

INDEX

- AB-PBI. *See* Polybenzimidazole (PBI)
- ABS. *See* Acrylonitrile-butadiene-styrene (ABS) polymer
- ACE. *See* Angiotensin converting enzyme (ACE) inhibitors
- Acid(s), 159–160
- Acid-base interaction
cross-link formation, 778
- Acid-doped polybenzimidazole, 769
- Acoustic sensors, 148
- Acrylic polymers, 503
- Acrylonitrile-butadiene-styrene (ABS)
polymer, 798
- Activated sludge process
MBR process, 121
- Acute renal failure (ARF), 519
- ADC. *See* Affordable desalination collaboration (ADC)
- AdDur reverse osmosis plant
permeate quality, 34
plant specifications, 32
- Adequate dialysis requirements, 524
- Admissible organic carbon (AOC), 150
- Adsorbable organic halogen compounds (AOX), 226
- Adsorption
coagulation, 144
cytokines, 525
endotoxins, 525
GAC, 277
medical membranes, 499
membrane, 696–697
RO membrane, 15
toxin removal, 534
- Advanced large-sized BOE modules
specifications, 44
- Advanced large-sized reverse osmosis modules, 40–43
membrane arrangement, 41
process flow, 41
- Aeration
bubbles, 255
capacity, 231–232
MBR modules, 126
tanks, 231–233
- AES. *See* Auger electron spectroscopy (AES)
- Affordable desalination collaboration (ADC), 96–99
demonstration protocol, 97–98
desalination costs, 98
equipment protocol, 97–98
flow scheme, 99
goals, 97
organization, 96–97
- AFM. *See* Atomic force microscopy (AFM)
- AGMD. *See* Air gap membrane distillation (AGMD)
- Air and humidified feeds
CMS membranes, 625
- Air-coupled piezoelectric transducers, 891
- Airflow rate requirements
MBR, 256
- Airflow techniques, 148
- Air gap
distances, 353
external fiber morphology, 828
hollow-fiber membrane, 827
permeance change, 827
- Air gap membrane distillation (AGMD), 299, 303, 304, 337, 351–352
flux, 353
width, 353
- Air scour, 265

- Air separation, 594
 membrane-based gas separation, 659
 vacuum and pressure mode, 660
- Albumin dialysis, 535
- Alcohol photooxidation
 structure-reactivity trend, 711
- Alcohol sorption, 711
- Alginate gel
 solute diffusion, 425
- All-polymeric membranes
 example, 769
 immobilized imidazole system, 764
- Alternate pathway
 complement cascade, 525
- Alternative seawater reverse osmosis
 membrane system configurations, 70–76
- Alternative turbocharger reverse osmosis
 flow scheme, 91
- Alumina membrane, 791
 mesoporous structures, 900
 permeation porometry, 922
 visual appearance, 918
- Aluminum phosphate, 792
- Aluminum removal, 284
- American Membrane Technology Association (AMTA), 99
- Amine-solid-polymer
 mixed-matrix membranes, 808
- Ammonia, 49
- Ammonia separation
 mixed-matrix membranes, 805
- Amorphous fluoropolymers, 650–651, 664
- Amoxicillin removal and recovery, 736
- Ampicillin removal and recovery, 736
- AMT. *See* Applied Membrane Technology (AMT) Inc.
- AMTA. *See* American Membrane Technology Association (AMTA)
- Angiotensin converting enzyme (ACE)
 inhibitors, 526
- Anion rejection, 380
- Anomalous diffusion, 635
- AN69ST membranes, 507
- Antibiotic removal and recovery, 736–737
- AOC. *See* Admissible organic carbon (AOC)
- AOX. *See* Adsorbable organic halogen compounds (AOX)
- Applied current vs. silica rejection, 392
- Applied Membrane Technology (AMT) Inc., 315
- Applied transmembrane pressure vs. water flux, 323
- Aquatic life chemical treatment, 81
- Aqueous organic solution permeation, 485
- ARF. *See* Acute renal failure (ARF)
- Aromatic polyamide membranes
 chlorine degradation rate, 18
 chlorine tolerance, 17–18
 hollow fiber, 6
- Arrhenius equation, 637, 644
- Arrival time shift factor, 885
- Arsenic concentrations, 284
- As-cast polyaniline membranes, 641
- Ashkelon Seawater Desalination Project, 84
- As-spun hollow fibers
 posttreatment and additional coating, 830
 spinning solution, 822, 827
- Asymmetric membrane
 CA, 4
 formation, 822
 hollow fiber, 822, 829–830
 macrovoids, 829–830
 manufacture, 587
 polyimide membrane gas separation, 587
 structure, 587
 synthetic hemodialysis, 529
- Atomic absorption analysis
 inductively coupled plasma analysis, 197
- Atomic force microscopy (AFM), 134, 320, 329–330, 860, 865–867
 hollow-fiber ultrafiltration membrane, 826
 HVHP, 330
 roughness, 136
- ATR. *See* Attenuated total reflectance (ATR)
- Atrazine removal, 279
- Attenuated total reflectance (ATR), 844
 chemical structures, 844
 Nafion, 847
- Audible tests, 148
- Auger electron spectroscopy (AES), 842, 850–851
- Autothermal reforming syngas
 composition, 743
 feed-side carbon and sweep-side temperature profiles, 744
 feed-side carbon monoxide, 744
- AZEO SEP
 hybrid ethanol dehydration plant, 472, 473, 480
 hybrid ethyl ester esterification plant, 473
 pervaporation hybrid systems, 472
 PV, 471–474, 481, 486
 solvent dehydration, 481

- Backscattered electrons (BSE), 863
- Backwashing, 156–158
 - disposal, 164–165
 - effects on flux restoration, 157
 - effects on water consumption, 157
 - fouled membranes, 264–265
 - importance, 265
 - membrane, 63
 - permeate, 265
 - pressure, 157
- Backwash water
 - microfiltration water treatment, 164
 - recirculation, 164–165
 - recovery of chemicals, 164
 - reuse, 164–165
 - treatment, 164–165, 165
 - ultimate disposal, 165
 - ultrafiltration water treatment, 164
- Barrer, 578
- Batch clarification/concentration, 448
- Batch-continuous operation, 243
- Batch degradation
 - TCE, 204–205
 - TCE study, 194–195, 204
- Batch desalting, 448
- Batch pervaporation process, 478
- Batchwise operation, 448
- BCS. *See* Brine conversion system (BCS)
- Beach wells, 51
- Bentonite suspension critical flux
 - submerged hollow-fiber membranes, 258
- Benzene, toluene, ethylbenzene, and xylene (BTEX), 577, 578
- Benzophenone tetracarboxylic dianhydride (BTDA), 453
- BET. *See* Brunauer-Emmett-Teller (BET) mode sorption
- Bimetallic nanoparticles
 - chitosan membranes, 194, 212
 - mixed-matrix, 194
- Bioartificial organs, 427
- Biocatalytic membrane reactors, 704
- Biochemical oxygen demand (BOD), 121
- Biofouling, 152
 - protection, 13–14
 - reverse osmosis thin-film composite membranes, 13
 - RO, 13–14
 - UTDR membrane characterization, 885
- Bioline coating, 506
- Biological angiogenesis, 413
- Biological fouling, 152
 - prevention, 34
- Biomaterial-induced activation
 - coagulation, 509
- Biomedical applications, 489–512
 - biocompatibility, 508–510
 - medical membrane materials, 501–507
 - medical membrane properties, 496–500
 - therapeutic treatments, 490–495
- Biopharmaceutical industry
 - processing cassettes, 443–444
 - protein-based therapeutics, 435
- Bioprocess design, 411
- Bioreactor technology, 411
- Blends in membranes, 777–778
- Blocking (clogging)
 - mitigation, 264
 - modules, 264
 - submerged membranes, 262–264
- Blood pressure medications, 526
- Blood treatment membrane, 491–492
- BOD. *See* Biochemical oxygen demand (BOD)
- BOE. *See* Both open-ended (BOE) modules
- Boltzmann constant, 603
- Bondi's free-volume method, 582
- Bone tissue engineering, 413–414
 - testing, 414
- Booster bump
 - pressure exchanger system, 78
- Bore-side feed, 588
- Boron reduction, 80
- Both open-ended (BOE) modules, 36
 - element cross section, 38
 - element flow pattern, 38
 - hollow-fiber membrane, 37, 38
 - specifications, 39
- Boundary layers
 - heat transfer, 338–340
 - mass transfer, 338–340
- Bound toxins
 - protein, 535
- Brackish water desalination
 - low-pressure membrane, 7–8
 - RO membrane, 8
 - systems integration, 85
- Brackish water reverse osmosis (BWRO), 71
 - elements performance, 8
- Brine conversion system (BCS), 7, 8, 9
 - flow diagrams, 10
- Brine water, 39
- Bromide concentration
 - desalinated seawater, 49

- Brunauer-Emmett-Teller (BET) mode sorption, 636
- BSE. *See* Backscattered electrons (BSE)
- BTDA. *See* Benzophenone tetracarboxylic dianhydride (BTDA)
- BTDA-diaminophenylidene. *See* Matrimid 5218
- BTEX. *See* Benzene, toluene, ethylbenzene, and xylene (BTEX)
- Bubbles
- aeration, 255
 - cross-flow filtration, 263–264
 - fouling rate, 255
 - generation, 699
 - high solids feed, 263–264
 - hollow-fiber membrane, 262
 - production, 255
 - role, 253
 - shear stress induced, 255
 - submerged membranes, 253–261
- Bubbling rate
- flat-sheet membranes, 259
 - submerged hollow-fiber membranes, 258
- BWRO. *See* Brackish water reverse osmosis (BWRO)
- CA. *See* Cellulose acetate membrane;
- Contact angle
- C-AFM. *See* Contact atomic force microscopy (C-AFM)
- Cake control mechanisms, 253
- Capillary membranes, 317
- Carbon dioxide
- concentration *vs.* recovery, 747
 - diffusivity, 941, 948
 - facilitated transport membranes, 737–746
 - feed pressure, 740
 - flue gas, 728, 747
 - gas separation, 805
 - infinite-dilution diffusivity, 947
 - model description, 743
 - modeling results, 743–744
 - recovery landfill gas, 663
 - selective membrane, 737–738
 - selective polymeric membrane, 725
 - selective WGS membrane reaction, 743–744
 - separation, 590, 662
 - synthesis, 737–738
 - synthesis gas, 728
 - transport measurement and mechanism, 738
 - vs.* water content, 740
- Carbon dioxide flux
- feed pressure, 738–739
 - water content, 739–740
- Carbon dioxide permeability, 644, 941
- feed pressure, 738–739
 - PEBAX, 658
 - polymer composition, 944
 - temperature, 740–741, 944
 - vs.* water content, 739–740
- Carbon dioxide removal, 737
- facilitated transport membranes, 725
 - natural gas, 662
 - polar rubbery membranes structure, 929–949
 - property characteristics, 929–949
 - theory and experiment, 932–936
 - XLPEO, 947–948
- Carbon membrane, 791
- pore structure, 602
 - precursor material and morphology, 608
- Carbon membrane gas separation, 599–626
- challenges, 622–625
 - development, 626
 - disadvantages, 622–625
 - formation, 604–615
 - modules, 620–621
 - separation performance, 616–619
 - structure, 599–600
 - transport, 601–603
- Carbon molecular sieve membranes, 599, 607, 625
- aging effects, 624
 - air and humidified feeds, 625
 - hollow-fiber impurities, 624
 - polymeric membrane, 620
 - pores size, 603
 - ramp rate, 614
 - reproducibility, 622
 - separation performance, 617–619
- Carbon monoxide *vs.* feed flow rate, 745
- Carbon-polymer membranes, 798
- Carbon tetrafluoride (CF₄), 310
- Cardo-type polyimide, 592
- chemical structures, 592
- Carman-Kozeny equation, 459
- Carmeda Bioactive Surface technique, 506
- Cartridge filters, 63–64
- SWRO systems, 64
- CAS. *See* Conventional activated sludge (CAS)
- Cascade activation
- coagulation, 508–509

- Catalytic crystals
 membrane reactors, 712
- Catalytic membrane
 XPS, 708
- Catalytic membrane reactor (CMR), 703
- Caustic, 159
- CAVF. *See* Continuous arteriovenous hemofiltration (CAVF)
- CAVU. *See* Continuous arteriovenous ultrafiltration (CAVU)
- CCI. *See* Continuous chlorine injection (CCI) method
- CCP. *See* Cubic close packing (CCP)
- CEC. *See* Council of European Communities (CEC)
- CED. *See* Cohesive energy density (CED)
- Cell function monitoring, 425–426
- Cellulose acetate membrane, 4–6, 66, 378, 503, 528, 791, 792, 807
 asymmetric membrane, 4
 CSLM image, 862
 CTA, 43
 history, 21–22
 modules, 22
 performance, 949
- Cellulose-based polymers, 502
- Cellulose derivatives, 502–503
- Cellulose esters, 503
- Cellulose ethers, 503
- Cellulose membranes, 527
 hemodialyzers, 528
- Cellulose triacetate (CTA), 23, 43, 44, 310
 CA, 43
 chemistry, 27
 fiber form, 44
 RO, 21–44, 44
 RO membrane, 31
 schematic flow diagram, 32–33
 test unit, 32–33
- Centralized energy recovery systems, 76
- Cephalexin removal and recovery, 736
- Cephalosporin removal and recovery, 736
- Ceramic membranes, 134, 899
- Ceramic titanium nitride
 intensity profile, 848
- Cermet, 680
- CF. *See* Concentration factor (CF)
- CF4. *See* Carbon tetrafluoride (CF4)
- CFC. *See* Halogenated hydrocarbons
- CFD. *See* Computational fluid dynamics (CFD) model
- CFMF. *See* Cross-flow microfiltration (CFMF) systems
- Chelating agents, 159–160
- Chemical cleaning, 15, 158–160
 effects, 161
 efficiency factors, 160
 membrane, 63, 161
- Chemically enhanced backwash, 265
- Chemical oxygen demand (COD), 280
- Chemical recovery
 backwash water, 164
- Chemical resistance
 PVDF hollow fiber membrane, 125
- Chemicals
 chitosan membranes, 191–192
- Chemical structure
 chitosan membranes, 190
- Chitosan-embedded membrane
 bimetallic nanoparticles mixed-matrix, 194
 iron nanoparticle, 192–194, 200
 nickel, 192–194
 silica gel, 192–194, 200
 synthesis flowchart, 194
- Chitosan film
 EDS, 199
- Chitosan membranes
 analysis methods, 195–196
 characterization, 196–197
 chemicals, 191–192
 chemical structure, 190
 chlorinated organic remediation, 189–212
 discussions, 197–212
 experimental section, 191–197
 nanoparticles, 204
 results, 197–212
 silica gel, 192
 synthesis, 192–194, 197–204
 XRD analysis, 201
- Chitosan nanoparticles
 silica gel, 203
- Chlorinated organic remediation
 chitosan membranes, 189–212
- Chlorine
 ammonia, 49
 disinfecting power, 30
 injection, 33
- Chlorine degradation rate
 aromatic polyamide membranes, 18
- Chlorine tolerance
 aromatic polyamide membranes, 17–18
 RO membrane, 17

- Chloroform removal, 279
- Chromium
 - concentration, 729
 - flux, 729
 - removal and recovery, 729–730
- Chronic kidney disease (CKD), 519
- CIP. *See* Cleaning-in-place (CIP)
- CKD. *See* Chronic kidney disease (CKD)
- Cleaning
 - chemical, 15, 63, 158–161
 - costs, 62
 - fouled membranes, 264–265
 - membrane, 223–226
 - MF, 155–160
 - microfiltration water treatment, 149–159
 - submerged membranes, 225, 246, 265
 - SWRO membrane, 62
 - UF, 155–160
 - ultrafiltration water treatment, 149–159
- Cleaning-in-place (CIP), 283
- Cleaning protocols
 - Kubota, 265
 - MBR, 265
 - Memcor, 265
- Clearance, 522
- Clearance validation
 - virus, 552
- Clotting, 525
- CMR. *See* Catalytic membrane reactor (CMR)
- CMS. *See* Carbon molecular sieve membranes; Compact Membrane Systems
- Coagulation, 58–59
 - adsorption process, 144
 - biomaterial-induced activation, 509
 - cascade activation, 508–509
 - sedimentation process, 144
- Coarse-bubble aeration, 255
- Coating
 - silicone rubber, 830
- Cobalt
 - feed and strip solutions, 734
 - removal and recovery, 733–734
- COD. *See* Chemical oxygen demand (COD)
- C20 ODPPA extractant radioactive
 - Strontium-90 removal, 735
- Cohesive energy density (CED), 582
 - correlation, 586
- Colloidal filtration, 916, 921
- Colloidal fouling, 152
- Colloidal nanoparticles, 211
- Compact Membrane Systems, 664
- Complement activation, 509–510, 525
- Composite membranes, 6, 562, 655, 674, 777–778
 - heteropolyacids, 770–771
 - inorganic particles, 770–771
 - nonporous, 674
 - oxygen transport, 903
 - schematic illustration, 563
 - silica, 680
 - silicone rubber, 562
- Composting plants
 - leachates treatment, 281
- Compressive strain
 - Zirfon composite UF membrane, 888
- Computational fluid dynamics (CFD) model, 827
- Concentrate disposal device, 81
- Concentration factor (CF)
 - calculations, 275
- Concentration polarization, 460–461
 - effects, 338–340
 - equation, 437
 - MD, 331–340
- Confocal scanning laser microscopy (CSLM), 860–863
 - CA membrane, 862
- Connected pore size distribution (CPSD), 921
- Constant flux operation, 140f
 - TMP, 243
- Constant-pressure operation, 140
- Contact angle, 708, 709
 - determination, 853
 - hysteresis, 853
 - MD, 324
 - measurements, 135, 324
 - water, 324
- Contact atomic force microscopy (C-AFM), 865, 867
- Contactors, 687–700
 - categories, 689
 - dispersive contacting, 699
 - fluid phases, 688
 - solid-fluid, 696
 - solid-fluid phase, 689
 - system, 689
 - two-fluid phases, 690–695
 - two immobilized phase interfaces, 697–698
- Contact-phase activation, 509
 - drug-mediated amplification, 510
- Contained microfiltration systems, 245
- Contained modules vs. submerged membranes, 244–246

- Contained ultrafiltration systems, 245
- Contaminant removal
water, 284
- Continuous arteriovenous hemofiltration
(CAVF), 493
- Continuous arteriovenous ultrafiltration
(CAVU), 493
- Continuous chlorine injection (CCI) method,
30
- Continuous pervaporation process, 477–478
- Convected deposition flux, 242
- Conventional activated sludge (CAS), 172, 174
capital costs breakdown, 179
direct costs, 178
MBR process, 226–228
MLSS, 226
operation and maintenance costs, 179
process, 217
process flow diagram, 174
TF plants, 180–181
total capital costs, 179
total life-cycle costs, 180–181
total operation and maintenance costs, 180
- Conventional reactor
properties, 714
- Conventional sedimentation, 59
- Cooperativity plots, 939
- Copolymerization with polyethylene glycol,
935
- Copolymer networks, 651
characteristics, 938
cooperativity plots, 940
storage modulus vs. temperature, 937
- Copper
feed and strip solutions, 731
removal and recovery, 730
- Cost
CAS plants, 178, 179, 180–181
desalination, 181–185
effective PEM materials, 772
low-temperature operation, 772
MBR, 233–235
palladium, 679
seawater desalination, 182, 183
submerged membranes, 245
SWRO, 100
wastewater treatment membrane bioreactors,
233–234
water desalination, 181–184
water reclamation, 173, 177–180
- Council of European Communities (CEC),
228
- CPA. *See* Cryoprotective agents (CPA)
- CPSD. *See* Connected pore size distribution
(CPSD)
- Critical concentration, 824
- Critical flux, 243, 257–258
transient effects, 260
- Critical temperature vs. selectivity, 806
- Cross arrangement
HF, 25
- Cross-flow configuration
MF, 141
UF, 141
- Cross-flow filtration, 242–243
membrane separation, 377
- Cross-flow membrane modules, 439
- Cross-flow microfiltration (CFMF) systems,
145
- Crosslinked aromatic polyamide membrane
chlorine tolerance
reverse osmosis thin-film composite
membranes, 17
- Crosslinked polyacrylonitrile supports, 454
- Crosslinked poly(ethylene glycol) diacrylate,
935
characteristics, 938
- Crosslinked polyethyleneoxide
(XLPEO), 931
carbon dioxide removal, 947–948
gas selectivity and FFV, 942
glass-rubber relaxation characteristics, 937
networks, 937
performance, 947–948, 950
representative network elements, 932
separation characteristics, 949
structural detail correlation, 940
temperature and pressure effects, 943
viscoelastic properties, 937
- Cross-link formation
acid-base interaction, 778
- Crosslinking, 613
- Cross-winding style, 28
- Cross-wound hollow-fiber bundle, 25
- Cryopreservation procedures
mass transfer control, 428
- Cryoprotective agents (CPA)
addition and removal, 428
- Cryptosporidium, 120
- CSLM. *See* Confocal scanning laser
microscopy (CSLM)
- CTA. *See* Cellulose triacetate (CTA)
- Cubic close packing (CCP), 906
- Cyclical backflushing, 224

- Cyprus seawater reverse osmosis plant
open intake structure, 51
- Cytokines
adsorption, 525
- DA. *See* Diamines (DA)
- Dais analytic membrane polymers, 773
- DAPI. *See* Matrimid 5218
- DBP. *See* Disinfection byproduct (DBP)
- DCB. *See* Dichlorobiphenyls (DCB)
- DCMD. *See* Direct-contact membrane distillation (DCMD)
- DDR. *See* Deca-dodecyl 3R (DDR)
- Dead-end configurations, 141
- Dead-end filtration, 243, 247
low solids feeding, 262–264
- DEAE. *See* Diethylaminoethyl (DEAE)
- Deca-dodecyl 3R (DDR), 792
- Decatungstate lipophilic salt
heterogenization, 705
- Dechlorination mechanism
DCB, 210
- Degasification, 393–395
mass transfer, 395–396
membrane morphology, 394
module, 396
unit installation, 394
- Degasifier
dissolved oxygen removal, 397
flow rate and vacuum conditions, 399, 400
TOC and THM removal, 398
- Degradation
compositional effect, 206
DCB, 195, 206–211
long-term study, 211
methods, 194–195
study, 195
TCE, 193, 204–206
- Dehumidification system, 595
- Dehydration
ethylene hydroxide, 597
IPA, 597
organic compounds, 595
- Delamination
dual-layer asymmetric hollow fiber membranes, 832
- Demineralization
sweet whey, 283
- Dense ceramic metal composite membranes (cermet), 680
- Dense films, 800–801
dope formulation, 801
mixed-matrix, 801
- Dense membranes, 674
inorganic material group, 903
oxygen transport, 903
recombination processes, 909
- Dense structures, 902–903
- Density
membrane, 529–530
- Department of Energy (DOE)
hydrogen separation technical targets, 679
technical targets PEMFC, 762
- Deposit resistance, 241
- Desal 5 DL, 855, 866
- Desalinated seawater, 80
bromide concentration, 49
industrial applications, 47
- Desalination
ADC, 98
costs, 98, 181–185
EDI, 390–391
feed water, 172
performance, 390–391
process options, 181
RO permeate quality, 173
SWRO, 54, 56, 82
treatment systems, 54
water, 171–186
water reclamation, 171–188
vs. water reuse, 185–186
- Desalination plant
advantages, 56
disadvantages, 56
discharge, 54
intake, 54
SWRO, 54
- Design optimization for target processes, 924
- Desorption isotherm
permeation porometry, 922
- Dew point, 577
- DGM. *See* Dusty gas model (DGM)
- Dialysate
exogenous agent exposure, 511
- Dialysis
alternative modes, 533
treatment time and frequency, 534
- Dialyzers
design and performance, 530–532
dimensions, 530
HD membranes, 530–532
lengths, 531

- membranes, 527
- reuse, 526
- surface area and fiber number, 531
- Diamines (DA), 453
 - polyimide production, 610
- Diaminophenylidene (DAPI). *See* Matrimid 5218
- Dianhydride
 - polyimide production, 610
- Dichlorobiphenyls (DCB)
 - analysis, 196
 - conversion, 210
 - degradation mechanism, 208–210
 - degradation study, 195, 206–211
 - hydrodechlorination process, 209
 - hypothesized reductive dechlorination mechanism, 210
 - pressure-induced operation, 207
- Diethylaminoethyl (DEAE), 503
- Differential element of volume, 477
- Differential pressure, 34
- Diffuse reflectance ultraviolet (DR-UV) spectra, 705
- PVDF, 706
- Diffusion
 - carbon dioxide, 941, 948
 - hopping, 911
 - PI, 584
 - polymer membrane, 640
 - small molecules, 644, 645, 646
 - surface transport, 911
- Dimethylacetamide (DMAC), 311
- Dimethylformamide (DMF), 311
- Dimethylglycine (DMG), 727
- Dimethyl sulfoxide (DMSO), 310
- Diol isomers, 806
- Dip coated phenol-formaldehyde novolak resin, 610
- Dip coated resol-type phenolic resin, 611
- Diphenyl isophthalate (DPIP), 653
- Direct-contact membrane distillation (DCMD), 298, 301, 303, 304, 311, 321, 341–343, 698
 - configuration, 332–334
 - flux, 312, 343
 - mechanism, 314
- Direct energy recovery devices, 91–94
- Direct filtration, 142
- Direct-flow-based contacting, 697
- Direct integrity tests, 147–148
- Direct methanol fuel cell (DMFC), 755, 758, 775
 - low crossover, 761
 - membrane thickness, 763
 - requirements, 759
 - schematic diagram, 759
- Discharge
 - power plant intake, 55
- Disinfecting power
 - chlorine, 30
- Disinfection byproduct (DBP), 50, 131
 - precursors, 278
- Disinfection tests, 31
- Disk filters, 57
- Dispersion-based membrane contactor, 690
- Dispersive contacting
 - contactors, 699
- Disposal
 - backwash water, 165
- Dissolved organic carbon (DOC)
 - changes, 119
- Dissolved organic matter (DOM), 144
- Dissolved oxygen removal
 - degasifier, 397
 - methods, 373
- Dissolved ozone concentration
 - MF, 115
 - MF filtration flux, 115
- Distillate temperature, 303
- Distillation method
 - separation system, 596
- Distributed polyacetylene polymers
 - gas permeability and selectivity, 650
- Distribution piping
 - feed water, 75
- Disulfonated polysulfone polymers, 774
- Diuron, 279
- DMAC. *See* Dimethylacetamide (DMAC)
- DMEM. *See* Dulbecco's Modified Eagle's Medium (DMEM)
- DMF. *See* Dimethylformamide (DMF); Dual-media filter (DMF)
- DMFC. *See* Direct methanol fuel cell (DMFC)
- DMG. *See* Dimethylglycine (DMG)
- DMSO. *See* Dimethyl sulfoxide (DMSO)
- DOC. *See* Dissolved organic carbon (DOC) changes
- DOE. *See* Department of Energy (DOE)
- DOM. *See* Dissolved organic matter (DOM)
- Donnan potentials, 858
- Dope, 587, 800–801
 - composition, 824
 - flow rates, 833

- Dope formulation
dense mixed-matrix films, 801
- Double-pass reverse osmosis
interstage caustic dosing, 380–381
interstage pH boron rejection, 381
TOC rejection, 381
- Downcomer region, 253
- Downstream pressure
vs. VMD fluxes, 350
- DPIP. *See* Diphenyl isophthalate (DPIP)
- DRAM. *See* Dynamic random access memory (DRAM)
- Dried polymer solution of chitosan
FTIR analysis, 199
- Drinking water
NF, 276–279
- Drug-mediated amplification
contact-phase activation, 510
- DR-UV. *See* Diffuse reflectance ultraviolet (DR-UV) spectra
- Dryer system
membrane, 595
- Dry flow method, 328–329
- Dry-jet wet-spinning
hollow-fiber membrane, 823
PES single-layer hollow-fiber membranes, 829
- DSIMS. *See* Dynamic secondary ion mass spectrometry (DSIMS)
- Dual-layer asymmetric hollow fiber membranes
delamination, 832
extrusion process, 831
layer shrinkage, 832
membrane morphology, 832
- Dual-layer hollow fiber membranes, 831–834
heat treatment methods, 834
interface, 834
mixed-matrix, 802
posttreatment, 834
SEM morphology, 834
structure shrinkage percentage, 832
zeolite particles, 802
- Dual-layer membranes
inter-layer diffusion, 833–834
- Dual-layer spinneret
structure and flow channels, 831
- Dual-media filter (DMF), 29, 32
- Dual-mode sorption, 636
- Dual-step desalination, 283–284
- Dulbecco's Modified Eagle's Medium (DMEM), 423, 424
- DuPont, 6
- Duropore polyvinylidene fluoride membranes
reflection amplitude, 893
- Dusty gas model (DGM), 914
- DWEER
isobaric energy recovery system, 92, 93, 95
pressure exchanger, 78
- Dynamic random access memory (DRAM), 371
- Dynamic secondary ion mass spectrometry (DSIMS), 851
- EBW. *See* Enhanced backwash (EBW)
- EDC. *See* Endocrine disruptors (EDC)
- EDI. *See* Electrodeionization (EDI)
- EDS. *See* Electron dispersive spectroscopy (EDS)
- E factor, 388
- Effective porosity, 326–328
- Effluent, 463
- Effluent organic matter (EfOM), 280
- Effluent quality
MBR, 228
- Effluent treatment
textile industry, 280
- EfOM. *See* Effluent organic matter (EfOM)
- Einstein-Stokes equation, 497
- EIS. *See* Electrochemical impedance spectroscopy (EIS)
- Electrochemical impedance spectroscopy (EIS), 857–858
- Electrodeionization (EDI), 381–383
desalination performance, 390–391
estimation, 387
feed water hardness vs. water recovery, 385
feed water requirements, 386–387
ion removal, 383–384
ion transport device, 384
module resistance, 389–390
Omexell spiral-wound, 382
power consumption, 390
spiral-wound, 382
system, 372
system material balance, 385
voltage estimation, 390
weakly ionized species rejection, 390–392
- Electroless deposition
Pd, 677
- Electroless palladium plating solution
composition, 678
- Electroless plating
palladium ion source, 677

- Electromigration
 ion exchange membranes, 382–383
- Electron dispersive spectroscopy (EDS), 803,
 842, 848–849
 analysis, 202–203
 chitosan film, 199
- Electron spectroscopy chemical analysis
 (ESCA), 842, 849
- ELM. *See* Emulsion liquid membranes (ELM)
- Elongational drawing, 829–830
- Emulsification membrane, 699
- Emulsion liquid membranes (ELM), 722
- Endocrine disruptors (EDC), 278
- Endotoxins, 436
 adsorption, 525
- End stage renal disease (ESRD), 519
- Energy consumption
 SWRO, 97
- Energy costs, 100
 SWP, 98
- Energy dispersive X-ray spectroscopy. *See*
 Electron dispersive spectroscopy (EDS)
- Energy recovery
 SWRO, 88–95
 systems, 76–79
 ultralow seawater desalination, 88–94
 utilization, 94–95
- Energy usage
 submerged membranes, 245
- Engineered cartilage culture
 microdialysis, 424
- Engineered tissue products
 preservation and storage, 411
- Enhanced backwash (EBW), 155, 158
- Enhanced gas selectivity, 932
- Enhanced oil recovery (EOR), 663
- Enhanced sedimentation, 59
- Enriched air
 oxygen, 594
- Entropic selectivity, 602
- Enveloped viruses
 tangential-flow filtration, 548
- EO. *See* Ethylene oxide (EO)
- EOR. *See* Enhanced oil recovery (EOR)
- Epoxy resin
 HF, 26
- EPS. *See* Extracellular polymeric substances
 (EPS)
- ERI pressure exchange, 79
- ESCA. *See* Electron spectroscopy chemical
 analysis (ESCA)
- ESRD. *See* End stage renal disease (ESRD)
- Esterification, 472
- Ethanol-water mixtures
 LEP, 322
- Ethilenevinylalcohol. *See* Ethylene vinyl
 alcohol (EVAL)
- Ethylene hydroxide (EtOH)
 dehydration, 597
- Ethylene oxide (EO), 504, 510, 936
 manufacturing plants ethylene recovery, 572
 plant ethylene recovery unit performance,
 573
- Ethylene recovery
 and vinyl acetate manufacturing plants, 572
- Ethylene separation
 mixed-matrix membranes, 805
- Ethylene vinyl alcohol (EVAL), 504, 527
- EtO. *See* Ethylene oxide (EO)
- EtOH. *See* Ethylene hydroxide (EtOH)
- EVAL. *See* Ethylene vinyl alcohol (EVAL)
- Evaporative casting
 polymeric membranes, 890
- Excebrane membranes, 507
- Exhaust gases, 592
- Exogenous agent exposure
 dialysate, 511
- External fiber morphology
 air gap distance, 828
- Externally mounted acoustic transducer, 889
- Extracellular polymeric substances (EPS), 152
- Extracorporeal treatment filtration processes
 renal failure, 500
- Extrusion process
 dual-layer asymmetric hollow
 fiber membranes, 831
- Facilitated transport membranes, 721–749
 carbon-dioxide-selective membranes,
 737–746
 polymer, 662
 schematic, 722
 strip dispersion supported liquid membranes,
 729–736
 types, 721
- Fast protein liquid chromatography (FPLC),
 426
- FBS. *See* Fetal bovine serum (FBS)
- Feed inlet temperature
 MD flux, 346
- Feed manipulation, 264
- Feed pressure
 carbon dioxide flux, 738–739
 water selectivity, 740

- Feed-side carbon monoxide
 - autothermal reforming syngas, 744
- Feed sources
 - permeate flux, 378
- Feed temperature, 348
- Feed water
 - characteristics, 150
 - conductivity vs. product resistivity, 391
 - desalination, 172
 - distribution piping, 75
 - EDI, 386–387
 - quality, 172
 - reclamation, 172
 - requirements, 386–387
 - sources, 172
- Ferric salts, 58
- FESEM. *See* Field emission scanning electron microscopy (FESEM)
- Fetal bovine serum (FBS), 424
- FFV. *See* Fractional free volume (FFV)
- FIB. *See* Focused ion beam (FIB)
- Fiberglass reinforced pipe, 52
- Fiberglass reinforced plastic, 63
 - pressure vessels, 98
- Fiber surface
 - yeast suspension after long-term filtration, 257
- Fickian diffusion, 635
- Fick's first law, 913, 932
- Field emission scanning electron microscopy (FESEM), 320, 863, 887
- Filtration, 57, 233
 - performance evaluation, 111–120
 - sewage fields, 127
 - virus, 552
 - water supply, 127
- Filtration flux
 - changes, 119
 - method effects, 115–117
 - ozone dosage effects, 114, 115
 - ozone dosage relationship, 114
- Filtration media replacement
 - frequency, 63
- Filtration system
 - Zenon ZeeWeed, 174
- Fine chemical and pharmaceutical synthesis, 461–462
- Finite difference grid, 484
- Fixed flux, 242
- Flat sheet (FS), 246, 247, 250–251
 - precursor, 622
- Flat-sheet membranes, 318, 439, 442, 886
 - bubbling rate, 259
 - mixed-liquor suspension critical flux, 259
 - module, 317, 474
- Flocculated water filtration, 144–145
- Flocculation, 58–59
- Flory-Huggins equation, 827
- Flory-Huggins mode sorption, 636
- Flory-Huggins theory, 824
- Flow angles
 - spinnerets, 826
- Flow distribution, 264
- Flow velocity
 - tubular modules, 224
- Flue gas
 - carbon dioxide capture, 728, 747
- Fluid management
 - submerged membranes, 245–246
- Fluid phases
 - applications, 695
 - contactors, 688
- Fluid-solid contacting, 696–697
- Fluoride removal, 284
- Fluoropolymers, 650
 - gasoline vapor separation system, 664
 - grafts, 775
- Flux, 401
 - AGMD, 353
 - chromium, 729
 - convected deposition, 242
 - DCMD, 312, 343
 - distribution, 258–259, 261
 - permeate, 883, 885
 - SGMD, 348
 - simulated, 261
 - steady state, 261
 - submerged hollow-fiber membranes, 259
- Flux restoration
 - backwash pressure, 157
- Foaming membrane, 699
- Focused ion beam (FIB)
 - Wattman Anopore support, 906
- Foils
 - palladium, 674
- Food industry
 - nanofiltration, 283
- Foulant
 - net flux, 243
- Fouling, 150–151, 223–226, 281, 355
 - air sparging control, 255
 - backwashing, 151, 264–265
 - bubbles, 255

- control, 219, 253
- indices, 153–155
- MD, 355
- mechanisms, 253
- membrane engineering, 127–128
- microfiltration water treatment, 149–159
- NF, 274–275
- operating strategies, 155
- pretreatment process, 163
- rate, 255
- resistance, 27, 127–128
- reverse osmosis thin-film composite membranes, 14–16
- strategies mitigating, 263
- submerged membranes, 262–264
- tendency, 27
- types, 151–153
- ultrafiltration water treatment, 149–159
- Fourier Transform Infrared Spectroscopy Analysis (FTIR), 196, 198–200
 - ATR, 844
 - dried polymer solution of chitosan, 199
 - PVDF membranes, 706
 - silica gel, 199
 - spectra, 705
 - sulfosuccinic acid, 199
- Fourier transform Raman spectroscopy (FT-Raman), 846
 - Nafion, 847
- Fourth form of membrane contactors, 689
- FPLC. *See* Fast protein liquid chromatography (FPLC)
- Fractional free volume (FFV)
 - PEGDA, 945
 - PEGMEA, 945
 - PTMSP, 649
 - XLPEO, 942
- Fractionation, 448
 - protein, 448
- Free-volume model, 946
- Free-volume theory, 944–945
- Fresh drinking water
 - RO, 45
- FRP. *See* Fiberglass reinforced pipe; Fiberglass reinforced plastic
- FS. *See* Flat sheet (FS)
- FTIR. *See* Fourier Transform Infrared Spectroscopy Analysis (FTIR)
- FT-Raman. *See* Fourier transform Raman spectroscopy (FT-Raman)
- Fuel cell membranes, 755–778
 - new, 764–778
 - types, 756
 - WGS reactor, 727
- Fuel gas conditioning, 573–574, 591
 - unit flow diagram, 574
- Fujairah plant, 73
 - seawater desalination schematic, 73
- Fujita-modified Cohen-Turnbull model, 946
- Fukuoka plant
 - seawater RO desalination, 39–40
 - specifications, 40
- Fully nondestructive techniques, 919
- GAC. *See* Granular activated carbon (GAC)
- Gained output ratio (GOR), 352
- Gamma-butyrolactone (GBL), 314, 612
- Gas
 - absorption, 690
 - bubbles, 437
 - diffusivity, 933
 - polymer membrane diffusion, 635
- Gas chromatography (GC), 745
- Gas diffusion coefficient, 582
 - temperature, 943
- Gas diffusion layers (GDL), 757
- Gas exchange (GE)
 - devices, 495
 - surface modifications, 506
- Gas-liquid contacting
 - applications, 693
 - membranes, 691
- Gas-liquid displacement porometry
 - mercury porosimetry and measurements, 329
- Gas-liquid systems, 690
 - mass transfer, 692
- Gasoline station tank vent
 - gasoline-vapor recovery unit, 571
- Gasoline vapor recovery systems, 568–569
 - flow schematic, 570
- Gasoline-vapor recovery unit
 - retail gasoline station tank vent, 571
- Gasoline vapor vent gas composition, 569
- Gas permeability
 - distributed polyacetylene polymers, 650
 - polyaniline composite membranes, 641
 - polymer membrane, 639
- Gas permeation steps, 637
- Gas permeation test, 326–327
- Gas permeation unit (gpu), 578, 727

- Gas purification
 - characterization, 918–922
 - defects, 902–907
 - manufacturing, 917
 - morphology, 902–907
 - porosity, 902–907
 - supported membrane structure optimization, 908–916
 - synthesis, 917
 - thin supported inorganic microstructural optimization, 899–925
- Gas selectivity
 - XLPEO, 942
- Gas separation
 - mixed-matrix membranes, 802
 - MSCM, 672–673
 - polymers, 581
 - using solid-polymer mixed-matrix membranes, 797
- Gas-solid membrane contactor, 697
- Gas solubility
 - rubbery polymer, 933
- Gas stripping, 690
- Gas transport
 - mesoporous membrane, 913–914
 - parameters, 901
 - permeability and selectivity, 931–932
 - pressure dependence, 638–639
 - SSF membranes, 605
 - temperature dependence, 637–638
- GBL. *See* Gamma-butyrolactone (GBL)
- GC. *See* Gas chromatography (GC)
- GDL. *See* Gas diffusion layers (GDL)
- GE. *See* Gas exchange (GE); Zenon ZeeWeed
- Gibbs energy, 460
- GKSS. *See* Herman Von Helmholtz Society of German Research centers (GKSS), Geesthacht, Germany
- Glass-rubber relaxation, 935
- Glassy polymers, 560, 648
 - sorption behavior, 639–640
- Glucose
 - concentration profiles, 418
 - radial concentration profiles, 419, 420
- GMP. *See* Good manufacturing practice (GMP)
- Good manufacturing practice (GMP), 411
- GOR. *See* Gained output ratio (GOR)
- Gore-Tex membranes, 302
- gpu. *See* Gas permeation unit (gpu)
- Grafted ceramic hollow-fiber membranes, 315
- Grafts
 - fluoropolymers, 775
- Granular activated carbon (GAC)
 - adsorption, 277
 - experimental conditions, 113
 - tower, 113
- Granular media pretreatment filtration, 59–63
- Grease
 - MBR design considerations, 230
- Gross flux
 - net flux, 233
- Groundwaters
 - organics removal, 277–278
 - remediation, 282
 - softening, 276
- GVHP, 306, 311, 316, 322, 326, 330, 353
- Hagen-Poiseuille equation, 273, 459
- Halogenated hydrocarbons, 663
- HB series modules, 36
 - specification, 37, 39
- HCP. *See* Hexagonal close packing (HCP)
- HD. *See* Hemodialysis (HD) membranes
- HDF. *See* Hemodiafiltration (HDF)
- Heat transfer
 - boundary layers, 338–340
 - MD membrane, 337–338
- Heat treatment methods
 - dual-layer hollow fiber membranes, 834
- Hemodiafiltration (HDF), 493
 - sieving coefficient, 498
- Hemodialysis (HD) membranes, 490–492, 519–536
 - current market trends, 533
 - dialyzer design and performance, 530–532
 - future, 533–535
 - materials, 527–529
 - requirements, 525–526
 - schematic, 520
 - sieving coefficient, 498
 - spinning technology, 527–529
 - structure, 527–529
 - transport requirements, 521–524
- Hemodialyzers, 531
 - cellulose membranes, 528
 - modified cellulose membranes, 528
 - performance, 532
 - synthetic membranes, 528
- Hemofiltration (HF), 493
- Henry's law constant, 674, 692, 933
- Henry's law sorption, 636

- Henry's solubility constant, 922
- Henry's sorption sites, 640
- Herman Von Helmholtz Society of German
Research centers (GKSS), Geesthacht,
Germany, 562, 567, 578
- Heterogeneous catalytic reactions, 190
- Heterogenization
decatungstate lipophilic salt, 705
solid-state characterization techniques, 705
- Heteropolyacids
composite membranes, 770–771
- Hexafluoroisopropylidene diphthalic anhydride
(6FDA), 827
- Hexagonal close packing (HCP), 906
- HF. *See* Hemofiltration (HF); Hollow fiber
(HF)
- HFMB. *See* Hollow fiber membrane
bioreactors (HFMB)
- High boron rejection seawater reverse osmosis
membranes, 9–13
- High-energy usage, 463
- Highly resistant polymers
classes, 452
- High membrane filtration flux
ozone dosage, 119–120
- High-molecular weight (HMW)
blood proteins, 493
- High-performance liquid chromatography
(HPLC), 275
- High-performance size exclusion
chromatography (HPSEC), 150
- High-performance tangential-flow filtration
schematic representation, 545
- High permeate flux, 437
- High-pressure boilers
water specification, 376
- High pressure pump
efficiency, 96
- High-pressure reverse osmosis modules, 42
performance, 43
specifications, 42
- High-pressure seawater reverse osmosis
elements, 70
- High-productivity (low-energy) membrane
elements, 69–70
- High-rejection seawater reverse osmosis
membrane elements, 69
- High-resolution transmission electron
microscopy (HRTEM), 202–203
- High-temperature polymer, 652–653
chemical structures, 654
gas separation applications, 653
- High-temperature proton exchange membrane
fuel cell membrane
examples, 765–768
properties, 761
- HMW. *See* High-molecular weight (HMW)
- Hollow fiber (HF)
geometry, 530–531
preparation, 23
- Hollow fiber (HF) carbon molecular sieve
membranes
organic exposure, 624
- Hollow fiber (HF) membrane, 123, 137, 246,
439, 442
air gap, 827
aromatic polyamide, 6
axial undulations, 530
BOE modules, 37, 38
configuration, 26–27, 136–137
cross arrangement, 25
dry-jet wet-spinning, 823
dual-layer hollow fibers, 831–834
epoxy resin, 26
hydrogen recovery, 672
inner diameters, 530
material, 110
MF, 132
microscopic view, 24
mixed-matrix membranes, 802
module permeation, 481–486
modules, 228–229, 317, 475, 588
phase inversion fabrication, 821–834
potential operational problems, 229
PV, 481–486
schematic view, 220
shear rate, 825
sieving coefficient, 498
single-layer asymmetric, 825–830
spinneret design and flow behavior, 825
spinning dope, 823
spinning technology, 529
stagnant and mobile bubbles, 262
structure, 110
vertical, 247
virus removal, 446
wall thickness, 530
- Hollow fiber membrane bioreactors (HFMB),
412–419
cell proliferation, 415
tissue engineering, 412–419
- Hollow fiber packing density
sieving coefficients, 531
solute clearances, 531

- Hollow fiber reverse osmosis membranes
seawater desalination, 22–23
- Hollow fiber reverse osmosis module
structure, 26
- Hollow fiber ultrafiltration membrane,
132, 445
biopharmaceutical manufacturing, 445
three-dimensional AFM image, 826
- Hollow sphere, 907
- Homogeneous catalysis synthesis
hybrid process, 286
- Horizontal hollow fiber membranes, 247
- Horizontal Ranney collector intake well, 53
- HPLC. *See* High-performance liquid
chromatography (HPLC)
- HPSEC. *See* High-performance size exclusion
chromatography (HPSEC)
- HRT. *See* Hydraulic retention time (HRT)
- HRTEM. *See* High-resolution transmission
electron microscopy (HRTEM)
- HSA. *See* Human serum albumin (HSA)
- Huber, 251–252
- Huber VRM rotating submerged flat-sheet
module, 252
- Human serum albumin (HSA), 510
- Humidified feeds
CMS membranes, 625
- HVHP, 306, 311, 316, 322, 326, 353
AFM, 330
- Hybrid compression-condensation membrane,
566
- Hybrid membranes, 655, 656, 769
- Hybrid process
homogeneous catalysis synthesis, 286
- Hybrid reverse osmosis system configurations,
73
- Hybrid systems, 566
MD, 356
- Hydraulic permeability, 521
- Hydraulic retention time (HRT), 177
- Hydrocarbon-hydrocarbon separation, 662
- Hydrocarbon vapor-air mixtures, 569
- Hydrodechlorination process
DCB, 209
- Hydrodynamics
submerged membranes, 253–261
- Hydrogenation
nitrobenzene, 190
- Hydrogen flux deterioration, 679
- Hydrogen gas, 930
- Hydrogen permeability
improvement, 676
- Hydrogen purification
supported membranes, 915
- Hydrogen recovery
offgas reformer, 590
plant, 591
- Hydrogen separation membranes, 589, 660,
671–680
characteristics, 678
high temperature, 674–679
porous nonmetallic membranes, 672–673
- Hydrogen sulfide separation
mixed-matrix membranes, 805
- Hydrogen upgrading
refineries, 661
- Hydrophilicity
characterization, 852–855
determination, 853
- Hydrophilic membranes, 470
- Hydrophobicity, 135, 308
- Hydroscopic metal oxides, 771
- Hypersensitivity reactions, 510
- ICDD. *See* International Centre for
Diffraction Data (ICDD)
- ICI. *See* Intermittent chlorine injection (ICI)
method
- Idealized transmembrane pressure cycle, 244
- ILM. *See* Immobilized liquid membrane (ILM)
- Immersed membranes. *See* Submerged
membranes
- Immobilized liquid membrane (ILM), 697
- Immobilized phase interfaces
types, 688
- Immunoisolation, 427–428
- Imposed flux. *See* Fixed flux
- IMS. *See* Integrated membrane system (IMS)
- Indirect integrity tests, 148–149
- Inductively coupled plasma analysis
atomic absorption analysis, 197
- Industrial water management
applications of MBR, 234
- Infinite-dilution permeability, 934
- Infinite-dilution diffusivity, 934
carbon dioxide, 947
- Infinite-dilution solubility, 934
- Infinite flux, 285
- Infrared attenuated total reflectance (IR-ATR)
Nafion, 847
- Infrared (IR) spectroscopy, 842–844
- In-line coagulation, 143–144
- Inorganic barrier fillers
sulfonated polymers, 778–779

- Inorganic chemicals
 MBR design considerations, 230–231
- Inorganic fouling, 151
 UTDR membrane characterization, 882–884
- Inorganic membranes, 456, 899
 sol-gel preparation, 456
 state-of-art, 791
- Inorganic particles
 composite membranes, 770–771
- Inorganic scaling, 151
- Inorganic solid acid membranes, 772
- Integral asymmetric polymeric membranes, 452–453
- Integrated membrane bioreactor, 172
- Integrated membrane system (IMS), 160–164
 design approach for water treatment, 162
 microfiltration water treatment, 160–163
 ultrafiltration water treatment, 160–163
 UPW, 377–402
- Integrity testing, 147, 148, 265–266
- Intensive chemicals, 265
- Interfacial morphologies
 mixed-matrix membranes, 795
- Interfacial polymerization (IP), 890
- Inter-layer diffusion
 dual-layer membranes, 833–834
- Intermittent chlorine injection (ICI)
 method, 27, 30, 33, 34
 advantages, 31
- Intermittent operation, 264
- International Centre for Diffraction Data (ICDD), 201
- International Desalination Association, 47
- International Technology Roadmap for Semiconductors (ITRS), 371
- Interstage caustic dosing
 double-pass RO, 380–381
- Interstage pH boron rejection
 double-pass RO, 381
- Ion exchange membranes
 electromigration, 382–383
 facilitated transport, 726
- Ionic rejection
 chemistry, 379–380
- Ion removal
 EDI, 383–384
- Ion transport device
 EDI, 384
- IP. *See* Interfacial polymerization (IP)
- IPA. *See* Isopropyl alcohol (IPA)
- IR. *See* Infrared (IR) spectroscopy
- IR-ATR. *See* Infrared attenuated total reflectance (IR-ATR)
- Iron
 chitosan-embedded membrane, 192–194
- Iron nanoparticle
 chitosan-embedded membrane, 192, 193, 200
- Irreversible fouling, 151
- Irreversible permeate flux, 150
- Isobaric energy recovery
 characteristics, 94
 device, 91–94
 DWEER, 92, 93
 efficiency curve, 92
 flow scheme, 93
 seawater, 92
 technology, 96
- Isoelectric point, 135
- Isopropyl alcohol (IPA)
 circulation purifier, 596
 dehydration, 597
 selectivity, 348
 solutions, 347
- Isoproturon, 279
- Isotherm palladium phase diagram, 676
- ITRS. *See* International Technology Roadmap for Semiconductors (ITRS)
- Japan
 wastewater treatment facility, 15
- Japan Sewage Works Agency
 pilot plant schematic, 126
- JCPDS. *See* Joint Committee on Powder Diffraction Standards (JCPDS)
- Jeddah
 SWRO, 88
- Jeddah Phase I plant
 plant specifications, 29, 31
 Saudi Arabia, 28–30
- Jeddah Phase II plant
 differential pressure, 32
 permeate flow rate, 31
 permeate TDS, 31
- Joint Committee on Powder Diffraction Standards (JCPDS), 201
- Kapton, 611
- Karl-Fisher titration, 480
- K/DOQI. *See* Kidney Disease Outcome Quality Initiative (K/DOQI)
- Kidney Disease Outcome Quality Initiative (K/DOQI), 524

- Kidney failure, 519–520
 Kidney function, 519
 Kitachiba Water Purification Plant, 111
 Kitachiba Water Supply Authority, 111
 KMS. *See* Koch Membrane Systems (KMS)
 Puron
 Knudsen gas diffusion rates, 900
 Knudsen gas permeation, 920
 Knudsen mechanism, 913
 Knudsen number, 913
 Koch Membrane Systems (KMS) Puron, 248
 submerged hollow fiber module, 249
 Koch spiral-wound reverse osmosis membrane
 module, 883
 Kohlrausch–Williams–Watts (KWW), 935
 Krogh cylinder, 417
 approach, 416
 Kubota, 251
 intensive cleaning protocols, 265
 submerged flat-sheet module, 252
 Kuf. *See* Ultrafiltration coefficient (Kuf)
 Kuwait
 wastewater reclamation, 16–17
 KWW. *See* Kohlrausch–Williams–Watts
 (KWW)
- Lactate
 concentrations monitoring, 425
 probe relative recovery, 423
 Landfills
 gas, 591
 leachates treatment, 281
 NF, 281
 RO, 281
 Langmuir lattice, 913
 Langmuir-mode sorption, 636
 Langmuir's sorption sites, 640
 Large-scale integration circuits (LSI), 597
 Laser-driven particle image velocimetry
 technique, 254
 Layered metal mixed phosphonates-
 suloarylphosphonates, 771
 Layer shrinkage
 dual-layer asymmetric hollow fiber
 membranes, 832
 LCA. *See* Life-cycle analysis (LCA)
 LC-OCD. *See* Liquid chromatography-organic
 carbon detection (LC-OCD)
 Leachates treatment
 composting plants, 281
 Leather industry
 nanofiltration, 283
- LEP. *See* Liquid entry pressure (LEP)
 Lewis cell, 317
 Life-cycle analysis (LCA), 277
 Liquid
 interfacial tension, 693
 Liquid chromatography-organic carbon
 detection (LC-OCD), 150
 Liquid entry pressure (LEP), 308, 312,
 320–322
 ethanol-water mixtures, 322
 materials, 322
 schema, 321
 Liquid-filled membrane
 UTDR transducer, 881
 Liquid-liquid system
 extraction, 694
 mass transfer, 694
 membranes, 694
 phase contacting conditions, 693
 Liquid-polymer mixed-matrix
 membranes, 794
 preparation, 804
 Liquid-ring compressors, 569
 Liquid-solid contacting, 696–697
 Liquid transport
 mesoporous membrane, 914
 LMW. *See* Low molecular weight (LMW)
 solutes
 Loeb-Sourirajan membrane
 development, 21–22
 Loeb-Sourirajan process, 371
 Log removal value (LRV), 446
 Low crossover direct methanol fuel cell
 membrane properties, 761
 Low-fouling reverse osmosis membrane
 elements performance, 15
 wastewater reclamation, 14–17
 Low-humidity proton exchange membrane fuel
 cell
 membranes, 764, 769
 Low molecular weight (LMW) solutes, 490,
 493
 Low-pressure membrane
 brackish water desalination, 7–8
 Low-pressure microfiltration, 267
 Low-pressure ultrafiltration, 267
 Low-temperature operation
 cost-effective PEM materials, 772
 LRV. *See* Log removal value (LRV)
 LSI. *See* Large-scale integration circuits (LSI)
 Lysozyme
 PP membranes, 713

- Macroporous membrane gas transport, 913–914
- Macroporous membrane liquid transport, 914
- Macroporous structures, 905
- Macrovoids
asymmetric hollow fiber membranes, 829–830
- Magnetic ion exchange (MIEX), 145–146
configurations, 146
- Magnetic resonance imaging (MRI), 421
- Maintenance chemicals, 265
- MALDI-MS. *See* Matrix-assisted laser desorption ionization mass spectrometry (MALDI-MS)
- Manufacturing process
contamination, 401
- Marine environment
chemical treatment, 81
- MAS. *See* Membrane air stripping (MAS) process
- Mass transfer
boundary layers, 338–340
limitation, 412–413
membrane, 331
- Mass transfer area coefficient (MTAC), 522
- Matrimid 5218, 612
- Matrimid membranes, 798
- Matrix-assisted laser desorption ionization mass spectrometry (MALDI-MS), 842
- Matrix rigidification, 796
- MAX-DEWAX process, 463
- Maxwell model equation, 793, 796
- MBR. *See* Membrane bioreactor (MBR)
- MD. *See* Membrane distillation (MD)
- MEA. *See* Membrane-electrode assembly (MEA)
- Mean pore size, 326–328
- Medical membrane materials
biomedical applications, 501–507
- Medical membrane properties
biomedical applications, 496–500
- Medical membranes
adsorptive properties, 499
- Medication interactions, 526
- Membrane. *See also* specific area or type
analytical examination, 842
applications, 146–149
biocompatibility, 525
characterization change, 855
chromatography, 696–697
commercial availability, 141–142
commercial RO elements, 68
configurations, 63, 218–219, 221
damage reasons, 266
development, 429
distribution, 529–530
elements, 63, 439
manufacturers, 141, 142
materials, 105–106
material selection criteria, 640
meanings, 412
performance, 68
performance comparison, 741
potential, 858, 859
selection, 263, 264
separation application, 589
separation system, 563
strain, 889
structure shear rate, 825
synthesis, 197–198
- Membrane air stripping (MAS) process, 320
- Membrane-based gas separation, 633
air separation, 659
hydrogen separation, 660
permeability, 635
selectivity, 635
solubility-selective membrane, 642
tradeoff relations, 646
- Membrane bioreactor (MBR), 217, 240
activated sludge process, 121
aeration, 126
airflow rate requirements, 256
application examples, 124–127
applications, 233–235
application technology, 120–126
capital cost, 234–235
CAS processes, 226–228
commercialized, 121–122
commercialized modules, 122
cost, 233–235
cylindrical appearance, 125
design considerations, 230–233
design technology, 122–124
effluent quality, 228
equalization tank, 230
experiences with, 228–229
features, 120–121
grease, 230
inorganic chemicals, 230–231
integrated, 172
intensive cleaning protocols, 265
materials, 218
module design technology, 122–124
modules, 219–221

- Membrane bioreactor (MBR) (*Continued*)
- Municipal WWT, 234
 - necessary conditions, 121
 - oil, 230
 - operating costs, 235
 - operating principle, 218
 - pretreatment, 230–231
 - principle, 217–230
 - process flow diagrams, 175
 - sewage applications, 124–126
 - sludge characteristics, 226
 - stem cell expansion, 427
 - submerged hollow-fiber system design, 254
 - technology, 228–229, 235
 - values, 232
 - viscosity, 232
 - wastewater treatment, 217–236
 - wastewater treatment membrane bioreactors, 217–229
 - ZeeWeed filtration system, 176
- Membrane bioreactor (MBR) plants
- operation and maintenance plants, 179
 - pilot, 126
 - total life-cycle costs, 180–181
- Membrane distillation (MD), 297–360. *See also* specific type
- applications, 341–354
 - articles published, 304
 - characteristics, 306–307
 - characterization techniques, 320–330
 - concentration polarization, 331–340
 - configuration, 304
 - configurations, 297
 - contact angle measurements, 324
 - feed inlet temperature, 346
 - flux, 346
 - future, 357–359
 - heat transfer, 337–338
 - historical survey, 300–301
 - hybrid systems, 356
 - long-term performance, 355
 - manufacturer, 306–307
 - membrane fouling, 355
 - membranes and modules, 305–319
 - nomenclature, 299–300, 358–360
 - polarization, 331–340
 - requirements, 308
 - temperature polarization, 331–340
 - theoretical models, 331–340
 - thermal conductivity, 325
 - TPC, 339
 - transport mechanisms, 331–340
 - types, 298, 316
 - used, 304
 - wetting criteria, 322
- Membrane-electrode assembly (MEA), 757
- fuel cell test apparatus schematic, 758
- Membrane modules, 123–124, 439
- integration, 221–222
 - schematic view, 220
- Membrane morphology, 824
- characterization, 859–860
- Membrane preparation
- illustration, 107
 - technology, 104–105, 106–109
- Membrane properties, 134–136
- MM, 500
- Membrane reactors, 267–268, 703–714
- biocatalytic, 712
 - catalytic crystals, 712
 - inorganic, 713
 - microreactors, 713
 - selective oxidation, 710–711
 - state-of-art catalytic, 703
 - wastewater treatment advanced oxidation processes, 704–709
 - water gas shift, 745
- Membrane scientists challenges, 760–761
- Membrane technology, 61
- characteristics, 109
- Membrane Technology and Research, Inc. (MTR), Menlo Park, California, 578, 663
- Memcor (Siemens)
- intensive cleaning protocols, 265
- MEMCOR CS submerges, 250
- MEMCOR Memjet submerged, 251
- Mercury porosimetry and measurements
- gas-liquid displacement porometry, 329
- Mery-sur-Oise Water Treatment Plant
- process scheme, 162
- Mesoporous membrane
- gas transport, 913–914
 - liquid transport, 914
 - solid-polymer, 803
- Mesoporous structures, 904–905
- gamma alumina membrane, 900
- Metabolic activities, 423–424
- Metazachlor removal, 279
- Mexico
- Pemex Salina Cruz refinery, 53
- MF. *See* Microfiltration (MF)
- MFI. *See* Modified fouling index (MFI)
- MFI-UF. *See* Modified fouling index ultrafiltration (MFI-UF)

- Microcracking
 - support interface, 908
- Microdialysis, 421
 - probe, 421
- Microfiltration (MF), 101–127, 239
 - application, 139–141
 - application examples, 103
 - cleaning, 158
 - cross-flow configuration, 141
 - dissolved ozone concentration, 115
 - filtration flux, 115
 - future, 127
 - global capacity, 132
 - hollow-fiber membrane, 132
 - permeate flux, 115
 - pretreatment, 142–146
 - recent trends, 104–126
 - SEM image, 108
 - spiral-wound geometry, 138
 - trends, 104–127
 - water reuse, 186
 - water treatment, 131–165
- Microfiltration (MF) membrane
 - cleaning, 155–160
 - fabrication materials, 133
 - manufacturers, 133–142
 - materials, 133–142
 - module configurations, 133–142
 - MWCO, 134
 - performance, 102–104
 - pore size, 102, 134
 - preparation process, 104
 - use, 102–104
 - water purification applications, 105
 - water treatment tools, 171
- Microfiltration modules structure
 - ozone-resistant membrane, 110–111
- Microfiltration water treatment, 131–164
 - backwash water reuse, treatment, and disposal, 164
 - integrated membrane systems, 160–163
 - manufacturers, 133–142
 - materials, 133–142
 - membrane applications, 146–148
 - membrane fouling and cleaning, 149–159
 - module configurations, 133–142
 - pretreatment, 142–145
- Micromembrane probes
 - fouling detection, 422
 - in situ calibration, 422–423
- Micromembranes, 714
- Micropollutants, 278–279
- Microporous carbon, 904
- Microporous membrane
 - materials, 904
 - separation types, 912
 - transport site hopping, 911–912
- Microporous structures, 903–904
- Micro-Raman spectroscopy, 846
- Microreactor
 - properties, 714
 - scheme, 714
- Middle East Desalination Research Center, 82
- Middle molecular solutes, 523
- Middle molecular weight (MMW)
 - waste metabolites, 493
- Middle molecule removal, 533
- MIEX. *See* Magnetic ion exchange (MIEX)
- Million standard cubic feet per day (MMscfd), 578
- Miniplugging factor index (MPFI), 153
- Mitsubishi, 248–249
 - intensive cleaning protocols, 265
 - submerged HF module, 249
- Mixed liquor suspended solids (MLSS), 121
 - CAS process, 226
 - values, 232
 - viscosity, 226–228, 227
- Mixed-liquor suspension critical flux
 - flat-sheet membranes, 259
- Mixed-matrix membranes (MMM), 655, 674, 789–808
 - amine-solid-polymer, 808
 - ammonia separation, 805
 - asymmetric, 801
 - carbon dioxide separation, 805
 - concept, 792–794
 - dense films, 801
 - development strategies, 794
 - future, 809
 - gas separation, 802
 - hydrogen sulfide separation, 805
 - interfacial morphologies, 795
 - liquid-polymer, 794, 803–804
 - nanocomposite, 800
 - permeabilities, 808
 - polyethylene glycol polymer, 804
 - polyethylene glycol solid-polymer, 807
 - recent progress, 794–808
 - selective flakes, 800
 - selectivities, 808
 - selectivity vs. DEA loading, 809
 - solid-liquid-polymer, 807

- Mixed-matrix membranes
 - (MMM) (*Continued*)
 - solid-polymer, 794, 795
 - sulfur dioxide separation, 805
- Mixed-matrix technology
 - material combination, 792
- MLSS. *See* Mixed liquor suspended solids (MLSS)
- MMM. *See* Mixed-matrix membranes (MMM)
- MMMPeg. *See* Polyethylene glycol polymer mixed-matrix membranes (MMMPeg)
- MMscfd. *See* Million standard cubic feet per day (MMscfd)
- MMW. *See* Middle molecular weight (MMW)
- Modified cellulose membranes
 - hemodialyzers, 528
- Modified cellulosic membranes, 527
- Modified fouling index (MFI), 153
- Modified fouling index ultrafiltration (MFI-UF), 153–155
- Modified free-volume model, 944–946
- Modified less system
 - schematic, 325
- Modified Nafion, 777
- Module configurations, 136–139
- Module design, 264
- Molecular sieve carbon membranes (MSCM)
 - gas separations, 672–673
- Molecular sieving, 602
- Molecular weight cutoff (MWCO), 273, 278, 438, 446, 463
 - MF membrane, 134
 - UF membrane, 134
- Molecular weight distribution
 - treatment process, 120
- Molecules
 - kinetic diameters, 791
- Monitoring nutrient gradients, 423
- Monolith configuration, 138–139
- Monolith-type membrane
 - schematic diagram, 140
- MPFI. *See* Miniplugging factor index (MPFI)
- MRI. *See* Magnetic resonance imaging (MRI)
- MS2 bacteriophage, 149
- MSCM. *See* Molecular sieve carbon membranes (MSCM)
- MTAC. *See* Mass transfer area coefficient (MTAC)
- MTR. *See* Membrane Technology and Research, Inc. (MTR), Menlo Park, California
- Multilayer structures
 - design considerations, 914–915
- Multilayer transport
 - concepts, 923
- Multiple immobilized fluid phase interfaces, 689
- Multistep and multistage system designs, 564–565
- Municipal wastewater reclamation, 282
- MWC. *See* Molecular weight cutoff (MWCO)
- MWCO. *See* Molecular weight cutoff (MWCO)
- Nafion, 759
 - chemical structure, 760
 - FT-Raman spectra, 847
 - IR-ATR, 847
- Nanocomposites, 655
 - penetrant permeability, 656
- Nanofiltration (NF), 271–287
 - AFM images, 866
 - applications, 283
 - concentrates, 275
 - drinking water and process water production, 276–279
 - food industry, 283
 - landfill leachates treatment, 281
 - leather industry, 283
 - membrane fouling, 274–275
 - performance, 273
 - process, 272–275
 - process design, 272–273
 - publications, 272
 - solvent-resistant, 284–286
 - wastewater polishing and water reuse, 280–282
- Nanofiltration (NF)-270 membrane
 - thin section, 864
- Nanofiltration multistage flash (NF-MSF), 284
- Nanofiltration polyethersulfone 10 (NF-PES) 10, 866
- Nanoparticle chitosan membrane chlorinated
 - organic remediation, 189–213
 - experimental section, 191–196
 - results, 197–211
 - silica gel membrane, 192–194
- Nanoporous carbon, 673
- Nascent fibers. *See* As-spun hollow fibers
- Natural gas
 - carbon dioxide removal, 662
 - processing, 573–574, 591

- purification, 663
 - sweetening processes, 662–663
- Natural organic matter (NOM), 275, 398
 - rejection, 278
- Natural polymers, 502
- NC-AFM. *See* Noncontact atomic force microscopy (NC-AFM)
- Nephelometric Turbidity Units (NTU), 57
 - design flux, 401
- Nernst-Planck equation, 726
- Net flux
 - foulant, 243
 - gross flux, 233
- Neumann-type BC, 417
- NF. *See* Nanofiltration (NF)
- NF-MSF. *See* Nanofiltration multistage flash (NF-MSF)
- NF-PES. *See* Nanofiltration polyethersulfone 10 (NF-PES) 10
- Nickel
 - chitosan-embedded membrane, 192–194
- Nitrobenzene
 - hydrogenation, 190
- Nitrogen-enriched air, 594
- Nitrogen enrichment equipment, 594
- Nitrogen gas generator
 - UBE, 593
- N-methyl pyrrolidone (NMP), 612, 824
- NMP. *See* N-methyl pyrrolidone (NMP)
- NMR. *See* Nuclear magnetic resonance (NMR) spectroscopy
- NMWCO. *See* Nominal molecular weight cutoff (NMWCO)
- NOM. *See* Natural organic matter (NOM)
- Nominal molecular weight cutoff (NMWCO), 498
- Nonbackwashable fouling, 151
- Nonbubbled filtration. *See* Dead-end filtration
- Noncellulosic synthetic membranes, 527
- Noncontact atomic force microscopy (NC-AFM), 865, 867
- Nonenveloped viruses, 546–547
- Non-Fickian diffusion, 635
- Non-radioactive Strontium-87
 - removal, 734–735
- Nonsolvent pretreatment, 613
- Nonwetting liquid phase, 690
- NTU. *See* Nephelometric Turbidity Units (NTU)
- Nuclear magnetic resonance (NMR) spectroscopy, 842
- Ocean water desalination, 85
- Octafluorocyclobutane (OFCB), 310
- OD. *See* Osmotic distillation (OD)
- ODA. *See* Oxydianiline (ODA)
- OFCB. *See* Octafluorocyclobutane (OFCB)
- Offgas reformer
 - hydrogen recovery, 590
- Office of Saline Water (OSW), 21
- Oil
 - losses, 463
 - MBR design considerations, 230
 - micelle mixtures, 285
- Olefin-paraffin separations, 662
- Omexell spiral-wound electrodeionization, 382
- One-stage membrane processes
 - vs. two-step, 565
- One-stage selective purge systems, 563
- Oocyst challenge test, 149
- Open intake structure
 - Cyprus SWRO plant, 51
- Open-ocean intakes, 50–51
 - systems, 54–57
- Operational fouling control, 224–225
- Optical microscopy, 860
- Organic compounds
 - dehydration, 595
- Organic fouling, 152–153
- Organic micropollutants
 - removal, 280
- Organic solvent nanofiltration (OSN), 451–466
 - applications, 461–464
 - membranes, 451–457
 - nomenclature, 463
 - performance data, 457
 - polymeric membranes, 451
 - porous membranes, 456
 - transport mechanisms, 458–460
- Organic solvents
 - permeability, 594
- Organics removal
 - groundwaters, 277–278
 - surface waters, 277–278
- Organophilic membranes, 470–471
- Osmosis, 377
- Osmotic distillation (OD), 698
- OSN. *See* Organic solvent nanofiltration (OSN)
- OSW. *See* Office of Saline Water (OSW)
- Outside-in-type hollow fibers, 445
- Oxidants, 159
- Oxidation, 612
 - posttreatment, 615–616

- Oxydianiline (ODA), 453, 455, 609–612, 615, 619, 620
- Oxygen
 concentration profiles, 418
 enriched air, 594
 generator, 660
 radial concentration profiles, 419
- Oxygen transport
 composite membranes, 903
 dense membranes, 903
- Ozonation, 146, 278
- Ozone dosage
 effects, 114
 high membrane filtration flux, 119–120
 relationship, 114
- Ozone resistant membrane
 application technology, 109–120
 microfiltration module, 112
 microfiltration modules structure, 110–111
 PVDF hollow fiber, 111
- Ozone technology characteristics, 109
- PA. *See* Polyamide (PA)
- PAC. *See* Powered activated carbon (PAC)
- Packing structures
 organized and random, 905–906
- PAE. *See* Poly arylene ethers (PAE)
- Palladium, 903
 cost, 679
 electroless plating, 677
 foils, 674
 membranes, 674
- PALS. *See* Positron annihilation lifetime spectroscopy (PALS)
- PAMAM. *See* Polyamidoamine (PAMAM) dendrimers
- PAN. *See* Polyacrylonitrile (PAN)
- Paper industry
 water reuse, 282
- Particle challenge testing, 149
- Particle image velocimetry (PIV) technique, 254
- Particulate fouling, 152
- Parvovirus clearance
 validation, 551
- Pathogenic microorganisms, 146–147
- PBI. *See* Polybenzimidazole (PBI); Poly m-phenylene-bibenzimidazole
- PC. *See* Polycarbonate (PC)
- PCP. *See* Personal care products (PCP)
- PDMS. *See* Polydimethylsiloxane (PDMS)
- PDPA. *See* Poly neopentyl glycol adipate (PDPA)
- PE. *See* Polyethylene (PE)
- PEBAX. *See* Poly amide-6-b-ethylene oxide (PEBAX)
- PEEK-WC. *See* Polyetherketone modified (PEEK-WC)
- PEG. *See* Polyethylene glycol (PEG)
- PEGA. *See* Poly ethylene glycol acrylate (PEGA)
- PEGDA. *See* Poly ethylene glycol diacrylate (PEGDA)
- PEGMEA. *See* Poly ethylene glycol methyl ether acrylate (PEGMEA)
- PEI. *See* Polyetherimide; Polyethyleneimine
- PEK-C-NF. *See* Polyetherketone cationic nanofiltration (PEK-C NF)
- PEK-C-UF. *See* Polyetherketone cationic ultrafiltration (PEK-C UF)
- Pelton turbine
 RO train motor, 77
 schematic, 77
- Pelton wheel, 88–89
 efficiency curve, 90
 RO flow scheme, 89
- Pemex Salina Cruz refinery
 Mexico, 53
- PEMFC. *See* Proton exchange membrane fuel cell (PEMFC)
- Penetrant permeability
 nanocomposites, 656
- Penicillin G
 feed and strip solutions, 737
 removal and recovery, 736
- PEO. *See* Polyethyleneoxide (PEO)
- Perfluoro polymers, 561
- Perfluorosulfonic acid (PFSA), 759
- Periodic backflushing, 437
- Perkin-Elmer thermogravimetric analyzer, 196–197
- Permeability, 577
 membrane-based gas separation, 635
 organic solvents, 594
 polyimide membrane gas separation, 582–586
 tradeoffs, 790
 van der Waals molar volume, 560
 water, 594
 Zirfon composite UF membrane, 888
- Permeate, 577
 AdDur RO plant, 34
 aqueous organic solution, 485

- conditioning, 79–80
- flow rate per unit membrane, 401
- flux, 883, 885
- parameter determination, 480
- Permeated-side flow, 260
- Permeate flow rate
 - Jeddah Phase II plant, 31
- Permeate flux
 - feed sources, 378
 - MF, 115
- Permeate recovery (REC), 275, 288
- Permeate total dissolved solids
 - Jeddah Phase II plant, 31
- Permeation porometry, 920, 921
 - desorption isotherm, 922
 - supported gamma-alumina membrane, 922
- Perovskites, 903
- Persistent organic pollutants (POP), 278
- Personal care products (PCP), 278
- Pervaporation (PV), 304, 469–487
 - AZEO SEP, 471–474
 - AZEO SEP plant, 486
 - computer simulation, 475–480
 - hollow-fiber membrane module permeation, 481–486
 - separation model, 481–486
 - solvent dehydration, 486
 - sweeping gas, 345
 - using solid-polymer mixed-matrix membranes, 799
 - VOC SEP, 471–474
- PES. *See* Polyethersulfone (PES)
- PES-NMP. *See* Polyethersulfone n-methyl pyrrolidone (PES-NMP) dopes
- Pesticides, 278, 279
- PFA. *See* Polyfurfuryl alcohol (PFA)
- PFSA. *See* Perfluorosulfonic acid (PFSA)
- PhAC. *See* Pharmaceutically active compounds (PhAC)
- Pharmaceutical industry, 374
- Pharmaceutically active compounds (PhAC), 278
 - rejection, 279
- Phase contacting conditions, 690
- Phase separation, 106
- Phase transfer catalysis (PTC), 286, 461
- Phenol degradation, 706
 - reaction, 707
- Phenolic resin, 609
- Phenol photodegradation
 - first-order rate constant, 709
- Phosphonated polyaryloxyphosphazenes, 776
- Phosphoric-acid-doped polybenzimidazole, 769
 - structures, 770
- PI. *See* Polyimide (PI)
- PIM. *See* Polymers intrinsic microporosity (PIM)
- Piping
 - submerged membranes, 245
- Pitzer model, 273
- PIV. *See* Particle image velocimetry (PIV) technique
- PLA. *See* Poly lactide (PLA)
- Planck's constant, 603
- Plant footprint, 177–178
- Plasma heterogenization
 - POM, 707
- Plasmapheresis, 494
- Plasma proteins
 - retention, 524
- Plate-and-frame membrane, 219
 - modules, 229
 - potential operational problems, 229
- PLGA. *See* Poly lactide-co-glycolide (PLGA)
- Plugged sieves, 796
- PMDA. *See* Pyromellitic dianhydride (PMDA)
- PMEA. *See* Poly methoxyethyl acrylate (PMEA)
- PMMA. *See* Polymethylmethacrylate (PMMA)
- PMP. *See* Polymethylpentene (PMP)
- PMSP. *See* Poly methylsilyl-1-propyne (PMSP)
- Polarization, 241–242
 - MD, 331–340
- Polar rubbery membranes structure
 - carbon dioxide removal, 929–949
- Polar volatile organic species, 691
- Polyacetylene polymers, 562, 648
- Polyacrylonitrile (PAN), 310, 439, 453, 454, 499, 504, 527, 612, 710
- Polyamide (PA), 378, 439, 504
- Poly amide-6-b-ethylene oxide (PEBAX), 657
 - carbon dioxide permeability, 658
- Polyamidoamine (PAMAM) dendrimers, 691
- Polyaniline composite membranes
 - gas permeability and selectivity, 641
- Polyarylene acid-base blends, 777–778
- Poly arylene ethers (PAE), 773
- Polyaryloxyphosphazenes
 - sulfonated and phosphonated, 776

- Polybenzimidazole (PBI), 769
 chemical structures, 653
 mixed-gas permeation and separation data, 653
 structures, 770
- Polybenzothiazole, 654
 chemical structures, 654
- Polybenzoxazole, 654
 chemical structures, 654
- Polycarbonate (PC), 504
- Polydimethylsiloxane (PDMS), 457, 459, 460, 561, 562, 578, 646, 647, 710, 797, 799
 selectivity vs. temperature, 648
- Polyelectrolyte membranes, 726
- Polyetherimide, 324, 453
 polymer, 313
- Polyetherketone cationic nanofiltration (PEK-C NF)
 XPS spectra, 850
- Polyetherketone cationic ultrafiltration (PEK-C UF)
 XPS spectra, 850
- Polyetherketone modified (PEEK-WC), 710
- Polyethersulfone (PES), 439, 453, 505, 612, 824, 827
 chemical structures, 844
- Polyethersulfone n-methyl pyrrolidone (PES-NMP) dopes
 viscosity vs. concentration, 824
- Polyethylene (PE), 313, 504
- Polyethylene glycol (PEG), 316, 438
- Poly ethylene glycol acrylate (PEGA)
 chemical structure, 936
- Poly ethylene glycol diacrylate (PEGDA)
 chemical structure, 936
 crosslinked, 935, 938
 FFV, 945
 rubbery modulus, 938
 time-temperature master curves, 939
- Poly ethylene glycol methyl ether acrylate (PEGMEA)
 chemical structure, 936
 FFV, 945
- Polyethylene glycol polymer mixed-matrix membranes (MMMpeg), 804
- Polyethylene glycol solid-polymer mixed-matrix membranes, 807
- Polyethyleneimine, 189
- Polyethyleneoxide (PEO), 506. *See also* Crosslinked polyethyleneoxide (XLPEO)
- Polyfurfuryl alcohol (PFA), 607
 membranes, 616
- Polyimide (PI), 453, 455, 611, 654
 characteristics, 585
 chemical structure, 582–583
 chemical structures, 654
 diffusivity, 584
 synthesis, 454
- Polyimide membrane gas separation, 581–596
 applications, 589–596
 asymmetric membrane manufacture, 587
 chemical structure, 582–586
 module, 588
 permeability, 582–586
- Polyimide pairs
 zeolite, 798
- Polyimide production
 DA, 610
- Polyimide-silica hybrid membranes
 falling-off ratio, 657
- Polyketone, 311
- Poly lactide (PLA), 429
- Poly lactide-co-glycolide (PLGA), 429
- Polymer
 chemical resistance, 453
 upper-bound limit, 790
- Polymer-based membranes
 materials, 218
- Polymeric chitosan, 198
- Polymeric materials, 378
- Polymeric membrane materials gas separation, 633–663
 applications, 659–663
 limitations, 643–645
 materials, 646–658
 principles, 635–642
- Polymeric membranes, 133–134
 evaporative casting, 890
 OSN, 451
 state-of-art, 789–791
- Polymeric solvent-resistant nanofiltration membranes, 272
- Polymeric systems, 189
- Polymer membrane
 diffusion, 635
 diffusivity-selective, 640
 gas, 635
 gas permeability, 639
- Polymer networks
 dynamic relaxation characteristics, 934–935
 experimental details, 935–936
- Polymer precursor
 composition and morphology, 607
 pretreatment, 612–631

- Polymers intrinsic microporosity (PIM), 658
 chemical structures, 658
- Poly methoxyethyl acrylate (PMEA), 507
- Polymethylmethacrylate (PMMA), 499
 membranes, 504, 527
- Polymethylpentene (PMP), 505
 chemical structures, 649
- Poly methylsilyl-1-propyne (PMSP), 311
- Poly m-phenylene-benzimidazole
 chemical structures, 653
- Poly neopentyl glycol adipate (PDPA)
 chemical structures, 649
- Polyolefin plant resin degassing, 567
- Polyolephines, 504
- Polyoxoanions, 704–705
- Polyoxometalates (POM), 704–706
 plasma heterogenization, 707
- Poly phenylene oxide (PPO), 310
- Poly phenyl p trimethylsilyl phenyl acetylene (PTMSDPA)
 chemical structures, 649
- Polyphosphazene blends, 777
- Poly p phenylene (PPP)
 chemical structures, 649
- Polypropylene (PP), 313, 504, 713
 lysozyme, 713
 trypsin, 713
- Polypyrrolone, 654
 chemical structures, 654
- Polysiloxane structures, 646
- Polysulfone (PSF), 310, 439, 453, 505
 chemical structures, 844
- Poly tert-butylacetylene (PTBA), 649
- Polytetrafluoroethylene (PTFE), 342, 394, 520, 650
- Poly triisopropylsilyl phenyl acetylene (PTPSDPA)
 chemical structures, 649
- Poly trimethylsilyl-1-propyne (PTMSP)
 chemical structures, 649
 FFV, 649
 membrane, 647
- Polyvinyl acetate (PVAc), 797
- Polyvinylalcohol (PVA), 316, 799
- Poly vinylbenzyltrimethylammonium fluoride (PVBTAf), 727
- Polyvinyl chloride (PVC), 52
 manufacturing vent gas, 571
- Polyvinylidene fluoride (PVDF), 105, 302, 310, 311, 316, 439, 453, 710
 DMAC, 323
 DR-UV spectra, 706
 XPS, 708
- Polyvinylidene fluoride (PVDF) hollow fiber membrane
 chemical resistance, 125
 ozone resistance, 111
 rejection rate of uniform latex, 124
 SEM image, 111
 SEM images, 124
- Polyvinylidene fluoride (PVDF) membranes
 FTIR spectra, 706
 porous, 127
 properties, 313
- POM. *See* Polyoxometalates (POM)
- POP. *See* Persistent organic pollutants (POP)
- Pore-filling membranes, 779
- Pore-flow model, 458
- Pore size, 328
 distribution, 326–328
 factors affecting, 604
 membrane, 529–530
 MF membrane, 102
 RO membrane, 379
 UF membrane, 102, 134
- Pore structure
 carbon membranes, 602
- Pore tortuosity, 326–328
- Porosity, 134, 326
- Porous aluminosilicate crystals, 673
- Porous hydrophobic membrane, 690
- Porous nonmetallic membranes
 hydrogen separation membranes, 672–673
- Porous OSN membranes, 456
- Porous stainless steel (PSS) composite membrane
 Sieverts' plot, 675
- Porous supports
 preparation, 917
- Positron annihilation lifetime spectroscopy (PALS), 613
- Postirradiation method, 775
- Posttreatment
 dual-layer hollow fiber membranes, 834
 oxidation, 615–616
- Posttreatment and additional coating
 as-spun hollow fibers, 830
- Posttreatment processes, 615–616
- Potentiometer, 859
- Potting material, 110
- Power consumption
 EDI, 390

- Powered activated carbon (PAC),
 - 142–143
- Power industry, 374–375
 - ultrapure water system, 376
- Power plant intake
 - discharge, 55
- Power usage
 - SWRO plants, 83
- PPO. *See* Poly phenylene oxide (PPO)
- PPP. *See* Poly p phenylene (PPP)
- Precipitation kinetics, 824
- Precoagulation, 142–143
- Precursor
 - FS, 622
- Preflocculation water filtration, 144–145
- Preirradiation method, 775
- Pressure decay test, 147
- Pressure dependence
 - gas transport, 638–639
- Pressure-driven membrane filtration processes
 - characteristics, 139
 - classification, 132
- Pressure exchanger
 - DWEER, 78
- Pressure exchanger (PX) isobaric recovery
 - system, 93, 95
- Pressure exchanges, 77, 78
 - booster bump, 78
- Pressure-induced operation
 - DCB, 207
- Pressure swing adsorption (PSA), 578, 581, 671
- Pressure vessels
 - fiberglass reinforced plastic, 98
- Pretreatment
 - filtration system membrane, 60–63
 - MBR design considerations, 230–231
 - microfiltration water treatment, 142–145
 - polymer precursor, 612–631
 - process fouling, 163
 - seawater desalination, 182
 - system, 57–58, 263
 - UF, 142–145, 184
 - water, 267
- Probability density curves, 328
- Process water production
 - NF, 276–279
- Productivity
 - UF, 437
- Product resistivity vs. feed water
 - conductivity, 391
- Product water
 - cost components, 83
 - quality, 146–147
- Propylene condensate, 566
- Propylene recovery system
 - process flow diagram, 568
- Protein
 - assays, 426
 - bound toxins, 535
 - concentration changes, 427
 - fractionation process, 448
 - uremic toxins, 523–524
- Protein-based therapeutics
 - biopharmaceutical industry, 435
- Protein concentration
 - retentate and permeate, 548
- Proton exchange membrane fuel cell (PEMFC),
 - 727, 744, 755, 757–759
 - DOE technical targets, 762
 - membrane thickness, 763
 - relative humidity, 762
 - schematic diagram, 757
 - use, 759
- PSA. *See* Pressure swing adsorption (PSA)
- Pseudo-first-order reaction rate constants
 - TCE, 205
- PSF. *See* Polysulfone (PSF)
- PSS. *See* Porous stainless steel (PSS)
 - composite membrane
- PTBA. *See* Poly tert-butylacetylene (PTBA)
- PTC. *See* Phase transfer catalysis (PTC)
- PTFE. *See* Polytetrafluoroethylene (PTFE)
- PTMSDPA. *See* Poly phenyl p trimethylsilyl phenyl acetylene (PTMSDPA)
- PTMSP. *See* Poly trimethylsilyl-1-propyne (PTMSP)
- PTPSDPA. *See* Poly triisopropylsilyl phenyl acetylene (PTPSDPA)
- Pulp industry
 - water reuse, 282
- Pulsed laser deposition, 909
- Pure water permeability (PWP),
 - 134–135, 886
 - compressive strain, 887
 - USP guidelines, 375
- Purification
 - natural gas, 663
- Purifying hydrogen process, 591
- PV. *See* Pervaporation (PV)
- PVA. *See* Polyvinylalcohol (PVA)
- PVAc. *See* Polyvinyl acetate (PVAc)

- PVBTAf. *See* Poly vinylbenzyltrimethylammonium fluoride (PVBTAf)
- PVC. *See* Polyvinyl chloride (PVC)
- PVDF. *See* Polyvinylidene fluoride (PVDF)
- PWP. *See* Pure water permeability (PWP)
- PX. *See* Pressure exchanger (PX) isobaric recovery system
- Pyknometer, 326
- Pyrolysis atmosphere, 615
- Pyrolysis process, 613–614
- Pyrolysis temperature, 613–614
- Pyromellitic dianhydride (PMDA), 453
- Pyromellitic dianhydride oxydianiline (PMDA-ODA), 453, 609–612, 615, 619, 620. *See also* Kapton structure, 455
- Quasi-homogeneous structure, 906
 deviations, 907
 properties, 918
- Quasi-nondestructive techniques, 919–920
- Radiation-grafted membranes, 775
- Radioactive Strontium-90 removal, 735–736
 C20 ODPPA extractant, 735
- Raised transmembrane pressure, 263
- Raise effective flux, 263
- Raman shift, 846
- Raman spectroscopy, 842, 846–848
- Ramp rate
 carbon molecular sieve membranes, 614
- Raw water temperature changes, 116
- Raw water turbidity changes, 117
- Rayleigh scattering, 892
- REC. *See* Permeate recovery (REC)
- Recirculation
 backwash water, 164–165
- Reclamation
 feed water, 172
 RO permeate quality, 173
- Recombination processes
 dense membrane, 909
- Recovery systems
 SWRO plants, 76
- Rectangular cross-flow module, 318
- Refining, 463–464
- Regenerated cellulose, 502
- Regenerative medicine, 409
- Rejection
 PCP, 280
 PhAC, 279
- Rejection rate of uniform latex
 PVDF hollow fiber membrane, 124
- Relative humidity
 PEMFC, 762
- Renal failure
 extracorporeal treatment filtration processes, 500
 treatment surface modifications, 507
- Renewable energy, 357
- Reproducibility
 CMS membranes, 622
- Research Institute of Innovative Technology for Earth (RITE), 592
- Residue, 578
- Resin degassing bin recovery unit
 performance
 membrane, 569
- Resin manufacturing industry, 472
- Resistance
 fouling, 27
- Retail gasoline stations, 570
- Retentate and permeate
 particle size distribution, 549
 protein concentration, 548
- Return sludge, 232
- Reverse osmosis (RO), 342, 377–378
 biofouling protection, 13–14
 cellulose triacetate membranes, 21–45
 CTA membranes, 44
 fresh drinking water, 45
 landfill leachates treatment, 281
 membrane materials, 5
 principle, 377
 publications, 272
 seawater desalination, 22
 thin-film composite membranes, 3–18
- Reverse osmosis cellulose triacetate membranes, 21–43
 history, 21
 most recent module, 35–42
 seawater desalination Toyobo RO module, 22–27
 seawater desalination Toyobo RO module performance, 28–34
- Reverse osmosis desalination, 36, 239
 plants, 36
 technology, 85
- Reverse osmosis elements
 membrane, 68
- Reverse osmosis flow scheme
 Pelton wheel, 89
 turbocharger, 90

- Reverse osmosis flux
 - seawater desalination, 183
- Reverse osmosis membrane, 4, 44
 - adsorption property, 15
 - application, 4
 - applications, 3–4
 - brackish water desalination, 8
 - chlorine tolerance, 17
 - CTA membranes, 31
 - module schematic flow diagram, 33
 - modules development, 35–39
 - performance, 8
 - performance trends, 7
 - pore size, 379
 - process, 17
 - processes, 4–6
 - progress, 8
 - seawater desalination, 9
 - separation, 47
 - system configuration, 65
 - technology, 6–13
 - technology trends, 7
- Reverse osmosis membrane life
 - UF, 184
- Reverse osmosis module
 - CTA, 35–43
 - seawater desalination, 24–26
- Reverse osmosis performance, 27
 - site test, 33–35
- Reverse osmosis permeate quality
 - desalination, 173
 - reclamation, 173
- Reverse osmosis plant, 163
 - seawater desalination, 10
 - viable cell count, 14
- Reverse osmosis recovery impact
 - seawater desalination, 184
- Reverse osmosis system, 4, 372
 - SW membrane, 87
- Reverse osmosis thin-film composite
 - membranes, 1–20
 - application, 3
 - biofouling protection, 13
 - crosslinked aromatic polyamide membrane
 - chlorine tolerance, 17
 - low-fouling, 14–16
 - major progress, 4–5
 - trends, 6–12
- Reverse osmosis train based
 - configuration, 74
- Reverse osmosis train motor
 - Pelton turbine, 77
- Reverse osmosis vessel groups, 75
- Reverse selective polymer membrane,
 - 650, 800
- Reversible fouling, 151, 223
- Reversible permeate flux, 150
- Reynolds number, 397
- Riser region, 253
- RITE. *See* Research Institute of Innovative Technology for Earth (RITE)
- RO. *See* Reverse osmosis (RO)
- Roughness, 326–328
- Rubbery membranes, 561
- Rubbery modulus
 - PEGDA, 938
- Rubbery polymer, 560, 561, 797
 - gas solubility, 933
- SAD. *See* Specific air demand (SAD)
- Saline Water Act, 21
- Saline Water conversion Corporation, 88
- Salinity
 - seawater sources, 49
- Salt bridges, 160
- SAM. *See* Scanning auger microscopy (SAM)
- Saudi Arabia
 - Jeddah 1 RO plant, 28–30
 - SWRO, 88
- SBS. *See* Sodium bisulfate (SBS)
- Scaffold materials, 410–411
- Scanning acoustic microscopy
 - pinhole determination, 893
- Scanning auger microscopy (SAM), 851
- Scanning electron microscopy (SEM),
 - 134, 310, 320, 329, 796, 860, 863–864
 - analysis, 202–203
 - supported gamma-alumina layer, 910
- Scanning electron microscopy energy
 - dispersive X-ray spectroscopy (SEM-EDS) analysis, 197
- Scanning force microscopy (SFM), 865
- SCF. *See* Supercritical fluid (SCF)
- Scientists challenges, 760–761
- SDI. *See* Silt density index (SDI)
- SDS PAGE. *See* Sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS PAGE)
- SE. *See* Secondary electrons (SE)
- Seawater
 - isobaric energy recovery system, 92
 - water production costs, 185

- Seawater desalination, 47–85
 - cost breakdown, 183
 - costs, 82, 182
 - Fujairah plant schematic, 73
 - future trends, 84
 - hollow-fiber RO membranes, 22–23
 - integration, 85
 - media filtration, 182
 - membrane life impact, 184
 - plant configuration, 50–53, 50–81
 - plants, 13, 182, 183
 - pretreatment, 182
 - process design conditions, 185
 - RO, 22
 - RO flux, 183
 - RO membrane, 9
 - RO module, 24–26
 - RO plant, 10
 - RO processes, 13
 - RO recovery impact, 184
 - total life-cycle costs, 183
 - Toyobo RO module, 22–35
 - UF, 182, 186
 - ultralow-energy RO, 87–100
 - water production costs, 82–83
 - vs. water reclamation, 173
- Seawater intake facilities, 50–53
- Seawater reverse osmosis (SWRO), 70–72, 76, 87, 283–284
 - configuration advantages, 72
 - cost effectiveness, 100
 - desalination, 54, 56, 64–76, 82
 - element design, 96
 - energy optimization, 95–96
 - energy recovery technology, 88–95
 - Jeddah, 88
 - key system elements, 64–65
 - operations, 12
 - process, 35
 - products, 11
 - reduction, 88–95
 - 1970s, 99
 - Saudi Arabia, 88
 - ultralow-energy reverse osmosis seawater desalination, 95
- Seawater reverse osmosis (SWRO)
 - membrane, 84
 - classification, 69–70
 - cleaning costs, 62
 - design, 96
 - elements, 12
 - investigations, 12
 - performance parameters, 66–69
 - types, 66–69
- Seawater reverse osmosis (SWRO) plants
 - construction, 48
 - desalination, 39–40, 54, 56
 - Fukuoka, 39–40
 - operation, 13
 - power usage, 83
 - recovery ratio, 80
 - recovery systems, 76
 - treatment, 61
- Seawater sources
 - salinity, 49
 - temperature, 49
- Secondary electrons (SE), 863
- Secondary ion mass spectrometry (SIMS), 842, 851–853
- Sedimentation, 59
- Sedimentation process
 - coagulation, 144
- Selective adsorption, 601
- Selective condensation, 601
- Selective oxidation
 - membrane reactors, 710–711
- Selective polymeric membrane
 - carbon dioxide, 725
- Selective surface diffusion (SSD) membrane, 604
- Selective surface flow (SSF) membranes, 602
 - advantages, 605
 - examples and applications, 606
 - formation, 606
- Selective water gas shift membrane reaction
 - carbon dioxide, 743–744
- Selectivity, 578
 - membrane-based gas separation, 635
 - tradeoffs, 790
 - UF, 437
- SEM. *See* Scanning electron microscopy (SEM)
- SEM-EDS. *See* Scanning electron microscopy energy dispersive X-ray spectroscopy (SEM-EDS) analysis
- SEMI. *See* Semiconductor Equipment and Materials International (SEMI)
- Semiconductor Equipment and Materials International (SEMI), 371
- Semiconductor industry, 371–372
 - UPW, 373
- Semiconductor ultrapure water systems
 - point-of-use UF, 398–401
- Semicrystalline polymer, 657

- Semipermeable medical membranes
transport properties, 496
- Separation model
PV, 481–486
- Separation system
distillation method, 596
- Sessile drop method
contact angles, 855
- Sewage fields
filtration, 127
- Sewage reuse, 120
- Sewage treatment plants
design process conditions, 176
- SFM. *See* Scanning force microscopy (SFM)
- SGM. *See* Supported gas membrane (SGM)
- SGMD. *See* Sweeping gas membrane distillation (SGMD)
- Shear enhanced processing hollow-fiber pervaporation plant
VOC, 487
- Shear-induced back transport, 242
- Shear stress induced
bubbles, 255
- Shell-side feed, 588
- Short-bed-length fluid-solid contactor, 697
- Side-stream system, 222
- Siemens
intensive cleaning protocols, 265
- Siemens Water Technologies, 250
- Sieve-in-a-cage morphology, 796
zeolite particles, 796
- Sieve membranes
carbon molecular, 614
- Sieverts' plot
PSS composite membrane, 675
- Sieving coefficients
HDF membranes, 498
HD membranes, 498
HF membranes, 498
hollow-fiber packing density, 531
- Sieving properties, 529–530
- Silane coupling agents, 798
- Silica gel, 771
chitosan-embedded membrane, 192–194, 200
chitosan membranes, 192
chitosan nanoparticles, 203
composite membranes, 680
FTIR analysis, 199
membranes, 791
nanoparticle membrane, 192–194
- Silica poly(ether ether ketone) (SPEEK), 767, 768, 769, 777–778
- Silica rejection
vs. applied current, 392
performance, 392
vs. SWE, 393
- Silicoaluminophosphate, 792
- Silicon-based polymers, 646–647
- Silicone membranes
vapor recovery, 664
- Silicone rubber
coating, 830
composite membranes, 562
- Siloxane polymer, 646–647
application, 647
- Silt density index (SDI), 48, 131, 153, 374
- Simazine
removal, 279
- Simple gases
physical properties, 643
- SIMS. *See* Secondary ion mass spectrometry (SIMS)
- Singapore
wastewater reclamation, 16
- Single fiber testing
minimodule, 621
- Single hollow-fiber membrane
model, 482
- Single-layer asymmetric hollow-fiber membrane, 825–830
- Single open-ended hollow-fiber membrane, 37
- Single-stage seawater reverse osmosis systems, 70–72
water, 71
- Sintering temperature, 916
- 6FDA. *See* Hexafluoroisopropylidene diphthalic anhydride (6FDA)
- SLM. *See* Supported liquid membrane (SLM)
- Sludge characteristics
MBR, 226
- Sludge retention time (SRT), 225
- Sludge treatment, 232
- SMC. *See* Synthetically modified cellulose (SMC)
- SMM. *See* Surface modifying macromolecules (SMM)
- SOC. *See* Synthetic organic chemicals (SOC)
- Sodium bisulfate (SBS), 13
- Sodium dodecyl sulfate polyacrylamide gel electrophoresis (SDS PAGE), 426
- Sol-gel amorphous silica, 904

- Sol-gel preparation
 - inorganic membranes, 456
- Solid-fluid phase
 - contactors, 689, 696
- Solid inhomogeneity, 907
- Solid-liquid-polymer mixed-matrix membranes preparation, 807
- Solid-polymer mesoporous membrane, 803
- Solid-polymer mixed-matrix membranes, 794, 795, 799–800
 - formulate and process, 800–801
 - gas separation, 797
 - PV, 799
- Solid-state characterization techniques
 - heterogenization, 705
- Solubility-selective membrane
 - membrane-based gas separation, 642
- Solute clearance, 522
 - hollow-fiber packing density, 531
- Solution-diffusion model, 459–460
- Solvent dehydration
 - AZEO SEP pervaporation plant, 481
 - PV, 486
- Solvent exchange methods, 286
- Solvent-resistant nanofiltration (SRNF), 284–286
 - membranes, 272
 - vegetable oil industry, 285
- Sorption
 - alcohol, 711
 - glassy polymers, 639–640
- Source water
 - conditioning chemicals, 62
 - quality, 48
 - selection guidelines, 58
- Southeast Asia seawater treatment, 11–13
- Spacer-filled channels, 320
- Spanish seawater reverse osmosis projects, 84
- Specific air demand (SAD), 256
 - values, 256
- Spectroscopic ellipsometry, 919
- SPEEK. *See* Silica poly(ether ether ketone) (SPEEK); Sulfonated polyether ether ketone (SPEEK)
- SPEK. *See* Sulfonated polyether ketone (SPEK)
- SPI. *See* Sulfonated polyimides (SPI)
- Spiked integrity monitoring system, 149
- Spinnerets
 - flow angles, 826
- Spinning solution
 - as-spun hollow fibers, 822
- Spinning technology
 - HF, 529
- Spiral-wound electrodeionization (SWEDI), 382, 389
 - vs. silica rejection, 393
- Spiral wound (SW) membrane, 8
 - application, 319
 - cross section, 882
 - EDI, 382
 - geometry, 138
 - MF, 138
 - modules, 282
 - RO system, 87
 - schematic diagram, 139
 - thin-film composite, 67
 - UF, 138
- SRNF. *See* Solvent-resistant nanofiltration (SRNF)
- SRT. *See* Sludge retention time (SRT)
- SS. *See* Suspended solids (SS)
- SSD. *See* Selective surface diffusion (SSD) membrane
- SSF. *See* Selective surface flow (SSF) membranes
- SSIMS. *See* Static secondary ion mass spectrometry (SSIMS)
- Stagnant and mobile bubbles
 - hollow-fiber membrane, 262
- Standard rejection seawater reverse osmosis membrane elements, 69
- State Water Project (SWP)
 - energy costs, 98
- Static secondary ion mass spectrometry (SSIMS), 851
- Staverman reflection coefficient, 498
- Steaming potential measurements, 855–856
- Stefan-Maxwell equations, 459
- Stem cells, 409
 - differentiation, 412
 - expansion, 411, 427
 - MBR, 427
 - preservation, 412
 - transplantation technical challenges, 410–412
- Sterile filtration, 435
- Sterilizability, 526
- Stirred cell ultrafiltration modules, 440
- Stretched exponential relaxation time
 - distribution function, 935
- Strip dispersion supported liquid membranes, 722–724
 - facilitated transport membranes, 729–736

- Strontium
 - feed and strip solutions, 735
 - removal, 734–735
- Submerged flat-sheet systems, 254
- Submerged hollow-fiber membranes
 - bentonite suspension critical flux, 258
 - bubbling rate, 258
 - flux distribution, 258–259
 - imposed flux, 259
 - modules, 247
 - TMP profiles, 259
- Submerged hollow fiber module
 - Mitsubishi, 249
- Submerged hollow-fiber system design
 - MBR, 254
- Submerged membrane bioreactor fouling
 - mitigating strategies, 264
- Submerged membranes, 239–268
 - applications, 267
 - blocking, 262–264
 - bubbling and hydrodynamics, 253–261
 - capital costs, 245
 - cleaning, 246, 265
 - concepts, 247
 - vs. contained modules, 244–246
 - energy usage, 245
 - features, 240–241
 - fluid management, 245–246
 - future, 268
 - history and development, 239–240
 - integrity test methods, 266
 - mode of operation, 245
 - module cleaning strategies, 225
 - module geometries, 246–252
 - operation modes, 241–245
 - packing density, 244
 - pipng and valves, 245
 - practical aspects, 262–266
 - replacement and repair, 246
 - standardization, 246
 - system, 222
 - turn-up/turn-down, 246
 - water treatment, 267
- Submerged microfiltration systems, 245
- Submerged ultrafiltration systems, 245
- Substituted polyacetylenes, 648–649
- Subsurface intakes, 51–53
- Sulfonated polyarylene, 776–777
- Sulfonated polyarylene ethers, 773
- Sulfonated polyaryloxyphosphazenes, 776
- Sulfonated polyether ether ketone (SPEEK), 767–769, 773, 777–778
- Sulfonated polyether ketone (SPEK), 778
- Sulfonated polyimides (SPI), 774
 - five-member ring, 774
 - six-member ring, 774
- Sulfonated polymers
 - inorganic barrier fillers, 778–779
- Sulfonated polyphosphazene, 776
- Sulfonated styrenic block copolymers, 772–773
- Sulfosuccinic acid, 190
 - FTIR analysis, 199
- Sulfuric acid fluxes, 729
- Supercritical fluid (SCF), 695–696
- Supercritical fluid-liquid systems, 695–696
- Superglassy polymers, 650
- Supersparger, 699
- Supported amorphous silica structure
 - FIB TEM, 911
- Supported gamma-alumina layer
 - SEM of defects, 910
- Supported gas membrane (SGM), 698
- Supported inorganic membranes
 - definitions, 901
 - destructive techniques, 922
 - nomenclature, 924
- Supported liquid membrane (SLM), 697, 722
 - antibiotic removal and recovery, 736
 - schematic, 724
 - strip dispersion, 724
- Supported membranes
 - concepts, 901
 - homogeneity and defects, 906
 - hydrogen purification, 915
 - structure transport properties, 910–911
 - water purification, 915
- Supporting structures
 - design considerations, 916
- Support interface
 - microcracking, 908
- Surface bubble, 907
- Surface characterization, 841–866
 - charge, 855–858
 - chemical structure, 842–851
 - hydrophilicity, 852–854
 - microscopical methods, 861
 - morphology, 859–866
 - spectroscopic methods, 843
- Surface decomposition, 909
- Surface defect, 907
- Surface diffusion separation
 - types, 912
- Surface-modified membranes, 505–506

- Surface modifying macromolecules (SMM), 313–315, 324
- Surface-selective flow membranes, 673
- Surface transport by diffusion hopping, 911
- Surface waters
organics removal, 277–278
- Surface water softening, 276
- Surfactants, 160
- Surplus sludge production, 227
- Suspended solids (SS), 263–264
- Sustainable flux, 243, 256, 257–258
- Sustainable flux operations, 263, 264
- Sustainable permeability
submerged membrane MBR, 256
- SW. *See* Spiral wound (SW) membrane
- SWEDI. *See* Spiral-wound electrodeionization (SWEDI)
- Sweeping gas membrane distillation (SGMD), 299, 301, 304, 345–347
applications, 348
configuration, 337, 346
flux, 348
- Sweeping gas pervaporation, 345
- Sweetening processes
natural gas, 662–663
- Sweet whey
demineralization, 283
- SWP. *See* State Water Project (SWP)
- SWRO. *See* Seawater reverse osmosis (SWRO)
- Symmetric membranes, 587
- Synthesis gas
carbon dioxide capture, 728, 747
- Synthetically modified cellulose (SMC), 503
- Synthetic organic chemicals (SOC), 131
- TA. *See* Therapeutic apheresis (TA)
- TAB. *See* Tetraaminobiphenyl (TAB)
- Tangential-flow filtration, 543–544
operation modes, 544
schematic representation, 542
virus, 541–552
virus capture, 545–549
virus clearance, 550–551
virus purification, 546
- Tangential-flow membrane, 442
modules, 439
- Tangential-flow microfiltration, 541
- Tangential-flow module. *See* Flat-sheet membranes
- Tangential-flow ultrafiltration, 440
cassette, 442
model, 441
module characteristics, 443–444
system, 442
- TCE. *See* Trichloroethylene (TCE)
- TDS. *See* Total dissolved solids (TDS)
- TEA. *See* Total exchangeable anion (TEA)
- TEC. *See* Total exchangeable cation (TEC)
- Teflon AF, 651
- Teflon AF-1600
chemical structures, 651
physical properties, 652
- Teflon AF-2400
chemical structures, 651
physical properties, 652
- TEM. *See* Transmission electron microscopy (TEM)
- Temperature dependence
gas transport, 637–638
- Temperature polarization
effects, 338–340
MD, 331–340
- Temperature polarization coefficient (TPC)
MD, 339
- TEOS. *See* Tetraethylorthosilicate (TEOS)
- Terbutylazine
removal, 279
- Tetraaminobiphenyl (TAB), 653
- Tetrachloroethylene
removal, 279
- Tetraethylorthosilicate (TEOS), 680
- Tetraoctylammonium bromide (TOABr), 287
- Textile industry
effluent treatment, 280
- TGA. *See* Thermogravimetric analysis (TGA)
- Therapeutic apheresis (TA), 494
- Thermal conductivity
MD, 325
- Thermally induced phase separation (TIPS), 308, 890
- Thermal membrane crystallization, 712
- Thermal soak time, 614
- Thermochemical stability, 923
- Thermodynamic equilibrium, 853
- Thermoelectric power generation industry, 374
- Thermogravimetric analysis (TGA), 191, 196–197, 201–202, 202
- Thermoplastic synthetic polymers, 503
- Thermosetting polymers, 607
- Thermostatic sweeping gas membrane distillation (TSGMD), 348
configurations, 337
module, 318

- Thin channel module, 317
- Thin-film composite membranes,
87–88, 454
RO, 3–18
SW, 67
- Thin gamma-alumina membranes
visual appearance, 918
- Thin membranes and intermediate layers, 924
- THM. *See* Trihalomethane (THM)
- Three-center reverse osmosis system
configuration, 74–76
- Three-dimensional atomic force microscopy
image
hollow-fiber ultrafiltration membrane, 826
- Three-dimensional tissue culture
tissue engineering, 412–419
- Thrombogenicity activation, 508–509. *See*
also Coagulation
- Time-of-flight (TOF)
analyzers, 851
quantitative analysis, 852
SIMS, 852
surface sensitivity analysis, 852
- Time *vs.* TMP, 223
- TIPS. *See* Thermally induced phase separation
(TIPS)
- Tissue engineering, 409–429
future, 427–428
hollow-fiber membrane bioreactors,
412–419
mathematical modeling, 415–416
micromembrane probe monitoring,
420–426
multidisciplinary approach, 410
technical challenges, 410–412
three-dimensional tissue culture,
412–419
- Titania, 771
- Titration, 858
- TMC. *See* Transition metal catalysis (TMC)
- TMP. *See* Transmembrane pressure (TMP)
- TOABr. *See* Tetraoctylammonium bromide
(TOABr)
- TOC. *See* Total organic carbon (TOC)
- TOF. *See* Time-of-flight (TOF)
- Toray's seawater reverse osmosis membranes
performance, 9
- Total dissolved solids (TDS), 11, 31, 376
concentration, 48
- Total exchangeable anion (TEA), 386–387
- Total exchangeable cation (TEC), 386–387
- Total life cycle costs, 181
- Total organic carbon (TOC), 142, 380, 707
degasifier removal, 398
double-pass RO, 381
rejection, 381
- Total plant surface area, 178
- Toxin removal
adsorption, 534
- Toyobo double-element modules, 25
- Toyobo reverse osmosis module
hollow-fiber, 29
main supply record, 29
operation results, 30–31
seawater desalination, 22–35
- TPC. *See* Temperature polarization coefficient
(TPC)
- Track-etched polycarbonate membranes, 857
- Transition metal catalysis (TMC), 286
- Transmembrane pressure
vs. volumetric flux, 208
- Transmembrane pressure (TMP), 155, 223,
241, 259, 260, 313, 493, 521, 705, 889
changes, 116
constant flux operation, 243
cycle, 244
profiles
submerged hollow-fiber membranes, 259
vs. time, 223
- Transmission electron microscopy (TEM), 134,
191, 860, 864–865
- Transport
carbon membrane gas separation,
601–603
HD membranes requirements, 521–524
MD mechanisms, 331–340
microporous membrane, 911–912
semipermeable medical membrane
properties, 496
site hopping, 911–912
- Treated water quality, 117–119
- Treatment units
equipment specifications, 113
- Trialkanolamine catalyst, 710
- Trichloroethylene (TCE), 191
analysis, 195–196
batch degradation, 204–205
batch degradation study, 194–195
degradation, 193
degradation study, 204–206
kinetic analysis, 205
pseudo-first-order reaction rate constants,
205
removal, 279

- Trihalomethane (THM), 374
 - degasifier removal, 398
- Trypsin
 - PP membranes, 713
- TSGMD. *See* Thermostatic sweeping gas membrane distillation (TSGMD)
- Tubular configuration, 137–138
- Tubular membranes, 138, 439
 - schematic view, 221
- Tubular modules, 229
 - flow velocity, 224
- Tungsten-based catalyst binding, 708
- Turbidity monitoring, 149
- Turbocharger, 89–91
 - characteristics, 90
 - efficiency curve, 92
 - RO flow scheme, 90
- Turbostratic carbon
 - structure, 600
- Turbulence, 437
- Two-fluid phases
 - contactors, 690–695
- Two immobilized phase interfaces
 - contactors, 697–698
- Two-pass seawater reverse osmosis system, 71
- Two-stage seawater reverse osmosis system, 72–73
- Two-step membrane processes
 - vs.* one-stage, 565
- UBE industries, 582, 595
- UBE Membrane Dryer, 595
- UBE nitrogen gas generator
 - nitrogen products, 582, 593
- UF. *See* Ultrafiltration (UF)
- UKM. *See* Urea kinetic modeling (UKM)
- ULSI. *See* Ultra large-scale integration circuits (ULSI)
- Ultimate disposal
 - backwash water, 165
- Ultrafiltration (UF), 101–128, 239, 271, 421, 453, 541, 544
 - application, 139–141
 - application examples, 103
 - cleaning, 158
 - cross-flow configuration, 141
 - future, 127
 - global capacity, 132
 - plant, 163
 - pretreatment, 142–146, 184
 - productivity, 437
 - publications, 272
 - recent trends, 104–126
 - RO membrane life, 184
 - seawater desalination, 182, 186
 - selectivity, 437
 - spiral-wound geometry, 138
 - trends, 104–127
 - unit characteristics, 400
 - water reuse, 186
 - water treatment, 131–165
- Ultrafiltration biopharmaceutical separations, 435–449
 - membranes and devices, 438–445
 - principles, 437
 - processes, 446–448
- Ultrafiltration coefficient (Kuf), 521
- Ultrafiltration (UF) membrane, 32, 101
 - cleaning, 155–160
 - disks, 440
 - fabrication materials, 133
 - manufacturers, 133–142
 - materials, 133–142
 - module configurations, 133–142
 - MWCO, 134
 - performance, 102–104
 - pore sizes, 102, 134
 - preparation process, 104
 - SEM image, 107
 - use, 102–104
 - water purification applications, 105
 - water treatment tools, 171
- Ultrafiltration water treatment, 131–164
 - backwash water reuse, treatment, and disposal, 164
 - integrated membrane systems, 160–163
 - manufacturers, 133–142
 - materials, 133–142
 - membrane applications, 146–148
 - membrane fouling and cleaning, 149–159
 - module configurations, 133–142
- Ultra large-scale integration circuits (ULSI), 597
- Ultralow-energy reverse osmosis seawater desalination, 87–100
 - ADC, 96–98
 - energy recovery technology, 88–94
 - SWRO energy optimization, 95
- Ultrapure water (UPW), 371–402
 - integrated membrane technology, 377–402
 - notation, 402–403
 - power industry, 376
 - semiconductor industry, 373

- Ultrasonic time-domain reflectometry (UTDR), 879
 amplitude arrival time, 891
 signal amplitude, 883
- Ultrasonic time-domain reflectometry (UTDR) membrane characterization, 879–896
 inorganic membrane fouling, 882–884
 measurement, 880–881
 membrane biofouling, 885
 membrane compaction, 886–888
 membrane formation, 889–890
 membrane morphology, 891–893
- Ultrasonic time-domain reflectometry (UTDR) transducer
 liquid-filled membrane, 881
 water bath immersion, 892
- Unconstrained Brownian diffusivity, 497
- United States Department of Energy (US DOE)
 hydrogen separation technical targets, 679
- United States Pharmacopeia (USP) guidelines
 PW and WFI, 375
- Upper-bound limit
 polymer, 790
- UPW. *See* Ultrapure water (UPW)
- Urea kinetic modeling (UKM), 525
- Urea reduction ratio (URR), 524
- URR. *See* Urea reduction ratio (URR)
- US DOE. *See* United States Department of Energy (US DOE)
- USP. *See* United States Pharmacopeia (USP) guidelines
- UTDR. *See* Ultrasonic time-domain reflectometry (UTDR)
- Vacuum membrane distillation (VMD), 299, 301, 304, 349–352
 configuration, 312, 335–336
 fluxes *vs.* downstream pressure, 350
- Vacuum rotating membrane (VRM), 251
- Vacuum-side boundary layer
 resistance, 396
- Valves
 submerged membranes, 245
- Van der Waals molar volume
 permeability, 560
- Van't Hoff-Arrhenius expression, 943
- Van't Hoff equation, 273
- Vapor gas separation, 559–577, 663
 applications, 567–576
 design, 563–566
 developing technology applications, 575–576
 membranes, 642
- Vapor-induced phase separation (VIPS), 890
- Vapor-liquid equilibrium (VLE), 304, 460.
See also Gas-liquid systems
 principle, 304
- Vapor-permanent gas selectivity, 561
- VaporSep, 663
- VCM. *See* Vinyl chloride monomer (VCM)
- Vegetable oil industry, 461
 conventional processing approach, 461
 SRNF, 285
- Vent gas systems
 membrane, 561
 PVC, 571
- Vertical hollow fiber, 247
- Vertical intake well, 52
- Very large-scale integration circuits (VLSI), 597
- Vibratory shear enhanced processing (VSEP)
 module, 282
- Vinyl acetate, 573
- Vinyl acetate manufacturing plants
 ethylene recovery, 572
- Vinyl acetate plant ethylene recovery unit
 performance, 573–574
- Vinyl chloride monomer (VCM), 571, 578
 recovery, 571
- Vinyltrimethylsilicon (VTMS), 310
- VIPS. *See* Vapor-induced phase separation (VIPS)
- Virus
 clearance validation, 552
 filtration, 552
 log clearance, 551
 removal membrane modules, 447
 tangential-flow filtration, 541–552
- Virus removal
 hollow-fiber membranes, 446
- Viscosity
 MBR, 232
 MLSS, 226–227
- Viscous liquid permeation, 920
- VLE. *See* Vapor–liquid equilibrium (VLE)
- VLSI. *See* Very large-scale integration circuits (VLSI)
- VMD. *See* Vacuum membrane distillation (VMD)
- VOC. *See* Volatile organic components (VOC)
- VOC SEP. *See* Volatile organic components shear enhanced processing (VOC SEP)

- Void space, 902
- Void volume
 - membrane, 326
- Volatile organic components (VOC), 344, 398, 470, 799
 - SEP hollow-fiber pervaporation plant, 487
- Volatile organic components shear enhanced processing (VOC SEP)
 - PV, 471–474
- Voltage estimation
 - EDI, 390
- Volumetric flux
 - vs. transmembrane pressure, 208
- VRM. *See* Vacuum rotating membrane (VRM)
- VSEP. *See* Vibratory shear enhanced processing (VSEP) module
- VTMS. *See* Vinyltrimethylsilicon (VTMS)

- Waste heat, 357
- Waste stream
 - quality and quantity, 62
- Wastewater polishing
 - NF, 280–282
- Wastewater reclamation
 - Kuwait, 16–17
 - low-fouling RO membrane, 14–17
 - Singapore, 16
- Wastewater reuse plants, 14
- Wastewater treatment
 - MBR, 217–236
- Wastewater treatment advanced oxidation processes
 - membrane reactors, 704–709
- Wastewater treatment facility
 - Japan, 15
- Wastewater treatment membrane bioreactors, 217–235
 - applications and cost, 233–234
 - design, 230–232
 - membrane bioreactor process, 217–229
- Wastewater treatment plants (WWTPs), 234
- Water
 - century, 2
 - contact angles, 324
 - contaminant removal, 284
 - desalination, 171–186
 - drinking and process NF, 276–279
 - dual membranes, 267
 - high-pressure boiler specifications, 376
 - permeability, 594
 - process pretreatment, 267
 - requirement, 372
 - SWRO systems, 71
- Water bath immersion
 - UTDR transducer, 892
- Water consumption
 - backwash pressure, 157
- Water content
 - carbon dioxide flux, 739–740
 - carbon dioxide permeability, 739–740
- Water desalination
 - cost, 181–184
 - process options, 181
 - vs. water reuse, 185
- Water flux vs. applied transmembrane pressure, 323
- Water for injection (WFI)
 - USP guidelines, 375
- Water gas shift (WGS), 726
 - carbon dioxide, 743–744
 - experiments, 745
 - fuel cells, 727–728
 - membrane reactor, 679, 728, 737, 743–744, 745, 748
- Water production, 16
 - cost influences, 84
 - costs, 82–84
 - seawater desalination costs, 82–83
- Water production costs
 - seawater, 185
- Water purification
 - characterization, 918–922
 - defects, 902–907
 - manufacturing, 917
 - MF membrane, 105
 - morphology, 902–907
 - porosity, 902–907
 - supported membranes, 915
 - supported membrane structure optimization, 908–916
 - synthesis, 917
 - thin supported inorganic microstructural optimization, 902–916
 - UF membrane, 105
- Water quality
 - treatment processes, 118
- Water reclamation, 171–186, 177–181
 - cost, 177–180
 - cost estimation, 173
 - membrane desalination, 171–188
 - process design conditions, 185

- Water reclamation (*Continued*)
 process options, 174–177
 quality of plant, 186
 vs. seawater desalination, 173
- Water recovery vs. EDI feed water hardness, 385
- Water resource
 deterioration, 3
- Water reuse
 vs. desalination, 185–186
 MF technology, 186
 NF, 280–282
 paper industry, 282
 pulp industry, 282
 UF technology, 186
 vs. water desalination, 185
- Water-scarce regions, 171
- Water selectivity
 feed pressure, 740
 vs. water content, 740
- Water-soluble molecules, 523
- Water supply filtration, 127
- Water treatment
 IMS design approach, 162
 MF, 131–165
 MF membrane, 171
 submerged membranes, 267
 UF, 131–165
 UF membrane, 171
- Wattman Anopore support
 FIB TEM cross section, 906
- Wet/dry flow method, 328–329
- WFI. *See* Water for injection (WFI)
- WGS. *See* Water gas shift (WGS)
- WHO. *See* World Health Organization (WHO)
- Wilhelmy plate method, 854
- Wilhelmy rod method, 854
- World Health Organization (WHO), 10
- WWTPs. *See* Wastewater treatment plants (WWTPs)
- XLPEO. *See* Crosslinked polyethyleneoxide (XLPEO)
- XPS. *See* X-ray photoelectron spectroscopy (XPS)
- X-ray diffraction (XRD), 613
 analysis, 196, 200
 chitosan membranes, 201
- X-ray photoelectron spectroscopy (XPS), 310, 314, 330, 708, 842, 849–850
 catalytic membrane, 708
- XRD. *See* X-ray diffraction (XRD)
- Yeast suspension after long-term filtration
 fiber surface, 257
- Young's equation, 853
- Zenon ZeeWeed, 248, 257
 500d submerged HF cassette, 248
 filtration system, 174, 176
 intensive cleaning protocols, 265
 MBR, 176
- Zeolite, 599, 902, 904
 dual-layer mixed-matrix hollow-fiber membrane, 802
 membranes, 673, 791
 particles, 796, 802
 polyimide pairs, 798
 sieve-in-a-cage morphology, 796
- Zeta potential, 135
- Zinc, 732–733
 feed and strip solutions, 732
 removal and recovery, 732–733
- Zirconia, 771
- Zirconium phosphate-sulfophenyl phosphonate platelet
 schematic structure, 771
- Zirfon composite UF membrane
 permeability and compressive strain, 888
- ZSM-5, 792, 799, 901, 904