Future Perspective

This book focuses on technologies for converting solar energy into chemical energy, in particular, hydrogen as a main form of chemical energy. To date, various methods have been proposed in a wide area of research, ranging from photovoltaic cells, photocatalysts, solar cells combined with electrolysis, solar thermal chemical reactions, photosynthesis-mimicking approaches to algae breeding, as discussed in detail in this book. The advancement of studies in these fields promises numerous possibilities of utilizing solar energy, but at the same time also reveals challenges and difficulties that need to be overcome.

The importance of developing solar energy conversion technologies is increasingly being recognized. Energy is the most basic element for human and industrial activities. Today, society uses enormous amounts of energy, leading to growing demands for abundant inexpensive energy supplies. For centuries, civilization has relied on the use of natural energy resources buried in the earth such as natural gas, oil, coal and uranium. However, the continuous use of these natural energy resources in massive amounts is causing severe damage to the global environment. First of all, natural energy resources buried in the earth are limited and will thus become completely depleted one day. Accordingly, the development of technologies for sustainable energy supply such as solar energy conversion is indispensable in the long run. It is no exaggeration to say that our future may be bleak if we do not succeed in the large-scale and practical application of solar energy conversion.

So how can we achieve our goal? The total amount of solar energy reaching the earth surface is sufficiently large but there are some obstacles in its application. First, the density of solar energy per unit area and unit time is not necessarily large, which requires the use of solar energy conversion devices over a large area. Secondly, the solar energy density incessantly changes with time. In particular, solar light is only available during the day. Thirdly, the solar energy density changes according to location. In general, well populated areas, where energy usage is high, have many cloudy and rainy days, indicating that they are not suitable places for solar energy conversion. On the other hand, deserts have abundant sunlight and most are far away from areas of dense population. It should be mentioned also that solar light has a wide spectral distribution, which makes high conversion efficiency difficult. This situation suggests that the development of a
single efficient technique is not sufficient, and there is a need to develop a diversity
of techniques from various perspectives and review their appropriate combinations.
The diverse discussions presented in this book will contribute to this end.

In relation to this situation, we also have to note that electric energy as well as
light energy cannot be stored effectively. Therefore, it is necessary to include
techniques for energy storage and transport such as electric to chemical energy
conversion and vice versa in solar energy conversion technologies. In particular,
finding efficient electrodes for electrochemical oxygen evolution and oxygen
reduction is of key importance because both reactions have high over-voltages at
present and lead to large energy losses though they are fundamental reactions in
mutual conversion between electrical and chemical energy. This book also attaches
high importance to this topic.

Another serious problem arising from the above situation is that it imposes
severe requirements on solar energy conversion technologies. Namely, high effi-
ciency, low cost and long-term durability are fundamental conditions for the suc-
cessful application of solar energy conversion technologies. These conditions are,
however, quite difficult to meet to a sufficient extent, because there is a trade-off
between high efficiency and low cost or between long-term durability and low cost.
In fact, this is why large-scale practical applications of solar energy conversion
technologies are delayed. Moreover, in actual researches, we often face various
other dilemmas. To overcome such difficulties, evidently further studies with deep
insight into the physics and chemistry of materials are needed. Needless to say, it is
of crucial importance to find new stable efficient materials with the further devel-
opment of properties of available promising materials and their effective and skillful
utilization for solar energy conversion.

Finally, it is worth noting that we may have a means of working out a new
strategy for achieving a breakthrough in the above difficulties. The photosynthesis
system in natural plants is able to repair damaged parts and restore the original state.
It also has the ability to organize itself so that it realizes the highest possible
efficiency. Highly functional arrangements of electron-transferring molecules in the
lipid bilayer membrane prove that natural plants really have such ability. In prin-
ciple, it is possible to realize similar functions and abilities in artificial devices.
There is no reason why they cannot be achieved. Thus, it is a challenging goal to
clarify the principles of the self-restoring and self-improving functions and abilities
of the natural photosynthesis system and apply them to artificial solar energy
conversion devices. Chemical devices such as (photo)electrochemical electrodes
and photocatalysts will be suitable sites for incorporating such functions and
abilities. Successful incorporation will not only lead to solutions to the above
trade-off but also to the development of new technologies which can be applied to
other fields extensively. In this respect, studies on solar energy conversion tech-
nologies may play a leading role in the development of novel cutting edge tech-
nologies. Indeed, challenges and obstacles can serve as opportunities for making
such new discoveries and achievements.
## Index

### A
- A, 409
- Acceptor, 28
- Accessory BChl, 445
- Acetonitrile, 165
- Activation energy, 10, 18, 220, 232
- Activation state, 17
- Activity, 11
- Adiabatic, 15
- Advantages, 329
- AFM, 439
- AFM topography, 443
- AgCuInGaSe$_2$, 277
- A law of mass action, 37
- Alcohols, 215
- Alkali carbonate (Li$_2$CO$_3$, Na$_2$CO$_3$, and K$_2$CO$_3$) melts, 119
- Alkali metal redox cycle, 137
- Alkaline fuel cell (AFC), 115, 117
- Alloy, 205
- 3-aminopropyltriethoxysilane (APS), 449
- Ammonia, 224
- Amount, 306
- Anionic species, 202
- Anode, 12, 230
- Anode active material, 106
- Anodic current, 18
- Anodic photocurrent, 338, 339
- Anodic potential, 26
- Anodization, 332
- Anomalous difference map, 384
- Antenna, 372
- Antenna pigments, 457
- Archean sea, 184
- Arrhenius equation, 57
- Artificial photosynthesis, 300
- Associative mechanism, 100
- ATP, 372, 380

### B
- B800, 387
- Bacterial photosynthesis, 438
- Bacteriochlorophyll (BChl), 372, 380, 438
- Bacteriopheophytin (Bphe), 382, 445
- Band, 36
- Band bending, 39, 42
- Band diagram, 275
- Band edge, 31
- Band engineering, 308
- Bandgap, 271
- Band gap narrowing, 310
- Bases, 301
- Batteries, 105
- Bifunctional thiols, 425
- Biocomponents, 419, 421
- Bioenergetic evolution of CO$_2$ reduction and carbon assimilation, 215
- Bioinspired approaches, 215
- Biology-based, 451
- Biomimetic, 306
- Biomimetic hydrogenase, 313
- Bipolar plates, 117
- BiVO$_4$ electrode, 338
- BiVO$_4$ photoelectrode, 332
- BiVO$_4$ thin film, 338
- Bixon–Jortner Model, 81
- Black smoker chimneys, 222
- Boltzmann distribution, 16, 51
- Boltzmann’s constant, 234
- Boltzmann’s entropy formula, 8
- Bottleneck effect, 270
- Botryococcus braunii, 463
- Brookhaven National Laboratory, 128
- Built-in potential, 80
- Butler–Volmar equation, 19
- Butler–Volmer theory, 100

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M. Sugiyama et al. (eds.), Solar to Chemical Energy Conversion, Lecture Notes in Energy 32, DOI 10.1007/978-3-319-25400-5

481
Ca2+ binding site, 381, 384
CaMn4O5, 181
Carbamate species, 216
Carbohydrates, 126
Carbon-neutral energy source, 249
Carbon monoxide, 249, 214
Carbon monoxide dehydrogenases (CODHs), 214
Carbon nanotube, 433
Carbon nitride, 165
Carboxylate ligands, 185
Carotenoid, 380, 381, 404, 438
Catalysts, 117
Cathode, 12, 230
Cathode active material, 106
Cathodic current, 18, 449
Cathodic potential, 26
Cationic Species, 202
Chalcogel-type material, 219
Chalcopryrite, 272
Channel, 385
Charge-separated state, 374
Charge comproportionation, 181
Charge disproportionation, 180
Charge recombination, 85
Charge separation, 372, 380, 404, 419, 422
Charge separation efficiency, 310
Charge transfer, 68, 282
Charged particle, 30
Chemical energy conversion/storage systems, 123
Chemical evolution, 221
Chemical fuel, 249
Chemical potential, 11, 19, 23
Chemical reaction, 9, 16
Chemical routes, 328
600 nm class materials, 314
Chlorophyll, 160, 372, 404
Chlorophyll-protein complex, 405
Circular dichroism, 374
Clausius theorem, 8
C–N bonding, 223
C- or N- terminal His-tagged LH1-RCs, 440
Co-catalysts, 303
Co-evaporation, 273
Co-sputtering, 335
CO, 294
CO2, 291
13CO2, 294
CO2–, 192
CO2– anion radical, 205
CO2 reduction, 154, 281
Co3O4, 178
CO formation metals, 198
CO selectivity of metals, 199
Cocatalysts, 311
Coccolithophore, 469
Cofactor, 382
Coloading, 314
Concentrated optics, 264
Concentrated photovoltaic cell (CPV), 240
Concentrated solar cell (CPV), 241
Conclusion, 340
Conduction band, 27, 36, 282
Conductive atomic force microscopy (C-AFM), 439
Configuration Interaction (CI), 70
Conjugation, 159
Constrained density functional theory (CDFT), 70
Constrained Hartree Fock (CHF), 70
Conversion efficiency, 302
Coplanar, 267, 276
Copper Electrode, 199
Copper gallium selenides, 328
Cost and a bit tedious, 328
Cost of H2 production, 264
Covalent bond, 28
Crystal defects, 47
Crystal seeds layers, 336
Crystal structure, 421
CuGaSe2, 277
CuInGa(S,Se)2, 277
CuInGaSe2, 273
Current–bias characteristic, 34
Cyanobacteria, 459
Cysteine mutant PSI, 428
Cytochrome bc1, 386
Cytoplasmic side, 446
D
D-band models, 178
D2O, 294
d0 metal, 307
d10 metal, 307
D metals, 198
DC/DC converter, 240
Deactivation, 196
Deep sea water, 471
Dense PSI multilayer, 429
Densities of electronic states, 22
Density functional theory (DFT), 94
Density functional theory (DFT) calculations, 216
Density of states, 50
Depletion layer, 31
Depletion layer thickness, 25
Depletion region, 38
Device Simulators, 77
Diamond–like crystal structure, 28
Dielectric screening, 95
Dimethylformamide (DMF), 155
Diode, 31
Diode ideality factor, 234
Dirac-Frenkel time-dependent variational principle, 75
Direct methanol fuel cell (DMFC), 115, 121
Directing agent, 337
Distribution function, 21
Doctor blading technique, 324
Dogonadze and Levich treatment, 17
Donor, 28
Doped BiVO₄ photoanodes, 329
Doping, 28, 37
Doping concentration, 30
Drawback, 334
Drift and diffusion, 67, 77
Driving force, 11, 311
Dual cocatalysts, 314
Durability, 264
Dye–Sensitized Solar Cells (DSSC), 78
Dye sensitization, 308

E
2-electrode, 266
3-electrode, 266
EC cells, 319
Ecosystem, 459
Effect, 94
Effective density of states, 37
Electric double layer, 45
Electric potential, 12
Electrical connections, 321
Electrical leads, 321
Electrical resistance, 320
Electroactive species, 195
Electrocatalysis, 197
Electrocatalyst, 282
Electrocatalysts for the reduction of CO₂, 214
Electrocatalytic activities, 200
Electrochemical catalyst, 243
Electrochemical cell, 230
Electrochemical fuel cells, 222
Electrochemical interface, 94
Electrochemical potential, 14
Electrochemical reaction, 14, 27
Electrochemical reduction of CO₂, 191
Electrochemical synthesis, 331
Electrochemical water-splitting reaction, 213
Electrochemistry, 22
Electrode potential, 12, 94
Electrodes, 320
Electrolysis, 27
Electrolyte, 26, 291
Electron, 28, 31
Electron conductivity and photocurrent, The, 451
Electron donor, 157, 281, 370
Electron energy, 12, 19
Electron-hole pair, 233
Electron-hole recombination, 169
Electronic affinity (A°), 20
Electronic defects, 272
Electronic hybridization, 85
Electrophoretic deposition, 325
Electrostatic potential, 25
Elemental-based strategy, 185
Elemental strategy, 225
Elevated Pressure, 206
Emergence of life, The, 221
Emiliania huxleyi, 469
Endosymbiosis, 459
Energy conversion, 137
Energy conversion efficiency, 205
Energy density, 124, 462
Energy harvesting, 46
Energy transfer, 386
Enthalpy, 8, 231
Entropy, 8, 39, 231
EPR, 460
Equilibrium, 22, 25
Equilibrium chemical reaction, 11
Equilibrium constant, 12
Equilibrium contact between a metal and an electrolyte, 25
Equilibrium coverage, 100
Equivalent circuit, 233, 236
Evolutionary origin, 184
Excited state, 374
Exciton coupling, 374
Exciton dissociation, 68
Exciton transfer, 374
Experimental methods, 303
Extended X-ray absorption fine structure, 394
External work, 45
Eyring plot, 58

F
F₀, 409
Faradaic efficiency, 266
Faraday constant, 12, 232
F₂, 409
Femtosecond XRD, 399
Fermentation, 460
Fermi–Dirac (F–D) distribution, 23, 39, 51
Fermi energy, 23
Fermi level, 22, 40
Fermi level pinning, 45
Fermi’s Golden rule, 81
FET, 432
Fill factor (FF), 235
First-principles, 93
Fischer-Tropsch reaction, 127
Fisheries industries, 476
Flatband condition, 34
Flatband potential, 31
Fluorescence, 387
Food chain, 460
Formate, 294
Formate formation metals, 198
Formic acid, 154, 215
Fossil fuels, 153
Franck-Condon principle, 17, 20
Free energy, 9, 39
Free energy losses, 271
Frustrated Lewis acid-base pair, 218
Frustrated Lewis acid-base pair motif, 215
Fuel cells, 105, 114
Functions, 307
F X, 409

G
GalnP 2, 268
Galvanic cell, 13
Gas constant, 11
Gas Diffusion Electrode, 207
Gate, 432
GC-MS, 294
Generalized Mulliken-Hush (GMH) formula, 70
Gericher model, 82
Gerischer model, 15, 19
Gibbs energy, 9, 23, 231, 265
Global warming, 213
Gold nanoparticle, 427, 428
Grand canonical MD simulation, 98
Graphen oxide, 433
Gréigite, 219

H
H2A model, 263
H2O, 291
H 2 18O, 295
Half-reaction, 12
Harmonic oscillation, 20
HCO 3 −, 193
HCOO −, 192
Heat, 7
Heat of adsorption of CO, 201
Helmholtz energy, 9
Hematite, 267
Hemical Bath Deposition, 338
HER, 192, 196, 197
Heterogeneous electrocatalysts, 221
Heterogeneous photocatalysis, 163
Heterometallic oxides, 310
Histidine groups, 185
Hole, 28, 31
Hole scavengers, 305
Holmholdt layer, 97
Homogeneous molecular catalysts, 217
Hot charge transfer excitons, 76, 87
Hotoanode, 254
Hotocathode, 254
H-subunits, 446
Hydrocarbons, 463, 473
Hydrogen, 299, 473
Hydrogen-absorbing alloy, 111
Hydrogen bonding, 383
Hydrogen-bonding network, 182
Hydrogen evolution, 163
Hydrogen overvoltage, 196, 197
Hydrogen production rate, 265
Hydrogenase, 222
Hydronium ion, 98
Hydrothermal fluid, 222
Hydrothermal synthesis, 335
Hydrothermal vents, 221

I
I-V curves, 444
IC-TOFMS, 294
II (PSII), 419
Improved electrochemical deposition, 332
Incident photon-to-current efficiency, 274
Infrared spectroscopic, 200
Inorganic, 306
Inorganic-organic hybrid, 286
Integrated PV-electrolyzers, 268
Integration scheme, 269
Interconnected droplet-like nanoparticles, 331
Interfacial states, 44
Intermediate species, 179, 286
Internal conversion, 85
Internal energy, 7, 39
Intramolecular electron transfer, 158
Introduction, 300
Iodine-sulfur (I-S) cycle, 144
Ion exchange materials, 236
Ion exchange membrane, 208
Ionic liquid electrolyte, 206
Ionic liquids, 216
Ionization energy (I0), 20
IPCC, 467
IrO$_2$, 177
Irregular plate-like, 330
Isotope, 155
Isotope tracer analyses, 289
Issues, 307
ITO electrode, 449

J
Junction structure, 312

K
Kalahari desert, 185
Kinetic isotope effect, 183
Kok cycle, 181

L
La$_5$Ti$_2$CuS$_5$O$_7$, 328
Landu-Zener formula, 17
LaTiO$_2$N, 326
Law of mass action, 52
Layered double hydroxide (LDH), 163
Lead-Acid Batteries, 107
Lead sulfate, 107
Lectron affinity, 29
Lectron donors and acceptors, 404
LH1, 380
LH1-RC, 439
LH2, 380
LH2 complexes, 438
LHCI, 405
Li Ion Batteries, 112
Libido rule of acid-base catalysis, 182
Ligand adoption, 185
Ligands, 293
Light absorption, 307
Light-harvesting (LH), 160, 372, 379, 437
Linker, 423
Liquid Light Inc, 128
Load-line analysis, 276
Low-density energy, 471
Lowest unoccupied molecular orbital (LUMO), 289

M
Macrostate, 8
Manganese, 160
Marcus’ inverted region, 71
Marcus’ normal region, 71
Marcus Theory, 15, 67, 68, 87
Maximum power conversion point, 235
Maximum power point tracking (MPPT), 240
Measurements, 200
Mechanism, 301
Menaquinone, 375, 383
Mesoporous Silica, 160
Metal complex, 154, 289
Metal organic decomposition, 329
Metal sulfides, 218
Metal-sulfur clusters, 218
Metals or metal alloys, 214
Methane monoxygenase, 225
Methanol, 127
Methanol dehydrogenase, 225
Microstates, 8
Mirror-like surface, 334
Mischmetal, 111
MV, 442
Mn-based water oxidation catalysts, 179
Mn$_2$O$_3$, 179
Mn$^{3+}$, 179
MnO$_2$, 176
MnCO$_3$, 185
MnOOH, 179
Mo-containing CODHs, 217
Modeling, 270
Modification, 311
Molecular, 429
Molecular electric wire, 433
Molecular reaction pathway diagram, 200
Molecular wire, 430
Molten carbonate fuel cell (MCFC), 115, 119
Mono-particle layer, 326
Mott-Schottky plot, 26, 31
Multi-Configurational Time-Dependent Hartree (MCTDH), 73, 74
Multi-electron reactions, 282
Multi-electron transfer, 289
Multi-junction, 262, 268
Multi-step methods, 340
Multiple-junction solar cell, 241

N
N-assisted CO$_2$ reduction, 223
N-type semiconductor, 28
NADPH, 372
Nanobiodevices, 437
Nano-flower arrays, 337
Nanoporous WO$_3$ films, 333
Nanostructured gold electrode, 427, 428
Nanostructured WO$_3$ films, 336
Naphthoquinone, 410
Necking treatment, 325
Nernst equation, 15, 19
Neutral pH, 176
Ni-containing CODHs, 217
<table>
<thead>
<tr>
<th>Term</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ni-containing greigite</td>
<td>222</td>
</tr>
<tr>
<td>Ni-Metal Hydride Batteries</td>
<td>111</td>
</tr>
<tr>
<td>Ni-NTA</td>
<td>441</td>
</tr>
<tr>
<td>Nickelian mackinawite</td>
<td>221</td>
</tr>
<tr>
<td>Nitrate reductase</td>
<td>225</td>
</tr>
<tr>
<td>Nonadiabatic</td>
<td>15, 87</td>
</tr>
<tr>
<td>Nonadiabatic electronic coupling</td>
<td>70</td>
</tr>
<tr>
<td>Nonadiabatic quantum dynamics</td>
<td>73</td>
</tr>
<tr>
<td>Nonaqueous systems</td>
<td>199</td>
</tr>
<tr>
<td>Non-arable land</td>
<td>464</td>
</tr>
<tr>
<td>Non-ideal chemical potential</td>
<td>11</td>
</tr>
<tr>
<td>Nonideal mixed substance</td>
<td>11</td>
</tr>
<tr>
<td>Non–radiative transition</td>
<td>80</td>
</tr>
<tr>
<td>Normal hydrogen electrode (NHE)</td>
<td>13</td>
</tr>
<tr>
<td>Nucleophilic and electrophilic interactions</td>
<td>218</td>
</tr>
<tr>
<td>Nutritional supplement</td>
<td>475</td>
</tr>
<tr>
<td><strong>O</strong></td>
<td></td>
</tr>
<tr>
<td>O-O bond formation</td>
<td>178</td>
</tr>
<tr>
<td>O₂</td>
<td>291</td>
</tr>
<tr>
<td>¹⁸O₂</td>
<td>295</td>
</tr>
<tr>
<td>Of solvation states</td>
<td>21</td>
</tr>
<tr>
<td>Ohmic conductivity</td>
<td>448</td>
</tr>
<tr>
<td>Ohmic junction</td>
<td>48</td>
</tr>
<tr>
<td>One electron reduced (OER) species</td>
<td>157</td>
</tr>
<tr>
<td>Operative activation of CO₂</td>
<td>218</td>
</tr>
<tr>
<td>Open-circuit</td>
<td>50</td>
</tr>
<tr>
<td>Open-circuit voltage</td>
<td>240, 426, 235</td>
</tr>
<tr>
<td>Open system</td>
<td>95</td>
</tr>
<tr>
<td>Operating point</td>
<td>271</td>
</tr>
<tr>
<td>Operating temperature</td>
<td>239</td>
</tr>
<tr>
<td>Optical limit</td>
<td>270</td>
</tr>
<tr>
<td>Orbital degeneracy</td>
<td>181</td>
</tr>
<tr>
<td>Organic</td>
<td>306</td>
</tr>
<tr>
<td>Organometallic species</td>
<td>329</td>
</tr>
<tr>
<td>Oriented Immobilization</td>
<td>423</td>
</tr>
<tr>
<td>Oriented multilayers</td>
<td>428</td>
</tr>
<tr>
<td>Origin of Life theory</td>
<td>214</td>
</tr>
<tr>
<td>Orous plate-like WO₃</td>
<td>336</td>
</tr>
<tr>
<td>Other methods</td>
<td>340</td>
</tr>
<tr>
<td>Outlook</td>
<td>314</td>
</tr>
<tr>
<td>Overall water splitting</td>
<td>306</td>
</tr>
<tr>
<td>Overpotential</td>
<td>10, 100, 163, 176, 214, 282</td>
</tr>
<tr>
<td>Oxidation</td>
<td>12</td>
</tr>
<tr>
<td>Oxidation/reduction (redox) reaction</td>
<td>22</td>
</tr>
<tr>
<td>Oxidation reduction</td>
<td>457</td>
</tr>
<tr>
<td>Oxidation state</td>
<td>20</td>
</tr>
<tr>
<td>Oxide</td>
<td>307</td>
</tr>
<tr>
<td>Oxygen-evolving complex</td>
<td>391</td>
</tr>
<tr>
<td>Oxygen reduction reaction (ORR)</td>
<td>99, 176</td>
</tr>
</tbody>
</table>

**P**

P-GaInP₂, 322

P-n GaAs junction photovoltaic layer, 322

P-n junction, 233

P-type semiconductor, 28

P⁺680, 422

P700, 409, 421

Parabolic shape, 16

Parallel-plate capacitor, 96

Parameters, 311

Partial current, 200

Particle transfer method, 326

Particles, 330

Partition function, 58

Path, 8

PEC-PEC tandem, 268

PEC material lifetime, 264

PEC reactors, 262

PEC water oxidation, 337

Performances, 304

Perovskite, 177

pH dependence, 182

Phosphate buffer solution, 193

Phosphoric acid fuel cell (PAFC), 115, 118

Photo-electrodes, 319

Photo-induced electron transfer, 419

Photo-induced water splitting, 423

Photoanode, 284

Photocatalysis-electrolysis hybrid system, 345, 347, 349, 350, 352, 354, 355, 362

Photocatalysis, 45, 155

Photocatalyst, 46, 154

Photocatalytic, 262

Photocathode, 284

Photochemical reaction, 404

Photocurrent, 334, 426

Photocurrent density, 266

Photoelectrochemical, 333, 339

Photoelectrochemical CO₂ reduction, 281

Photoelectrochemical (PEC) water splitting, 250

Photoelectrochemical reaction, 27, 31

Photoelectrochemistry, 45

Photoelectrodes, 262

Photoelectrodes fabricated from photocatalyst, 323

Photon, 45

Photosensitizers, 290

Photosensor, 425

Photosynthesis, 284

Photosynthetic antenna core complex, LH1-RC, 451

Photosynthetic CO₂ fixation center, 223

Photosynthetic conversion, 124

Photosynthetic protein complexes, 451

Photosystem, 375

Photosystem I, 403
Index

Photosystem I (PSI), 419, 420
Photosystem II, 176, 392
Photosystem II (PSII), 420
Photovoltaic cell, 48
Photovoltaics, 67
Physical routes, 323
pK_{a} of the coordinated water ligand, 182
Plagging, 429
Planer solar cell, 241
Platinum catalyst, 121
Pn junction, 38
Point-contact current imaging (PCI) AFM, 441
Poisoning, 197
Poisson-Boltzmann equation, 80, 98
Poisson equation, 25, 42, 78
Poly-allylamine hydrochloride, 219
Poly histidine tag (Histag), 426
Polycrystalline Ceramic Semiconductors (Photocatalysts), 322
Polymer, 165
Polymer-electrolyte electrochemical cell (PEEC), 240
Polymer electrolyte fuel cell (PEFC), 115
Polymer electrolyte membrane (PEM), 115
Poor contact, 324, 326
Porous (Ga_{1-x}Zn_{x})(N_{1-x}O_{x}) electrode, 324
Porous photoelectrode, 355, 357, 360
Porous plate-like WO_{3}, 335
Potentiostat, 98
Powder spreading method, 323
Powdered photocatalyst, 300
Power generator, 430
Prebiotic organic synthesis, 214
Preelectrolysis, 196
Pressure, 8
Primordial life, 221
Processes, 302
Propylene carbonate, 199
Proton-motive force (PMF), 222
Proton gradient, 375, 380
Proton source, 281
Proton transfer, 182
PSI-LHCI supercomplex, 405
PSI, 403
PSI complex, 405
PSI core, 407
PSII, 426
Pt(111)—solution interface, 94
Purple bacteria, 370
PV-PEC multi junction structure, 268
Pyridine, 183
Pyridine-catalyzed CO_{2} reduction, 216
Pyridine derivatives, 183
Pyrrole, 221

Q
Q, 445
QM/MM, 75
Quantum efficiency, 290
Quantum master equation, 73
Quantum master equation (QME), 73
Quantum mechanical treatment, 17
Quantum yield, 156, 304, 375
Quasi Fermi level, 45
Quench, 387
Quinone (Q), 379
Quinone (Q) pool, 375, 386
Qy transition, 381, 383

R
Rate, 304, 306
Rate determining step, 178, 196, 313
Reaction center (RC), 370, 379, 404, 438
Reaction coordinate, 16
Reaction intermediates, 100
Reaction mechanism, 97
Recombination, 68
Reconstitution, 430
Reconstructed PSI, 432
Red chlorophylls, 412
Redox, 12
Redox-Flow Batteries, 109
Redox potential, 27, 370
Redox reaction, 48
Redox state, 387
Reduced state, 20
Reduction, 12
Reduction cocatalyst, 312
Reductive carboxylic cycle, 219
Red-shift, 384
Reference electrode, 13
Renewable energy sources, 213
Reorganization energy, 17, 20, 69, 82
Resonance energy transfer, 160
Response, 333
Rhenium, 156
Rhodobacter sphaeroides, 451
Rubisco, 375
RuO_{2}, 176
Ruthenium, 160
 Rutile TiO_{2}, 321

S
2-step cycle, 143
Schottky junction, 43
Secondary Batteries, 105
Selectivity, 293
Self-assembled monolayers (SAMs), 425, 439
Semiconducting powder, 326
Semiconductor, 161, 282, 300, 433
Semiconductor combination, 311
Semiconductor electrode, 27
Semiconductor/electrolyte interface, The, 274
Serial, 399
Short circuit current, 235
Shortcoming, 325
Silicon, 267
Single crystal semiconductors, 321
Sodium–Sulfur Batteries, 108
Sodium, 108
Sol–gel route, 329
Solar-to-hydrogen, 261
Solar cells, 229
Solar fuel, 261, 295
Solar heat, 138
Solar hydrogen, 345, 346, 347, 355
Solar simulator, 304
Solar to hydrogen (STH), 238
Solar to hydrogen (STH) conversion efficiency, 250
Solid-liquid junction, 255
Solid oxide fuel cell (SOFC), 115, 120
Solid Polymer Electrolytes, 208
Solubility of CO2, 195
Solvation effect, 94
Source-drain current, 426
Sp metals, 198
Space charge region, 25
Special pair (SP), 370, 383, 445
Specific adsorption of the cations, 204
Spectrum splitting, 269
Spinel, 177
Spirilloxanthin, 381, 382
Spirulina, 474
Spray pyrolysis, 337
Spray pyrolysis MOD method, 338
Sputtering technique, 334
Standard condition, 9
Standard electrode potential, 12, 13, 48
Standard formation enthalpy, 9
Standard formation entropy, 9
Standard formation Gibbs energy, 9
Standard hydrogen electrode (SHE), 13, 24, 192
Standard reaction Gibbs energy, 12
State, 8
State functions, 8
Statistical mechanics, 8
Strontium-doped lanthanum manganite, 120
Structural changes, 15
Sulfides and nitrides, 313
Sulfur, 108

Sulfur bacteria, 370
Sulfur compounds, 370
Summary, 314
Sunlight, 154
Supramolecular Metal Complex, 158
Surface chemical reactions, 302
Surface energetics, 275
Surface hopping, 73, 75
Surface orientation, 26
Surface states, 44
Surface treatments, 204
Synechococcus elongatus, 421
Synthetic organic photonics, 451
Systems, 305

T
Ta and Ti, 327
Tafel plot, 19
Tafel relationship, 200
Tandem PEC system, 253
TaON and Ta3N5 thin films, 324, 325
TaON particulated photoelectrodes, 323
Techno-economic, 262
Temperature difference, 222
Thermal catalysis, 225
Thermally converted, 332
Thermochemical conversion processes, 140
Thermochemical H2O splitting, 130
Thermochemical water splitting (WS), 137
Thermodynamic equilibrium, 39
Thermodynamically, 301
Thermodynamics, 7
Thermostability, 384
Three-dimensional nanoporous network, 332
Three phase electrodes, 209
Three steps, 302
Thylakoid membranes, 405
Total electrochemical potential, 24
Transformation of bridges, 326
Transition metal oxides, 312
Transition rate, 81
Transition state theory (TST), 57
Triad, 419
Triethanolamine (TEOA), 155
Triethylamine, 219
Triglycerides, 473
Trimethylamine, 197
Tungsten trioxide, 266
Turn over frequency (TOF), 57
Turnover number, 157
Two–level system, 80
Two-step photoexcitation, 291
Index

U
Ubiquinone (UQ), 375, 381, 383
Ubiquinone exchange, 385
Ubiquinone transport, 385, 387
Uniform porous layer, 333
UQ-1, 449
UQ-10, 449
Urea, 224
Utilization, 312
UV light, 308

V
Vacuum level, 24
Valence band, 27, 36, 282
Valence band maximum, 275
Vanadium, 110
Vanadium oxide, 110
Vegetable oil, 467
Verpotentia, 252
Violarite, 219
Viologen, 433
Visible light, 166
Visible-light-responsive, 300

Visible utilization, 308
Volmer step, 95
Voltage follower circuit, 426
Volume, 8

W
Water oxidation, 162
Water splitting, 165, 175, 229, 339
Water-splitting reaction, 427
WO3, 330
WO3 film, 330, 334
WO3 photoanodes, 324
Work, 7
Work function, 22, 24, 29
Working principle, 320

Y
Yttria-stabilized zirconia, 120

Z
Z-scheme mechanism, 291