3
- d**
- data storage 415
 decahydroquinoline (DHQ) 244
 dehydrogenation reactions 52, 114,
 201, 217–229, 241, 257–262, 328
 Density Functional Theory (DFT)
 calculations 54, 83, 176, 378
 deposition-precipitation (DP) method
 309
 Dess Martin periodinane (IBX) 203
 2,6-diamino-pyran-3,5-dicarbonitriles
 354, 363
 di-ammonium hydrogen
 orthophosphate 308
 1,4-diazabicyclo[2.2.2]octane 349, 419
 di-calcium hydrogen phosphate
 di-hydrate 450
 di-sodium hydrogen phosphate
 (Na₂HPO₄) 25, 39, 304, 388,
 449, 450, 453, 493
 diacetone alcohol (DAA) 175, 176
 diadsorbed mesityl oxide 176
 dialkyl phosphites 51
 diammonium hydrogen phosphate
 ((NH₄)₂HPO₄) 4, 20–24, 31, 38,
 39, 40, 53, 153, 328, 329, 393, 419
 1,3-dicarbonyl compounds 466
 2,4-dichlorophenol (2,4-DCP) pollutant
 degradation 466, 467
 Diels–Alder reaction 108, 454
 diethanolamine 29
 diethyl
 2,6-dimethyl-4-phenyl-1,4-dihyd-
 ropyridine-3,5-dicarboxylate
 357
 diethyl ether (DEE) 327, 329
 2,5-diformylfuran (DFF) 325, 429
 1,4-dihydropyridines 357, 358, 364,
 465
 3,4-dihydropyrimidin-2(1H)-one 354,
 363, 505
 dimethylbarbituric acid 353
 5,5-dimethylcyclohexane-1,3-dione
 357
 4,4-dimethyl-1,3-dioxane 144
 dioctyl sulfosuccinate sodium salt
 (C₂₀H₃₇NaO₇S) 25
 4-(1,3-diphenylprop-2-ynyl)morpholine
 360, 364
 dispersion of metals 214, 246, 261, 417
 dissodium oleyphosphate
 (DSOP : C₁₈H₃₅Na₂O₄P) 49
 dissolution-precipitation equilibrium
 44, 45
 dissolution-precipitation mechanism
 112, 208, 376
 divalent cobalt ions 219–224
 1,3-diyne derivatives 350
 1-dodecanol 211
 dodecyl phosphate (C₁₂H₂₇O₄P) 25

- doped photocatalytic HA 378–379
- double decomposition method 21, 354
- double emulsion droplets 24, 25
- dry mechanosynthesis 34, 35, 36, 48
- dry methods 20, 35–36, 417
- dry reforming of methane (DRM) 4, 6, 7, 12, 115, 153, 154, 170, 231, 269, 454, 514
- dual-phase membrane 461
- e**
- eggshell and animal bones
- biodegradation 437
 - biofilter (adsorbent) biomaterial 446–448
 - calcium carbonate/oxide/phosphate 445
 - calcium supplement 445–446
 - catalytic applications of materials 456
 - catalytic material preparation 451–454
 - catalytic materials 465–466
 - chemical composition and properties of 441–444
 - eggshell membranes (ESM) in fuel cell applications 464–465
 - gasification of biomass for hydrogen production 458–459
 - hydroxyapatite material 448–450
 - other catalytic applications 466–467
 - reactive carbon dioxide capture 459–460
 - selective catalytic oxidation 455–458
 - transesterification reaction for biodiesel production 461–464
 - water-gas-shift (WGS) reaction 460–461
- eggshell membranes (ESM) in fuel cell applications 464–465
- eggshell protein-rich membrane 459
- electrocatalysis
- charge transport mechanism 384–385
 - electrocatalytic sensors 386–396
 - fuel cell application 396–401
 - water oxidation 401–403
- electron paramagnetic resonance (ESR)
- characterization 146
- electrophotocatalysis 164
- Eley–Rideal mechanism 166–168, 188
- emulsion templating 24
- endothermic steam reforming of methane (SRM) 214, 217, 269, 286–288, 291
- energy additives 321
- from alcohols *via* Guerbet reaction 327–329
- Energy Dispersive Spectrometry (EDS) 90
- entropy 96, 97, 497
- environment-friendly apatitic calcium phosphate 73
- environmental footprint 438
- environmental remediation 383, 415, 454
- enynecarboxylic esters 311
- enzymatic catalysts 2
- enzymatic interesterification 427
- esterification reaction 307–308, 312, 325, 326
- ethane coupling 164
- ethanol 29, 147
- coupling reaction 177–180
 - to gasoline 180–182
 - steam reforming reaction 289
- ethanol/n-butanol Guerbet conversion reaction 86

- 4-ethylbenzaldehyde 357
 2-ethyl-1-butanol 181, 327
 2-ethyl-1-hexanol 181, 311
 2-ethylhexyl acetate 311
 2-ethylhexylphosphate (Phos) 209
 ethyl lactate (EL) 147, 150, 182
 ethyl tertiary butyl ether (ETBE) 320, 326
 ethylene 8, 87, 144, 145, 150, 164–166, 178, 189, 217, 218, 222, 223, 250, 251, 257, 259, 311, 327, 397, 399, 455, 457
 ethylene diamine tetracetic acid (EDTA) 87, 391, 394
 ethylene glycol (EG) 311, 397, 399
 exceptional ion-exchange capacity 6–7
 exothermic methane partial oxidation (POM) 164, 169–173, 188, 201, 214–217, 230, 269, 277, 281, 284, 285, 287, 291
- f**
- fatty acid methyl esters (FAME) 186, 300, 302, 303, 305, 306, 307
 Fe-g-C₃N₄ based catalysts 185
 Fe-g-C₃N₄/SBA-15 185
 γ -Fe₂O₃@HA-Ag NPs 426
 γ -Fe₂O₃@HA catalyst 244, 245
 γ -Fe₂O₃@HA@Cu(0) 363, 364
 γ -Fe₂O₃/HA/Cu(II) modified carbon paste electrode 430
 γ -Fe₂O₃@HA-DABCO 349, 363
 γ -Fe₂O₃@HA-DABCO-Pd 349
 γ -Fe₂O₃@HA@melamine 357–359
 γ -Fe₂O₃@HA-Ni²⁺ 353, 354, 363
 γ -Fe₂O₃@HAp@Cu(0) 360
 γ -Fe₃O₄@HA@Zn(II) 358, 360, 362, 363
 Fischer–Tropsch synthesis process 214, 216, 242, 269, 454
 fish bone 305, 308, 437, 438, 451, 467, 468
 fluoride-containing carbonated apatites 94
 formation enthalpy 96
 fossil fuels 141, 186, 253, 269, 459
 Fourier Transform Infrared Spectroscopy (FTIR) analysis 48, 50, 54, 82, 87, 88, 90–94, 106, 107, 113, 153, 157, 242, 244, 258, 273, 274, 309, 377, 393, 483
 free methyl radicals 165
 freeze dried gelatin nanoparticles 25
 Friedel–Crafts alkylation 497–499
 Friedel–Crafts reactions 185, 454, 456, 498
 Fritsch Pulverisette 6 planetary mill 34
 fuel additives from furfural 324–326
 fuel cell application 396–401, 464–465
 fuel cell technologies 287
 fural 324
 furaldehyde 324
 2-furaldehyde 324
 2-furancarboxaldehyde 324
 2,5-furan dimethyl carboxylate (FDMC) 325–326
 3-(furan-2-yl)-2-methylacrylaldehyde 325, 326
 furfural 3, 244, 245, 308, 309, 320, 324–326, 487
 2-furfuraldehyde 324
 furfural-n-propanol system 325
 furfural 324
 furo[3,4-*b*]chromenes 357, 358, 361, 363
- g**
- gas phase reactions
 alkane oxidative dehydrogenation reactions 217–227
 partial oxidation of methane 214–217

- gasification of biomass for hydrogen production 458–459
- gelatin nanoparticles 24, 25
- Gibbs free energy 96, 97
- Glaser–Hay reaction 350
- glutaraldehyd (GLU) 427, 428
- glycerol carbonate 320, 326, 327
- glycerol to lactic acid 182–183, 261 (3-glycidylxypropyl) trimethoxysilane (GPTMS) 50
- glycosaminoglycans (GAGs) 35
- Glycyrrhiza inflata 491
- gold supported HA (Au/HA) 155, 261, 308–310, 315, 386, 392
- graphene 2, 386, 391, 467
- green chemistry 73, 204, 353, 358, 364, 423, 426–430
- greenhouse gas (GHG) emissions 141, 252, 257, 269, 300, 319, 459
- Guerbet alcohols 144, 145, 251
- Guerbet condensation 8
- Guerbet coupling 110, 178, 180, 189, 246, 351
- Guerbet coupling of ethanol 110
- Guerbet cycle 150
- Guerbet ethanol coupling 180
- Guerbet reaction 84, 145, 148, 181, 249, 250, 320, 327–329, 350–352
- Guerbet-mechanism 178
- Gum Acacia assisted hydroxyapatite (GA-HA) 246
- h**
- Haber-Bosch process 1
- HA-core-shel- γ -Fe₂O₃ magnetic nanoparticles 353
- H α β TCP ceramic (α -TCP/ β -TCP/HA) 28
- HA/ γ -Fe₂O₃ nanoparticles 303, 428, 430
- HA- γ -Fe₂O₃ materials 210
- HAm-T catalysts 147
- Hammett indicator method 186, 303
- Hantzsch condensation reaction 357
- HAP analogs and their catalytic applications 425–426
- HAP catalysts and green chemistry 426–430
- hazardous environmental pollutants 141
- Heck reaction 154, 454
- heliophotocatalysis 375
- heterocyclic alcohols 209, 212
- heterogeneous catalysis 1–13, 20, 51, 55, 73, 84, 114, 117, 141, 157, 204, 230, 345, 364, 380, 382, 452, 454, 455, 468
- heterogeneous catalysts 2, 73, 141, 143, 174, 186, 201, 203, 204, 207, 211, 229, 255, 280, 301, 303, 304, 308, 311, 316, 320, 347, 353, 358, 360, 413, 418–420, 425, 429, 438, 440, 443, 444, 451, 453, 455, 457, 462, 464, 468
- hexagonal calcium hydroxyapatite (HA) 76
- hexamethyldisilazane [(CH₃)₃Si]₂NH (HMDS) 49
- hexanoic acid (HAcid) 209
- 1-hexanol 29, 181, 311
- n-hexanol 27
- high-density polyethylene (HDPE) 441
- high-resolution transmission electron microscopy (HRTEM) 86, 89, 90, 226, 274
- high-temperature hydroxyapatite compounds 115
- higher energy-density fuel additive 351
- highly crystalline carbonate-fluorapatite phase 302
- hollow CaCO₃ microspheres 30

- homogeneous catalysts 2, 174, 413, 425, 461, 462, 497
- homogeneous-heterogeneous reaction network 165
- H₃PO₄ 20, 23, 25, 30, 31, 49, 95, 101, 143, 154, 301, 304, 386, 392, 453, 454, 485
- hybrid HA/gelatin nanoparticles 24
- hydrated (biomimetic) apatites 90
- hydrocarbon fuel 328
- hydrogen production 1, 287
 - ammonia-borane hydrolysis reaction 318–319
 - borohydride hydrolysis reaction 316–318
 - water-gas-shift reactions 312–316
- hydrogen-selective membrane separation 460
- hydrogenation reactions
 - aromatic nitro compounds reduction 512–514
 - biomass-derived compounds to fuels and fine chemicals 242–245
 - crotonaldehyde 511–512
 - of benzene, phenol and diols 247–249
 - of carbon dioxide
 - alcohol synthesis 255
 - CO₂ methanation 253
 - CO₂-Fisher-Tropsch (FT) synthesis 253–255
 - fuel-type compounds 252
 - hydrogen-transfer processes 257
 - water-gas shift and reverse
 - water-gas shift 255–256
 - of olefins and nitro compounds 245–247
- hydrolysis methods 28–29
- hydrophile-lipophile balance (HLB) value 27
- hydrotalcite 152, 155, 204, 212, 302, 510
- hydrotalcite-hydroxyapatite (HT-HA) 302, 303
- hydrothermal method 20, 30–31, 182, 241, 251, 289, 308, 324, 379, 380, 390, 401
- hydrothermal processing 416, 417
- hydrothermal-impregnation method 311
- hydroxyapatite (Ca₁₀(PO₄)₆(OH)₂) 19, 73, 163, 241, 270, 413, 437, 441, 443
- hydroxyapatite (HA) 19, 76, 202, 204, 313, 350, 437
 - ball-milling method 32–34
 - co-precipitation method 20–22
 - dehydrogenation reactions 257–262
 - dry methods 35–36
 - emulsion templating 24
 - exceptional ion-exchange capacity 6–7
 - features 241
 - formulation of 8–11
 - high affinity with organic compounds 8
 - high thermal stability 4–6
 - in hydrogenation reactions
 - biomass-derived compounds to fuels and fine chemicals 242–245
 - of benzene, phenol and diols 247–249
 - of carbon dioxide 252–256
 - of olefins and nitro compounds 245–247
 - selective catalytic reduction of nitric oxide 249
- hydrolysis methods 28–29
- hydrothermal method 30–31

- influence of Ca/P ratio 143–152
- as macro ligands for organometallic moieties 347
- microwave-assisted synthesis 31–32
- nature of interactions with transition metal catalysts 271–274
- nonstoichiometric calcium-deficient or calcium-rich hydroxyapatites 46–47
- opportunities and challenges 11–13
- possible high porous volume and high specific surface area 4
- sol-gel method 22–23
- solubility 44–45
- sonochemistry 34–35
- stoichiometric and non-stoichiometric 242
- structure 42–43
- substitutions in the structure of 47–48
- supported bimetallic Co-Ni catalysts 3–4
- supported bimetallic Ni-Co catalysts 285
- supported bimetallic Pd-Co catalyst 314
- supported Cu catalysts 184
- supported palladium (0) nanoclusters catalyst 454
- surface functional groups 45–46
- surface modification and functionalization 49
- thermal stability 44
- tunable acid-base properties 7–8
- hydroxyapatite based catalysts 51
 - acetone to methyl isobutyl ketone 173–177
 - apatites as catalysts in C–C bond formation 347–361
 - apatites as catalyst supports 346–347
 - benzene to phenol 183–185
 - bimetallic catalysts 284–286
 - composition in reforming reactions 281–284
 - ethanol coupling reaction 177–180
 - ethanol to gasoline 180–182
 - glycerol to lactic acid 182–183
 - HA as macro-ligands for catalytic moieties 347
 - influence of Ca/P ratio 152–156
 - noble metal catalysts 286–287
 - oxidative coupling of methane 164–169
 - partial oxidation of methane (POM) 169–173
 - reforming of other hydrocarbons 287–290
 - stoichiometric and non-stoichiometric apatites 346
 - suitability of 274–281
 - transesterification 186–188
- hydroxyapatite biomaterial 441
- hydroxyapatite material 448–450
- hydroxyapatite supported palladium (0) nanoclusters (Pd(0)/HA) 318, 319
- hydroxyapatite supported Pd(II) catalyst (Pd/HA) 261, 311
- hydroxyapatite-based materials
 - apatite structure and model studies 76–81
 - apatite thermodynamics 95–98
 - electrocatalysis
 - charge transport mechanism 384–385
 - electrocatalytic sensors 386–396
 - fuel cell application 396–401
 - water oxidation 401–403
 - influence of substitution on surface reactivity 109–110
 - interfacial tension 103–106

- low temperature ion immobilization and adsorption properties 110–117
 - nature of acid and base sites 106–109
 - photocatalysis
 - dope 378–379
 - multiphase 379–382
 - principles 373–376
 - single phase 377–378
 - structure and properties 376–377
 - relevance of apatites in catalysis 84–87
 - solubility and evolution in solution 100–102
 - specificities of non-stoichiometric and/or biomimetic apatites 81–84
 - structural and compositional characterization 87–95
 - surface charge 102–103
 - hydroxyapatite-bound lanthanum complex (LaHA) 52
 - hydroxyethylmethacrylate (HEMA) 49
 - 4-hydroxyfuran-2(5H)-one 357
 - hydroxyisobutyric acid 144
 - α -hydroxyisobutyric acid 144
 - 5-hydroxymethylfurfural (HMF) 3, 429, 467
 - 5-hydroxymethyl-2-furfural (HMF) 3, 325, 326, 429, 467
 - α -hydroxyphosphonates 51, 504–505
 - α -hydroxyphosphonates synthesis 504–505
- i**
- imidazo[1,2-*a*]pyridine derivatives 360
 - imidazo[1,2-*a*]pyridine 360, 363, 364
 - imidazole-based ionic liquid 426
 - incipient wetness impregnation method 183, 303, 306
 - inductively coupled plasma (ICP) emission spectroscopy 87
 - inorganic-organic hybrid nanocatalyst 429
 - interfacial tension 103–106
 - interrupted coupling products 181
 - inverse mini-emulsion technique 25
 - in situ* and *operando* characterization techniques 228
 - ion exchange procedure 111, 249, 253
 - ion scattering spectroscopy (ISS) 86
 - ion-exchange resins 6–7
 - ionic chromatography 87
 - ionic-tagged mHA 419
 - ionometry using specific electrodes 87
 - Ir/TiO₂ 170
 - iron modified HA 324
 - isobutene 224, 320
 - isopropyl alcohol (IPA) 174
 - 2-(isopropoxymethyl) furan (2-IPMF) 326
- k**
- β -ketonitriles 351
 - KH₂PO₄ 23
 - KIO₃/HA catalyst 304
 - Knoevenagel condensation reaction 3, 425, 426, 454, 487–491
 - Knoevenagel reaction 3, 353, 465, 487–491
 - Kyoto Protocol 180
- l**
- LaAlO₃-8 457
 - labile carbonates 92, 94
 - lactic acid (LA) 23, 86, 147, 149, 182–183, 261

- Langmuir–Hinshelwood mechanism
166–168, 188
- Langmuir–Hinshelwood type kinetic
model 466, 467
- Langmuir-type isotherm 115, 117
- lauryl dimethylaminoacetic acid 32
- lead-doped hydroxyapatite 112
- Lewis acidity 85, 108
- Lewis acids 85–87, 106, 108, 144, 149,
151, 308, 314, 395, 465, 466, 497,
506
- Lewis to Brønsted acid sites (L/B) 3
- light olefins 455, 457
- linear alkylbenzenesulfonate 32
- lipase catalysts 427
- lipase immobilized HA/ γ -Fe₂O₃
biocatalyst 428
- liquid phase reactions
apatite-based catalysts 203–204
apatite/Pd(0) catalysts 211–214
apatite/Ru(III) catalysts 204–211
- lithium-doped NP (Li/NP) catalysts
495
- m**
- macro-porous HA ceramics 10
- maghemite (γ -Fe₂O₃) 420
- magmatic deposits 481
- magnesium carbonate 442
- magnetic γ -Fe₂O₃ 423
- magnetic γ -Fe₂O₃ nanocrystallites
210, 424
- magnetic HA 360, 414–427, 430
catalysis 420–430
- magnetic HAP nanoparticles 420–425
- magnetic hydroxyapatite (mHA) 50,
281, 350–352, 413, 415, 417–419,
421, 426, 427, 429, 430
- magnetic Mo-HA@ γ -Fe₂O₃ nano
catalyst 429
- magnetic nanocatalyst 349, 357, 423,
424
- magnetic natural HA (HA/Fe₃O₄ NP's)
358, 426
- magnetic resonance imaging 415
- magnetic separable solid catalyst 303
- magnetic Zn/HA/MgFe₂O₄ 421
- magnetite (Fe₃O₄) 382, 420, 423, 424,
426, 427
- malononitrile 353, 354, 466, 487,
495
- Mars and Van Krevelen mechanism
209, 218, 231
- “maturation” phenomenon 83
- mesityl oxide (MO) 110, 174, 511
- mesoporous ionic-modified
 γ -Fe₂O₃@HA-DABCO-Pd
containing palladium
nanoparticles 349
- mesoporous nano-hydroxyapatite
(mn-HA) 32, 33
- metal cations 3, 6, 75, 77, 96, 111, 142,
143, 176, 219–225, 272, 376, 383,
404
- metal ion modifications 219–225
- metal loaded spongy
carbonate-fluorapatite 301
- metal modified hydroxyapatites 114,
218–221, 227, 229, 230, 232
- metal nanoparticles 3, 12, 143, 157,
246, 261, 386, 403, 515
- metallic copper-based catalysts 182
- “Metastable Equilibrium Solubility”
(MES) 102
- methacrylic acid (MA) 311
- methane adsorption equilibrium
constant 167
- 2-methoxyaldehyde 354
- 4-methoxybenzaldehyde 353
- methyl acetate (MAA) 310

- 2-methyl-3-butyn-2-ol (MBOH) 84, 108, 145, 146
- methyl ethyl ketone 143, 323, 324
- methyl glycolate (MG) 329
- methyl isobutyl ketone (MIBK or 4-methyl-2-pentanone) 173–177
- methyl lactate (ML) 147, 150, 310
- methyl lactate (MLA) 147, 150, 310
- N*-methyl morpholine-*N*-oxide (NMO) 203
- methyl pyruvate (MPA) 155, 156, 309, 310
- methyl-2-furoate 309, 325, 326
- 1-methyl-3-(3-sulfopropyl)-imidazolium hydrogen sulfate acidic ionic liquid catalysts 467
- methyl-tert-butyl ether (MTBE) 326
- methylbenzyl alcohols (MB-OH) 328
- methylisobutylketone 352
- methylmercaptane 377
- methylmethacrylate (MMA) 49, 310
- methylphenylcarbinol 144
- Michael addition reaction 454, 494, 495
- micro arc oxidation 416
- microporous biochars 453
- microwave assisted co-precipitation 416
- microwave irradiation 241, 416, 417, 425, 448, 454, 504
- microwave-assisted synthesis 31–32
- mineral hydroxyapatite 437
- mini-emulsions 25
- mixed metal oxides 177
- mixed metal-based HA catalysts 300
- Mizoroki-Heck cross-coupling reaction 348, 349
- MnO₂/NAp 204
- MnOx/HA catalysts 154
- mole fraction of oligomer 181
- N*-monoalkylated hydroxylamines 418
- mono-ethanol-amine (MEA) 459
- monoammonium dihydrogen phosphate (NH₄H₂PO₄) 4, 8, 11, 23, 35, 154, 389
- monometallic supported porous HA nanorods 308
- 4-monosubstituted pyrido[2,3-d]pyrimidines 466
- montmorillonite 204, 511
- multi-layered biomaterial composite 437
- multicatalysis 12
- multicomponent reactions (MCRs) 352–361
- α-amino-phosphonates synthesis 506
- Biginelli reaction 505–506
- multiphasic HA-containing photocatalyst composites 381
- electronic transfers 380
- TiO₂ biphasic composites 380–381
- TiO₂ multiphasic composites 381
- multiwall carbon nanotubes (MWCNTs) 388, 398, 399, 402, 403
- M₁₀(XO₄)₆(Y)₂ 19
- M₅(XO₄)₃Y 75
- n**
- NaLaCa₃(PO₄)₃OH 425
- NaLaSr₃(PO₄) 425
- nanocomposite CoFe₂O₄/HA 428, 429
- nanocrystalline apatites 76, 83, 98, 113
- nanocrystalline HA 23, 311
- nanoemulsion technique 24
- nanoparticle infiltration 416
- nanoporous hydroxyapatite 485
- nano-sized HA powder 449
- nano-SnO₂ grafted natural-hydroxyapatite photocatalyst 311

- nano-tin oxide grafted natural-hydroxyapatite (SnO₂/HA) 311
- natural and doped HA-catalysts 186
- natural apatite (NAP) 203, 204
- natural bio-ceramic materials 448, 452, 453
- natural gas (NG) 153, 164, 177, 201, 253, 269, 312
- natural hydroxyapatite (nHA) 316
-supported copper solid acid catalyst 308
- natural phosphates (NP)
catalysts or catalyst supports 482–486
mineralogical composition of 481
organic synthesis
condensation reactions 487–491, 496
Friedel–Crafts alkylation 497–499
hydration of nitriles 501–504
hydrogenation reactions 511–514
 α -hydroxyphosphonates synthesis 504–505
MCRs 505–506
oxidation reactions 506–511
reforming of methane 514
Suzuki–Miyaura cross-coupling reaction 499–501
transesterification reaction 496–497
VOCs 515–516
- natural quarry calcium carbonate 438
- Na₂WO₄–Mn/SiO₂ 166
- Na₂WO₄/SiO₂ 457
- Na₂WO₄/TiO₂ 457
- neem (*Azadirachta indica*) oil 305
- (NH₄)₂HPO₄ 4, 20, 21, 23, 24, 31, 53, 153, 328, 329
- Ni hydroxyapatite system 114, 290
- Ni strontium hydroxyapatite system 214
- Ni-added strontium phosphate catalysts 284
- Ni–Ca–HA catalysts 277
- Ni–Ca–PO₄/HA catalysts 281
- Ni/CeO₂ catalyst 280
- Ni_{SA}/HA catalysts 7
- Ni/ZrO₂ DRM catalyst 276
- nickel calcium hydroxyapatite system 215
- nickel/HA/cobalt ferrite (Ni/HA/CoFe₂O₄) novel nanocomposite catalyst 420
- nitric acid production 1
- β -nitro-alcohol 424
- noble metal catalysts 182, 270, 286–287, 290, 458, 511
- N₂O catalytic decomposition 454
- N₂O decomposition 153
- non-active μ -oxo dimers 204
- non-alkoxide sol-gel process 23
- non-apatitic calcium phosphates 31
- non-noble metal based heterogeneous catalyst 429
- non-stoichiometric aluminum phosphate–hydroxyapatite 329
- non-stoichiometric apatites 13, 28, 76–77, 79, 81–82, 84–85, 90, 94, 98, 100–101, 105, 113–114, 346
- non-stoichiometric non-carbonated apatites 87
- non-stoichiometric calcium-deficient or calcium-rich hydroxyapatites 46–47
- normal hydrogen electrode (NHE) 401
- NP12 (poly(oxyethylene)12 nonylphenol ether 25
- NP5 (poly(oxyethylene)5 nonylphenol ether 25
- n*-type doping 378
- nucleophilic carbon-carbon bond forming reactions 347, 350–352

O

- octacalcium phosphate
 ($\text{Ca}_8\text{H}_2(\text{PO}_4)_6 \cdot 5\text{H}_2\text{O}$ (OCP)) 47,
 75, 101, 444
n-octane 29, 52, 202, 219, 226, 258
 octane number 145, 326
 octanol-1 oxidation 209
 1-octanol 29, 207
 olefins 181, 201, 217–218, 245–247,
 250, 257, 269, 328, 455, 457
 oleic acid esterification 308
 oligomer 3, 181, 465
 one-pot three-component A^3 -coupling
 reaction 353–354, 356–358,
 360, 362–363
operando impedance spectroscopy 228
 organic carbonates agents 326–327
 organic pollutant degradation 164
 organic synthesis, NP and
 NP-supported catalysts
 condensation reactions
 Claisen–Schmidt condensation
 491–494
 Knoevenagel reaction 487–491
 Michael addition 494–496
 Friedel–Crafts alkylation 497–499
 hydration of nitriles 501–504
 hydrogenation reactions 511–514
 α -hydroxyphosphonates synthesis
 504–505
 MCRs 505–506
 oxidation reactions 506–511
 reforming of methane 514
 Suzuki–Miyaura cross-coupling
 reaction 499–501
 transesterification reaction 496–497
 volatile organic compounds (VOCs)
 515–516
 orthophosphates (PO_4^{3-}) 3, 21, 87,
 308, 390
 orthophosphoric acid 6, 21, 25, 419
 Ostwald–Brauer process 1
 “over-stoichiometric” compounds 85
 oxidation reactions
 benzyl alcohol 509–511
 epoxidation of electron-deficient
 alkenes 510–511
 oxidative cleavage of cycloalkanones
 506–509
 oxidative coupling of methane
 164–169, 270, 455
 oxidative dehydrogenation (ODH) 52,
 79, 108, 201, 217–227, 231, 257,
 259, 261, 299
 oxidative dehydrogenation of ethane
 (ODHE) 202, 219, 222, 231, 259
 oxidative dehydrogenation of propane
 (ODHP) 79, 108, 163, 202, 219,
 224–225, 228–229, 257, 299
 oxidative dehydrogenation reactions
 (ODH) 52, 201, 217–218
 oxygen adsorption equilibrium constant
 167
 oxygen evolution reaction (OER)
 401–402
 oxygen reduction reaction (ORR) 467
 oxygenated additives 320, 326–327
 oxyhydroxyapatite 4–5, 109
 oxyhydroxyapatite formation 109

P

- palladium 185, 211, 247, 248, 313–314,
 318, 323, 326, 347–350, 381, 383,
 396–397, 404, 466, 499–500, 504,
 511
 palladium (II) ion exchanged
 hydroxyapatite (Pd^{2+} -HAP) 318
 palm kernel oil 303
 partial oxidation of methane (POM)
 112, 164, 169–173, 188, 201,
 214–217, 230, 269, 277, 281,
 284–285, 287, 290–291, 454, 514
 partially substituted hydroxyapatites
 299

- $\text{Pb}_{10}(\text{PO}_4)_6(\text{OH})_2$ 112
 $\text{Pb}_{10}(\text{PO}_4)_6\text{Cl}_2$ 112
 Pd nanoclusters 213, 247
 $\text{Pd}_0\text{NPs}@$ nano-HA 348
 $\text{Pd}_{\text{II}}\text{NPs}@$ nano-HA containing
 palladium nanoparticles 348
 $\text{Pd}_{2060}(\text{NO}_3)_{360}(\text{OAc})_{360}\text{O}_{80}$ 213
 $\text{Pd}_{561}\text{phen}_{60}-(\text{OAc})_{180}$ 213
 $\text{Pd}(\text{OAc})_2$ 214, 347
 $\text{Pd-Co}(1)/\text{Al}_2\text{O}_3$ 315
 $\text{Pd/Co}(1)/\text{HA}$ catalyst 315
 $\text{PdCl}_2(\text{PhCN})_2$ 6, 154, 347
 Pechmann reaction 426
 1,4-pentanediol 242–243
 2,3-pentanedione (2,3-PD) 147
 permanently polarized HA (p-HA)
 255
 phenol (carbolic acid) 183
 phenylacetylene 350, 358, 360,
 423–424
 phenylboronic acid 348, 500
 o-phenylenediamine 465
 (*R,S*)-1-phenylethanol 428–429
 phenylglyoxylic acid 361
 phenylpropionic acid 361
 phosphate deposits 481
 phosphate ores 481–482
 phosphate-bearing apatites 95
 phospho-vanado-molybdic acid
 complex 87
 phosphorous pentoxide (P_2O_5) 13, 23,
 482, 484, 489
 photocatalysis 164
 dope 378–379
 principles 373–376
 single phase 377–378
 structure and properties 376–377
 photocatalytic water splitting 374
 $\text{PO}(\text{Me}_3\text{O})_3$ 23
 $\text{PO}(\text{OEt})_3$ 22–23
 point of zero charge (PZC/pzc) 102,
 418
 poly(acrylic acid) 418
 poly(*N*-isopropylacrylamide)
 (PNIPAM) 50
 poly[(butylene-co-ethylene)-*b*-
 (ethyleneoxide)] [P(B/E-*b*-EO)]
 25
 polyfunctional catalysts 2
 polyhydroquinoline 357, 359, 364
 polyphosphates 3
 polyvinylpyrrolidone (PVP) 38
 “poorly-crystalline” apatites 82
 porous graphitic carbon nitride
 (g-C₃N₄) 185
 porous HA 26, 308, 381, 425, 453
 potassium hydroxide catalyst 305
 potato starch hydrolysis 1
 potential-determining 102
 poultry meat 438–439
 production 438
 precipitated amorphous calcium
 phosphates 89
 precipitation combined with
 mechanical grinding 416
 pressure-swing adsorption (PSA) 312
 proline 209–210
 prolinol 209–210
 1,2-propanediol 327
 propionic acid (PA) 147, 390
 protein 90, 379–380, 386, 413, 437,
 441, 444, 451, 460
 protide compounds 316–317
 proton-exchange membrane (PEM) fuel
 cells 464
 pseudo sol-gel method 303
 pseudo-sol-gel microwave-assisted
 protocol 32
 Pt-nanoparticles (Pt NPs) 249
 p-type doping 378
 p-xylene 25, 203
 pyrano[2,3-*d*]pyrimidine derivatives
 353

- pyrano[2,3-*d*]pyrimidinones 353
 derivative 353
 [1,2-*a*]pyridine derivatives 363
 pyrido[2,3-*d*]pyrimidines 355
 derivatives 353
 pyrimidinobenzimidazoles 427
 pyrophosphates ($P_2O_7^{4-}$) 3, 87,
 100–101
 pyruvaldehyde (PA) 155
 pyruvic acid (PA) 147, 150
- r**
- racemic acyclic propargylamine 358
 rare earth metals 165, 347, 455
 reactive carbon dioxide capture
 459–460
 rectisol 459
 recyclable, *in situ* prepared, catalytic,
 natural HA supported MnO_2
 420
 recyclable, non-functionalized
 Fe_3O_4 -HA magnetic nanorods
 423
 redox catalysts 2
 reduced grapheme oxide (rGO)
 391–393, 403
 reusable magnetic nanocatalyst 424
 reverse water-gas shift (RWGS) reaction
 253, 255–256, 277, 461
 Rh/ Al_2O_3 170, 287
 Rh/ $MgO-Al_2O_3$ catalyst 286
 Rh/ SiO_2 170, 216
 Rh/ TiO_2 170
 rhodium supported hydroxyapatite
 230
 rhombohedra calcite ($CaCO_3$) 444
 Ru-based oxidation catalysts 210
 Ru-CoHA catalyst 209
 Ru/HA- γ - Fe_2O_3 211
 Ru/HA catalyst 242–243, 247,
 261–262, 315, 318
 $RuCl_2(PPh_3)_3$ 207
 RuHA- γ - Fe_2O_3 catalyst 325
 RuNPs@nano-HA 319
 ruthenium complexes 177
 ruthenium supported HA (Ru/HA)
 315
 ruthenium-hydroxyapatite-encapsulated
 superparamagnetic γ - Fe_2O_3
 nanocrystallites 424
- S**
- Schizochytrium algae oil 306
 sealed Teflon-lined autoclave 30
 sedimentary deposits 481
 selected area electron diffraction
 (SAED) 33, 90
 selective catalytic oxidation 455–458
 selective hydrogenation 164, 241–262,
 329, 454, 511–512
 selective oxidation catalysis 201
 selexol 459
 semiconductor photocatalytic functions
 185
 semiconductors (SC) 374, 378, 380
 simple salt approximation (SSA) 96
 simulated biofluid method 416
 single crystal HA 317
 SiO_2 -based materials 2
 slightly-milky nanoemulsions 24
 SnO_2 /HA catalyst 311
 sodium lauryl ether sulfate 32
 sodium-doped nanohydroxyapatite
 (nHA) 306, 316
 sodium-modified hydroxyapatite
 (NaHA) 303
 sol-gel method 22–23, 303, 454, 515
 solar-type energy 311
 solar-type/ultrasound batch reactor
 311
 solid base catalysts 186, 303–304, 306
 solid base metal oxides 177
 solid waste powders 441
 sonochemistry 34

- Sonogashira cross-coupling reaction 349–351
- soybean oil 302–304
- soybean oil biodiesel 303–304
- specificities of non-stoichiometric and/or biomimetic apatites 81–84
- spongy carbonate-fluorapatite 301
- $\text{Sr}_{10}(\text{PO}_4)_6(\text{OH})_2$ 222, 289
- $\text{Sr}_{10}(\text{VO}_4)_6(\text{OH})_2$ 289
- $\text{Sr}_2\text{TiO}_4\text{-SP1}$ 457
- standard formation enthalpy 96
- steam reforming of methane (SRM) 169, 214, 217, 269, 286–288, 291
- stoichiometric (non-carbonated) apatite 87
- stoichiometric apatites 75, 79, 86, 94, 98, 101, 105, 113, 212, 346
- stoichiometric calcium phosphate hydroxyapatite 3
- strong electrostatic adsorption method 7, 279, 284
- strong metal-support interactions (SMSI) 114–115, 244, 273–274, 290
- strontium phosphate hydroxyapatite 324
- substituted vanadate anions 110
- sulfuric acid production 1
- sulphonated-chitosan encapsulated HA- Fe_3O_4 427
- surface charge 102–103, 106, 111, 376–377, 418, 466
- surface electronic transfers 374
- surface hydroxyl groups 165, 273, 277, 427
- surface ion immobilization 111
- surface/interfacial (free) energy or “tension” 103
- Suzuki–Miyaura cross-coupling reaction 347–348, 466, 499–501
- Swern reagent 203
- syngas production 4, 201, 455, 457
- synthetic HA supported bimetallic cobalt and nickel catalyst 454
- t**
- temperature programmed desorption (TPD) experiments 54, 85, 143, 310, 393, 394
- tert*-butyl hydroperoxide (TBHP) 309, 325
- tetracalcium phosphate (TTCP) 4–5, 44, 98
- 5,6,7,9-tetrahydro-1*H*-furo[3,4-*b*]chromene 360, 361
- tetraethoxysilane (TEOS) 50
- tetrahydrofurfuryl alcohol (THFAL) 326
- Therm’AP model 96
- thermal behavior 5, 98–100
- thermally stimulated depolarization current (TSDC) measurements 385
- thermodynamic dissolution-precipitation equilibrium 44–45
- thermogravimetric analyser (TGA) 50, 444
- thiourea-functionalized mHA 350–352, 418, 429–430
- three-stage homogeneous catalysis process 174
- $\text{TiO}_2\text{@HA}$ 51, 54
- toluene 29, 207–208, 210–211, 355, 465, 467, 497–498, 509
- transesterification reaction 186, 300–307, 326–327, 428–429, 454–455, 461–464, 496–497 for biodiesel production 462
- transition metal ions (TMI) 19, 201–202, 218, 347, 402, 404
- transition metal-substituted HA 165

- transition metals 6, 20, 165, 203, 211, 270–271, 286, 290, 313, 316, 347, 374, 454, 461, 499, 502
- trianisylcarbinol 143
- tricalcium phosphate ($\text{Ca}_3(\text{PO}_4)_2$ (TCP)) 4–5, 28–29, 35, 44, 98, 216–217, 227, 300, 274, 282, 287, 381, 442, 444–445, 448–451, 462
- β -tricalcium phosphate (β -TCP) 22, 86, 101
- triethanolamine 29
- triethoxyphosphine ($\text{PO}(\text{OEt})_3$) 22–23
- trimethyl phosphite ($((\text{CH}_3\text{O})_3\text{P})$) 23
- trimethylcarbinol 144
- trimethylsilyl cyanide (TMSCN) 350, 429
- triphenylcarbinol 143
- tritolycarbinol 143
- trivalent iron and chromium cations 224–225
- tunable acid-base properties 7–8, 218, 364
- turnover frequency (TOF) 110, 203, 207–211, 213, 245, 262, 319, 348, 401
- Tween 80 26–27
- TX-100 26–27
- U**
- ultrasonic irradiation 35, 416
- ultrasound-assisted precipitation method 35, 381
- ultrasound-wave energy 311
- uncalcined eggshell 464
- α,β -unsaturated aromatic enones 350
- UV-Vis-NIR techniques 272–273
- V**
- γ -valerolactone hydrogenation 243
- vanadate anions 110, 225–227
- vanadium impregnated hydroxyapatites 226
- vanadium oxy-hydroxy-apatite $\text{Ca}_{10}(\text{PO}_4)_{6-x}(\text{VO}_4)_x(\text{OH})_{2-2y}\text{O}_y$ solid solution 228
- vanadium pentoxide 1, 226
- vanadium substituted $\text{Ca}_{10}(\text{VO}_4)_x(\text{PO}_4)_{6-x}(\text{OH})_2$ stoichiometric apatite solid solution 86
- vanadium substituted hydroxyapatite 226–227, 231
- vegetable oil deodorization distillate (VODD) 302–303
- versatile mHAs 430
- vicinal-diiodoalkenes 311
- volatile organic compounds (VOCs) 8, 141, 146–147, 299, 458, 467, 515–516
- W**
- waste animal bone 307, 444, 453, 462, 466
- waste chicken eggshells 462
- waste cooking oil (WCO) 301–302, 304, 455, 462
- waste eggshells 438–440, 442–444, 447–449, 451, 455, 457–459, 461–462, 465
- water oxidation 401–403
- water treatment 376, 382, 383, 446
- water-gas-shift (WGS) reaction 153, 252, 255, 312–316, 458, 460–461
- water-in-oil-in-water (W/O/W) double emulsion drops 24
- water-soluble polar organic molecules 209
- Wavelength Dispersive Spectrometry (WDS) 90
- wet impregnation 111, 153, 219, 226, 231, 243, 306, 308, 315, 327, 452

World poultry meat and chicken meat
production 439

X

xonotlite nanowires 30

Z

zeolites 2, 6, 8, 78, 141, 152, 177–178,
204, 318, 320, 446, 448, 451, 459,
468, 510–511

zeta potential 102, 111, 419

Zn(II) anchored magnetic HA
nanocatalyst 423

Zn-bound hydroxyapatite 112

Zn^{II}/HA/Fe₃O₄ 423–424

Zn(II)/HAP/Fe₃O₄ 422

zwitterionic poly(3-carboxy-*N,N*-
dimethyl-*N*-(3'-acrylamido-
propyl) propanaminium inner
salt) (PCBAA) 38

