

Index

- Acid function
 balance with metal function, 344,
 353, 453, 456, 501, 566
- Bronsted sites, 97, 98, 145, 146, 205,
 211–213, 259, 355
- catalysis of paraffin and olefin
 isomerization, 56, 75, 96, 102
- characterization of, 199–214
- chloride-promoted alumina, 46, 145,
 146, 210, 410, 414, 425, 443,
 453, 506
- and coke production, 59, 391, 392,
 395, 406, 410, 414, 415, 418,
 419, 425, 506
- control of bifunctional mechanisms,
 45, 84, 95, 98, 101, 102, 567
- control in reformer, 200
- and dehydrocyclization, 46, 96, 567
- excessive hydrocracking, 95, 566
- Lewis sites, 53, 97–99, 145, 146,
 205–209, 211, 213, 259, 355,
 356
- strength for isomerization, 46, 75, 84,
 95, 99–101
- zeolite as source, 46–48, 96, 347,
 348, 354–387, 491
- Alumina (γ - and η -)
 acidity and basicity of, 145, 150, 204,
 205
- influence of halogens on, 200, 210,
 211, 259, 414, 425, 443, 453,
 456
- porosity of, 147, 191, 201, 202, 258,
 462, 592, 593
- precursors of, 142–144, 146
- [Alumina (γ - and η -)]
 strength of, 148, 191, 200, 201, 341,
 344, 448–452, 454–456, 462
- structure of, 145, 258
- support forming, 146, 147, 191
- surface area of, 127, 143, 147, 201,
 202, 258, 446, 447
- surface area retention, 143, 341–344,
 446
- surface hydroxyls of, 145–157, 164,
 165, 169, 205–207
- surface properties of, 145, 147
- thermal transformations of, 143, 144,
 342, 343, 442–451, 462
- Aromatics
 alkylation, 354, 359, 372
- Aromax, 348
- BTX, 4, 18, 347, 485
- CPA, 348
- Cyclar, 347
- general properties, 4
- M2-forming, 353
- MRU, 347
- production from propane, 347, 354
- RZ Platforming, 348, 484, 485
- zeolite-hybrid catalysts, 353–387
- Benzene production, 18, 19, 52, 53, 566,
 585–588
- Benzene reduction in gasoline, 138,
 335, 341, 552, 583–588
- Bifunctional catalyst, 14, 45, 47, 75, 76,
 84, 97–99, 101, 141, 199, 440,
 566

- [Bifunctional catalyst]
 reactions on, 46, 75, 76, 81–84,
 94–102
- Bimetallic catalysts
 advantages of, 52, 141, 191
 characterization of, 237–253, 259
 electronic effects in, 52
 geometric effects in, 52, 95
 platinum/germanium, 186, 191, 403,
 404, 418
 catalyst characterization, 251, 252
 catalyst preparation, 53, 186, 252
 interaction, 52, 248, 252
 role of germanium in, 53, 61, 251,
 252
- platinum/iridium, 185, 186, 261,
 403, 404, 463
 catalyst preparation, 185, 186
 interaction, 52, 185, 186
- platinum/rhenium, 15, 180–182,
 191, 261, 336–342, 403–409,
 412–415, 444, 463
 alloy formation in, 180–182,
 241–245
 catalyst characterization, 237–244
 catalyst preparation, 180–182
 rhenium oxidation state in,
 180–182, 237–244, 444
 role of rhenium in, 180, 337, 338
 sulfur interaction with, 56, 180,
 245, 337, 412, 418, 445
- platinum/tin, 15, 182–184, 191, 260,
 342–344, 394, 396, 403–405,
 410–414, 441, 445
 catalyst preparation, 53, 182–184
 electronic interaction, 184,
 185, 246
 oxidation state of tin in, 182–185,
 245, 260
 role of tin in, 52, 53, 59, 182, 412
 presulfiding of, 248, 410–413
 thiottolerance, 56, 61
- Carbonaceous deposits, 56–59, 81, 340,
 391–426, 440, 441, 452
- [Carbonaceous deposits]
 bimetallic catalysts and, 391–396,
 399–406, 409, 412–415, 418,
 425, 441
 characterization of, 57, 59, 231,
 392–398, 414, 441
 dehydrogenation of, 405, 420,
 452
 disordered, 59, 60, 399
 effect on activity and selectivity, 57,
 403, 424, 568
 effect of migration of chemisorbed
 species, 58, 59, 405,
 417–421
 effect of sulfur, 401–406, 410–413,
 425
 effect of surface hydrogen on, 58
 evolution with time on stream,
 58, 399–404, 414, 421, 440,
 441, 520, 568
 formation by polymerization of
 surface polyenes, 58, 59, 404,
 414, 417–421, 425
 geometric effects of, 60, 142, 402,
 405, 424
 graphitic, 59, 391, 395, 398,
 403–407, 420, 421
 H/C ratio, 396, 403, 410, 411, 426,
 551, 570
 as hydrogen transfer agents,
 424
 hydrogenolytic removal, 59, 398,
 403–410
 migration of precursors from
 metal to acid sites, 58, 59, 405,
 414–419
 ordered, 59
 reaction conditions and, 396–402,
 407, 408, 421–426
 reversible/irreversible, 57, 58, 391,
 403, 423
- Catalyst deactivation, 18, 20, 21, 56,
 411, 440, 514, 568, 573, 575,
 580
 effects of sulfur, 21, 411
- Catalyst design, 275, 330

Catalyst performance evaluation
of activity with model compounds,
284–288, 325, 326, 354
isothermal demonstration unit,
383–387
using more practical feedstocks,
374

Catalyst preparation steps
drying, 179, 188, 225, 244
impregnation, 142, 148–166,
172–178, 181–191, 225
adsorption models and
mechanisms, 149–166,
172–178, 188, 190
chloroplatinic acid, 148–179, 180,
184, 189–191, 225
diffusion effects on, 148, 149, 181,
188, 189
germanium precursors, 186
iridium precursors and species in,
185
metal dispersion, 148, 179–185,
343
metal profiles, 148, 149, 180–183,
187–192
metal uptake in zeolites,
176–179
palladium precursors, 155, 156
platinum precursors and species in,
176–180, 225
rhenium precursors and species in,
180–182
support dissolution during, 149,
159–162, 166
surface chemistry of hydroxyls,
149–156, 164, 165, 166, 188,
189
surface interactions in, 148, 149,
180–183, 244
techniques for, 53, 148, 149, 182,
183, 355
tin precursors and species in, 53,
182–185, 200
oxidation, 179, 183, 226, 244
reduction, 179, 183, 244

Catalyst presulfiding, 106, 410

Catalytic reforming
for aromatics as petrochemicals, 335,
341–349, 433, 482–486, 572
drivers for evolution, 335–345, 349,
433, 434, 531, 535–537
endothermicity, 576
for high-octane gasoline, 335,
340–344, 349, 433, 482, 483
modeling commercial units,
540–542, 546, 551–588
monitoring unit performance, 345,
497–528, 539, 540
control systems, 497–547, 556
reactor temperature profiles, 497,
552, 576–583
operating parameters, 349, 502, 513,
580

process
continuous catalyst regeneration,
15, 340–346, 409, 410,
434–439, 454, 477–485, 514
fully regenerative, 340–342,
434–437, 442–445, 477, 480
semiregenerative, 15, 336–338,
345, 346, 410, 433–435,
440–445, 477, 479, 482, 485,
551, 573, 576
severity, 340, 344, 349, 433, 434,
440, 506
staged loading, 339
unit optimization and
improvement, 340, 349, 433,
502, 534, 564, 572

Catalyst vendors
Axens, 339, 342, 343, 481, 485,
486
Criterion, 339, 342, 343
UOP, 339, 342, 344, 481–485

Characterization
of acidity properties, 199, 204–209,
213, 214, 259
by calorimetry, 210, 259
by Hammett indicators, 204, 205,
213
by infrared probe techniques,
204–209, 213, 259

[Characterization]

- by nuclear magnetic resonance, 214
- of alumina support
 - acidity, 206–210, 259
 - pore acidity, 202, 203
 - porosity, 201–204, 258
 - strength, 200, 201
 - surface area, 201, 202, 258
- by gas adsorption, 202, 203, 230, 259
- by mercury penetration, 201, 203
- of metal dispersion and particle size, 199, 215, 223, 240
 - chemisorption techniques, 217–225, 229, 230, 259, 454
 - nuclear magnetic resonance, 228–231
 - small angle x-ray scattering, 221–223
- titration methods, 220–222
 - with transmission electron microscopy, 216–222, 229, 260
- with x-ray adsorption fine structure analysis, 38, 224–228
- with x-ray diffraction, 215, 216, 221, 222
- of metal properties
 - Auger electron spectroscopy, 234
 - with calorimetry, 210, 235
 - infrared spectroscopy, 235, 395
 - with ion scattering spectroscopy, 234–236
 - with temperature programmed reduction, 232, 235–240
 - by x-ray photoelectron spectroscopy, 49, 232–234, 241, 246, 260
- of platinum/iridium, 219, 220, 232, 249, 251
- of platinum/rhenium, 237–239, 240–245
- of platinum/tin, 217, 245–248, 260
- reaction with probe molecules, 204
- small angle x-ray scattering, 204, 593
- temperature programmed oxidation, 59, 392, 393, 414

[Characterization]

- temperature programmed reaction, 38
- transient response method, 38
- Coke precursors, 20, 38, 524, 570
- Coking, 14, 52, 53, 502, 514, 520, 524, 551, 568, 570, 580, 581
- Commercial reforming catalysts, 491–493
- Commercial reforming processes
 - Houdriforming, 488
 - Magnaforming, 488
 - Platforming, 479, 482–485
 - Powerforming, 489, 490
 - Octanizing, 485–487
 - Rheniforming, 490
 - Ultraforming, 490–491
 - Zeoforming, 491
- Crude oil, 2

Dealkylation, 18, 20

- Dehydrocyclization, 14, 36, 42, 46, 50, 51, 63, 64, 78, 80–87, 96, 102, 348, 357–359, 372, 424
- Dehydrogenation, 14, 36–38, 43, 65, 78, 85, 95, 96

EUROPT-1, 43, 47, 51, 55–59, 65, 66

Gasoline

- quality properties, 10, 11, 335, 583
- pool composition, 109, 111
- production processes, 3, 335
- vapor pressure reduction, 10, 335

Heteroatomic compounds

- arsenic, 129, 130
- nitrogen, 6, 9, 107–112, 121
- organometallics, 10, 16
- oxygen, 9, 61
- silicon, 16, 54
- sulfur, 4, 6, 9, 107–117
- water, 9, 16

Hydrocarbon analysis

- boiling point, 27, 557, 558
- by gas chromatography, 22–26, 524
- by gas chromatography and mass spectroscopy, 23
- for nitrogen, 27, 28
- by nuclear magnetic resonance, 557, 559, 562, 563

octane number

- calculation from aromatics, 30, 523
- calculation from GC, 30, 523, 526
- engine for RON, MON, 30, 523, 526
- IR, 32, 526
- models, 31, 32
- PONA, 24, 557
- simulated distillation, 27, 115, 557, 559
- for sulfur, 27–29, 114, 115

Hydrocracking, 14, 21, 81, 95, 96, 372, 424

- acid function in, 96, 101, 344, 566
- exothermicity, 81, 84
- products of, 372, 566

Hydrogen

- direct/indirect effect, 63–65
- effect on aromatization, 38, 62, 65
- participation in active site on Pt, 98, 100
- pressure effect on yields, 63–66, 85, 502

production, 14, 20, 139, 551

- reactive chemisorption, 62–65, 97–101

spillover, 66, 98, 102, 354, 363, 371, 372, 424, 425

surface reconstruction, 62

types of surface, 97, 98

Hydrogenation, 43, 78, 85**Hydrogenolysis**, 14, 40, 43, 46, 52, 78, 95, 354

Anderson–Avery mechanism, 40

with bimetallic catalysts, 52, 53

effect of hydrogen, 64, 66, 354

[Hydrogenolysis]

- effect of sulfur on, 410, 412, 445
- fragmentation factor, 40
- metal catalyzed, 40, 41, 51
- thermodynamics of, 81, 84

Hydrotreating, 6, 16, 105, 111, 113, 117, 119, 129–131, 135–139,

433, 503, 551

catalysts, 105, 126–134

hydrodenitrogenation (HDN), 118, 121, 131

kinetics, 125

reactivities, 118, 121, 122

thermodynamics, 119, 122, 123

hydrodeoxygenation (HDO), 118

hydrodesulfurization (HDS), 106, 113, 117, 118, 121, 138, 139, 378

kinetics, 125, 126

reactivities, 117, 118

recombination, 117, 123–125, 136, 137

thermodynamics, 119–124

octane loss, 111, 113

poisons, 129–131

process, 132–138

Isomerization, 3, 14, 15, 36–42, 46, 50, 53–58, 64, 66, 78, 95–102, 361, 424

of aromatics, 38, 94, 95, 372

Kinetic models

of catalytic reformer, 540, 546, 552, 567, 568, 570–577

incorporating diffusion, 276, 296–299, 311, 312, 322, 323, 330, 564

naphtha reforming, 82, 282, 283, 293–297, 422, 423, 563, 567, 570–575, 583–585

and reforming reactions, 289, 361–369, 563

- [Kinetic models]
 - pore structure
 - effect, 276, 277, 296, 301–307, 313–323, 326–330, 366–370
 - models, 277, 278, 302, 306–313, 322–324, 564
 - optimization, 275–279, 308–312, 324–330
- Kinetics of reforming reactions, 14, 65, 82, 83, 89, 276, 282–292
- Mass transport and diffusion, 91, 92, 100, 203, 275–277, 296–301, 311
 - diffusivity coefficients, 300–308, 314–321
- Metals recovery from spent catalyst, 459–474
 - chemistry of, 468–474
- Metal surface sites
 - catalyzed hydrocarbon reactions, 35, 41, 84–86, 99
 - for chemisorption, 42
 - interaction with acidic sites, 53, 84
 - interaction with support, 35, 45, 53, 94
 - single atom, 45
- Monofunctional catalyst for
 - aromatization of paraffins, 37, 38
- Aromax, 348
 - characterization of, 214–219, 221
 - confinement model, 49
 - geometric constraint in, 348
 - importance of basic sites in, 49, 348
- Pt/K/L zeolite, 48, 49, 58, 142, 348, 406
 - characterization of, 210, 231, 253–258
 - hindered deactivation in, 49, 348
 - sensitivity to sulfur, 142
 - stabilization of small crystallites in, 49
- RZ Platforming, 348
- Te/X zeolite, 37
- Multimetallic catalysts, 142, 180, 187, 191, 192, 337, 339, 342, 482, 486
- Naphtha
 - boiling point, 6, 18, 107, 112, 557–560
 - effect on reforming, 17, 107
 - composition, 2–8, 18, 107–112, 557–560, 565
 - effect on reforming results, 16, 17, 107, 113, 557
 - fractions, 2, 6, 107, 112, 560
 - sources, 2, 108–110
- Naphthalenes
 - alkylcyclopentane
 - dehydroisomerization, 80, 81, 85–87, 566
 - kinetics of, 64
 - conversion to aromatics, 14, 81, 344, 565, 566
 - dehydrogenation, 14, 80, 81, 86, 93, 94
 - kinetics of, 80, 93
 - mechanism of, 93, 94
- Nitrogen compounds
 - basic, 6, 105
 - effect of activity and selectivity by, 54, 55
 - poisoning by, 54, 105, 107
- Octane number, 10, 11, 12, 13, 17,
- Olefins, 96, 100, 111, 112, 348, 354
 - dehydrogenation to, 84, 96, 97, 101, 372
 - hydrogenation of, 119
 - intermediates, 84, 97–101, 348
 - isomerization, 85, 94, 372
 - polymerizing to carbonaceous deposits, 97, 100, 101, 372, 417, 568
- Paraffin isomerization, 14, 87, 91, 95
- Paraffins, general properties, 3

- Petroleum composition, 2, 4
Physical mixture studies
 of metal and acid, 86, 88–94
Process licensors
 Amoco, 437, 490
 Axens (IFP), 340, 341, 344, 345, 477,
 481, 485–487
 Chevron, 435, 490
 Engelhard, 488
 Exxon, 489
 Houdry, 488
 UOP, 340, 341, 344, 345, 438, 439,
 479, 482–485
Pt/Re/Al₂O₃
 irreversibly held sulfur on, 54, 106,
 412
Pt/Re/S/Al₂O₃
 impact on hydrogenolysis, 54
 irreversibly held sulfur on, 54, 106,
 412
 sulfur tolerance of, 54, 106
Pt/SO₄²⁻-ZrO₂, 94, 96–99, 102
- Reaction mechanisms
 bond shift, 36, 40, 41, 51
 bond shift isomerization, 41, 42, 51,
 100
 C₅ cyclic, 36, 39, 40, 46, 47, 51, 53,
 58, 64
 1,5 ring closure, 37
 1,6 ring closure, 36, 38, 50
 ring opening, 36, 39, 41, 45, 46, 66
 thermal cyclization, 37
 triene, 37, 39, 50
 two dimensional, 37, 47
- Reaction sensitive structures, 67
Redispersions of metals, 210, 453, 455
Reformate composition, 17, 18
Reformer feeds
 boiling range, 107, 112
 cracked naphthas, 107, 109–114
 impurities in, 107–110, 112, 114
 olefins in, 107, 110–112
 straight run naphtha, 107, 108, 114,
 116, 117
- Regeneration, 337–341, 407–433,
 454–456, 460, 478–480, 521
efficiency, 459
hydrogen, 403 484
improvements, 344–346, 436, 484
oxygen, 391, 441–456
sintering, 343, 442, 452–456
 influence on catalytic reactions,
 443
 migration mechanisms in, 453
model, 453
- Reid vapor pressure, 10, 505, 523,
 530
- Single crystal studies, 50, 56, 65
 comparison with Pt/Al₂O₃, 43
reactivities of Pt corners, steps, kinks,
 ledges, and terraces, 42, 44
reconstruction of platinum, 44, 45,
 67
sulfur-induced reconstruction of
 platinum, 54
of surface geometries for platinum,
 42
- Skeletal rearrangement reactions, 35,
 42, 43, 50, 54
- Structure-insensitive reactions, 52
- Structure-sensitive reactions, 53, 402
- Sulfur
 activity and selectivity affected by,
 21, 56, 57, 379, 410–412
 effect on hydrogenolysis activity, 21,
 54, 55, 106
 effect on skeletal isomerization, 54,
 55
 nature of adsorption, 21
 as poisons for metallic catalysts, 15,
 16, 21, 54, 56, 93, 105, 106,
 532
removal legislation, 20, 105, 109,
 111, 113, 138, 139, 335, 433,
 456
reversible/irreversible forms, 54,
 106, 412

Surface unsaturated species, 37, 39, 44,
50, 86

[Thermodynamics]
of reforming reactions, 14, 52,
77–85, 91, 553, 556, 558, 568

Thermodynamics, 15, 76–78, 89, 90,
380–383, 552–555
equilibrium, 15, 78–85, 89–91, 96,
381, 382, 552–557

Zeolite channels
impact on metal, 39, 46, 49