

## Author Index

Adam, W., 228,281,283,322,323,356,493  
Allen, R.C., 497,498  
Anderson, J.M., 387  
Baldwin, T.O., 369,496  
Bard, A.J., 193,208  
Berenito, R.R., 498  
Biggley, W.H., 494  
Brabham, D.E., 489  
Broida, H.P., 101  
Brundrett, R.B., 231  
Carrington, T., 7,27,28,99  
Chandross, E.A., 143  
Cline, T.W., 369,496  
Clyne, M.A., 481  
Cormier, M.J., 1,344,361,378,380,387  
Coxon, J.A., 481  
Davidson, J.A., 111  
DeLuca, M., 285,335,345,356,357,358,359  
Dempsey, M.E., 345  
Derwent, R.G., 483  
Duthler, C.J., 101,109,110  
Eberhard, A., 369  
Eley, M., 377,378  
Fontijn, A., 393,425,426  
Fritsch, J.M., 249  
Fuhr, H., 498  
Golde, M.F., 73,485  
Golomb, D., 393  
Goto, T., 325,335,492  
Gundermann, K.-D., 209,228,229,244  
Hastings, J.W., 310,311,344,369,377,378,380,386,496  
Heller, C.A., 249,263,281,282,459  
Henry, R.A., 249  
Hercules, D.M., 1,229,243,247,263,427,459  
Herschbach, D.R., 29  
Hodgeson, J.A., 393  
Honda, K., 479  
Hopkins, T., 311,312,356,357  
Hori, K., 361  
Howes, R.M., 497  
Hoytink, G.J., 129,147  
Hsu, C.J., 486  
Hysert, D., 313  
Ienaga, K., 492  
Isobe, M., 492  
Jaeschke, W., 131

Johnson, F.H., 337  
Kasha, M., 489  
Kaufman, F., 27,28,83,99,109  
Kaufman, M., 130  
Kearns, D.R., 128,129,141,449  
Keszthelyi, C.P., 193  
Kihara, T., 479  
Kishi, Y., 325  
Kubota, I., 325  
Lee, D.C.-S., 265  
Lee, E.K.C., 110  
Lee, J., 1,129,141,228,245,247,248,281,309,310,356,381,386,449  
Lin, M.C., 59,61,71,487  
Liu, J.C., 493  
Matheson, I.B.C., 245  
McCapra, F., 283,313,322,323,358,460  
McElroy, W.D., 243,285,309,310,311,312,322,344,380,460  
Morrow, W., 487  
Murphy, C.E., 381  
Nealson, K.H., 369  
Nicoli, M.Z., 369,496  
Obenhaus, R.H., 486  
Ogryzlo, E., 100, 111,127,128,129,130  
Palmer, H.B., 486  
Rauhut, M., 244,282,356,451,459,460  
Reynolds, G., 460,478  
Richards, R.R., 488  
Rogowski, R.S., 488  
Roth, M., 313  
Sander, U., 131  
Schaap, A.P., 263  
Seitz, W.R., 427,449  
Seliger, H.H., 242,243,323,335,377,461,478,495  
Shimomura, O., 337,344  
Shoaf, A.R., 497  
Shur, B., 495  
Simpson, G., 493  
Slawinska, D., 490  
Slawinski, J., 491  
Smith, I.W.M., 43,59  
Snead, J.L., 488  
Sollott, G.P., 488  
Stanley, P.E., 494  
Stauff, J., 131,141  
Stedman, D.H., 59,81,110,426  
Steele, R.H., 497,498

Steinmetzer, H.C., 493  
Stjernholm, R.L., 498  
Strecker, R.A., 488  
Suzuki, N., 325  
Tachikawa, H., 193  
Thorington, L., 426,459,460  
Thrush, B.A., 27,71,73,81,99,110,141,425,483,485  
Tokel, N.E., 193  
Totter, J., 312  
Townsend, L. W., 481  
Ward, W.W., 495  
Wayne, R.P., 81,108,127,128,129,425,426,481  
Weller, A., 169,181,208  
White, E., 228,231,242,243,244,247,248,310,323,344,358,359  
Wilson, T., 265,281,282  
Young, R.A., 27,28,487  
Zachariasse, K., 169,181,208  
Zaklika, K.A., 313

## SUBJECT INDEX

### A

- Acanthoptilum*,  
 bioluminescence of, 362,367
- 2-acetamido-5-phenylpyrazine,  
 329
- Acetylene, 415
- Acridans,  
 peroxides of, 315
- Actinometric measurements,  
 in ECL, 203
- Actinometry apparatus,  
 in ECL, 205
- Activation energy,  
 for reactions of CS+0, 51  
 in dioxetane decomposition,  
 272  
 in radiative recombination,  
 21  
 in radical ion recombination,  
 190
- Active center,  
 bacterial luciferase, 378
- Active site in firefly luciferase,  
 289,303
- Acylaminopyrazine, 328,329,333
- Adamantyliden dioxetane, 268
- Adiabatic reaction,  
 definition, 1
- Aequorea*, 362,367
- Aequorin, 342,343
- AF-350, 342,343,362,363,367
- Afterglow, 141,487  
 air, 83,395,406,413,416  
 oxygen, 399  
 nitrogen, 76,393  
 of active nitrogen, 73
- Airglow, 416
- Air pollution, 405,473
- Aldehyde,  
 binding of, 375  
 effect on bacterial bioluminescence, 370  
 effect of chainlength on  
 bacterial bioluminescence,  
 370,374,383
- Aldehyde,  
 oxidation of, 375
- Alkali atoms,  
 electronic excitation energy  
 of, 104
- Alkali reactions,  
 by collisional excitation, 30  
 by chemiluminescent atom  
 exchange, 31
- Amines,  
 quenching by, 123
- 6'-aminoluciferin,  
 effect on emission color in  
 firefly luminescence, 296
- 3-aminophthalate, 210,242,246  
 fluorescence of, 245
- Aminophthalate ion,  
 as light emitter in lumino1  
 reaction, 231
- Aminopyrazine, 333
- Ammonia, 407
- AMP,  
 effect on emission color in  
 firefly luminescence, 301
- Angular momentum, 14
- Annihilation,  
 cation-anion annihilation of  
 naphthalene, anthracene  
 and tetracene, 147  
 energy considerations in  
 cation-anion, 155
- Anthozoa*,  
 bioluminescence of, 391
- Anthracene,  
 cation-anion annihilation  
 rate constant, 160  
 2,3 dicarboxylic acid, 215,  
 218  
 2,3 dicarboxylic hydrazide,  
 214,217  
 2,3 dicarboxylic hydrazide,  
 relative quantum yield of,  
 220
- Applications,  
 of luminescence, 468
- Arginine, 365

Arsenic, 445  
 Argon, 11  
 Ascorbic acid, 497  
 Atomic oxygen, 481,482,483,486,  
 487  
 ATP, 494  
 $\epsilon$ -ATP,  
   effect on emission color in  
   firefly luminescence, 297  
 ATP,  
   detection of, 468  
 ATP binding site,  
   in firefly luciferase, 300  
 Azodicarboxylates,  
   chemiluminescence of, 224

## B

Bacterial bioluminescence, 369,  
 341,494,495  
 Bacterial contamination,  
   determination of, 469  
 Bacterial luciferase,  
   as mixed function oxidase,  
   370  
 Barium, 486  
 Barium oxide, 486  
 Benzo(b)-phthalazine dione, 212  
 Bicyclic dioxetanes, 266  
 Bicyclic peroxide,  
   in the chemiluminescence of  
   hydrazides, 237  
 Biisoquinolinium salts,  
   autooxidation of, 250  
 Binding site,  
   FMNH<sub>2</sub>, 372  
   of firefly luciferase, 304  
   of firefly luciferase for  
   luciferin, ATP and MgATP,  
   297  
   of firefly luciferase for  
   dehydrolyciferin adenylate,  
   298  
   of firefly luciferase for  
   dehydrolyciferin, 298  
 Bioluminescence,  
   mechanisms, 5  
   oxygen labelling of *Renilla*,  
   *Cypridina*, 6

Biomass,  
   determination of, 470  
 Biosynthesis of luciferins,  
   model studies, 318  
 Blue fluorescent protein, 342  
 Born-Oppenheimer approximation,  
   for diatomic system, 8  
 Boron, 411  
 Bromine, 431,484  
 Bromine fluoride, 481  
 Bromoform, 486

## C

Calcium ion,  
   specificity of in *Aequorea*  
   luminescence, 472  
 Calcium requirement,  
   in bioluminescence, 388  
 Calculation,  
   statistical mechanical, 78  
 Cameron bands, 487  
*Campanularia*, 362  
 Carbon dioxide, 338,339,341,399,  
 403,487  
 Carbon dioxide production,  
   oxidative mechanism of during  
   sea pansy luminescence,  
   353  
 Carbon dioxide,  
   oxygen-18 incorporation in  
   *Cypridina* luminescence,  
   349  
   oxygen-18 incorporation in  
   firefly luminescence, 349  
   oxygen-18 incorporation sea  
   pansy luminescence,  
   349  
   production of during firefly  
   luminescence, 290  
   source of oxygen in during  
   bioluminescence, 351  
   source of oxygen in during  
   chemiluminescence, 352  
 Carbon disulfide, 416  
 Carbon monoxide, 398,402,411,  
 418,486,487  
 Carbon monoxide,  
   spectra, 118

- Catalysis,  
  of luminol chemiluminescence, 427
- Catalytic sites,  
  of firefly luciferase, 304
- Cavernularia*, 362,367
- Cetyltrimethylammonium bromide, 318,331
- Charge transfer, 123
- Chemiluminescence,  
  concept of electronic states in, 2  
  role of ionic intermediates in, 3  
  role of symmetry in, 3  
  mechanisms in solution, 4
- Chemiluminescence-gas phase, 7  
  in three-atom systems, 17  
  orbital degeneracy-induced, 40  
  in terms of electron transfer, 40
- Chemiluminescence,  
  infrared, 43  
  low level, 474  
  of monoacylhydrazides, 235  
  of diazaquinones, 236  
  of luminol, 237  
  O+NO, 83
- Chemiluminescence rate,  
  effect of water on, 352
- Chemiluminescence yields,  
  of triplet-triplet annihilation, 171  
  in radical ion recombination reactions, 186,187  
  total of hetero-excimer emission, 172  
  in radical ion recombination, 172
- Chemiluminescence,  
  in the atmosphere, 412,416
- Chemiluminescence intensity,  
  corrections in ECL, 198
- Chlorophyll, 498
- Chromium (III),  
  catalyst of luminol CL, 427, 432  
  analysis for, 436,432
- Chromium (II), 431,439
- Cis-Diethoxydioxetane, 266,271
- Cis-Diethoxyethylene,  
  as catalysts of dioxetane decomposition, 271
- Clytia*, 362
- Cobalt (II),  
  in luminol reaction, 427,432, 436,442
- Coefficients,  
  spontaneous emission, 47
- Coelenterate, 361,362,367
- Complexation,  
  effect of on luminol CL, 430, 436
- Control mechanisms,  
  in bioluminescence, 391
- Copper (II),  
  in luminol reaction, 427,433, 435,442
- Coronene, 178
- Cross section,  
  energy dependence at threshold for collision excitation, 36,37
- Ctenophore, 495
- Cyalume,  
  chemical light curve, 457
- 2-cyano-6-chlorobenzothiazole,  
  inactivation of firefly luciferase by, 305
- Cyclic dioxetanones, 315
- Cyclobutane,  
  dissociation of, 23
- Cyclopentadiene, 211
- Cypridina* luciferin, 328,337, 339,340,341,343,363,365
- Cypridina* oxyluciferin, 328,329, 337,338,339,343
- D
- Dark current, 467
- Deactivations,  
  dual, 67
- 1,4-dehydro-S-amino-phthalazine-1,4-dione, 209
- Dehydroluciferin,  
  binding of to luciferase, 287  
  firefly, 286

- DehydroLuciferyl adenylate,  
formation of, 290
- Diazabicyclooctane,  
as catalysts in dioxetane  
decomposition, 271
- Diazoquinones, 209,210
- 9,10-dibromoanthracene,  
as fluorescor, 271
- Dicarboxylperoxide, 138,139
- Diethylamine, 217,218,271
- 4-diethylamino phthalic hydrazide,  
213
- 1,4-dihydro(2,3g)naphtho-phthal-  
azine-1,4-dione,  
chemiluminescence of, 214,  
222
- 8,9-dihydropyrazino[1,2-a:3,4a']  
[1,1']-biisoquinolinium  
dibromide monohydrate,  
250,252,255,256,261
- 5,5 dimethyl oxyluciferin, 325
- Dimethyl phthalate, 217
- Dinoflagellates, 495
- Dioxetane, 6,22,23,237,249,258,  
263,265-278,492,493
- Dioxetanedione, 138
- Dioxyluciferin, 325
- Diphenylanthracene(DPA),  
138,193,226,235,479,493
- Diphyes, 362
- Diradicals, 269
- Doppler width, 105
- E
- Equilibrium dialysis,  
for determination of dehydro-  
luciferin binding sites in  
firefly luciferase, 299
- N-ethyl-maleimide,  
labeling of active sulfhydryls  
in firefly luciferase, 304
- Electrochemiluminescence, 5  
CL efficiency, 197,198,200,  
204
- Electrolysis, 132
- Electron exchange,  
singlet-triplet conversion  
via, 41
- Electron spin resonance, 490
- Electron transfer,  
in hydrazide chemiluminescence,  
234  
in chemiluminescence of  
monoacylhydrazides, 235  
in bacterial bioluminescence,  
385
- Electronic excitation, 119
- Electronic states,  
time dependence, 12  
adiabatic, 13  
diabatic, 13
- Emission,  
Vegard-Kaplan band, 74  
fully allowed, 78
- Emission spectrum,  
bacteria, 373
- Emitter,  
in firefly luminescence, 289
- Encounter complex,  
between solvated radical ions,  
170  
competing reactions of, 170  
spin relaxation time, 173
- Energy balance, 480
- Energy exchange,  
vibrational-vibrational, 47,  
49
- Energy gap, 123
- Energy pooling, 483
- Energy transfer, 481,482,483,  
485,489  
in bioluminescence, 387,391  
vibrational, 91  
from vibration in  $\text{NaN}_2$ , 36  
vibration-to-electronic in K,  
38  
energetics of, for K, Na, Br,  
39
- Endogenous rhythm,  
of spontaneous bioluminescence,  
475
- Enthalpy, 480  
redox processes in ECL, 194
- Ethylene, 399
- Etioluciferin, 337,338,339,343
- Excimers, 159
- Excitation,

vibrational, 54  
 Extraterrestrial life,  
 detection of, 471

## F

Fall-off,  
 ratios, 88  
 Firefly dehydroluciferin, 327,  
 328  
 Firefly luciferin analogues,  
 288  
 Firefly luminescence, 285,453,  
 493,494  
 Firefly oxyluciferin, 325,327  
 Flash apparatus,  
 vacuum U.V., 62  
 Flavin cation, 374,378  
 as bacterial emitter, 377,378,  
 382  
 Fluorescein,  
 iodide quenching of fluores-  
 cence, 246  
 Fluorescers, 136  
 Fluorescence,  
 of flavin, 373,381  
 of aminophthalate, 242  
 from  $K^*$ , 38  
 from collisionally excited  
 molecular states, 34  
 Flow system,  
 for BIQI++ luminescence, 257  
 FMN,  
 specificity of in bacterial  
 bioluminescence, 471  
 FMNH<sub>2</sub>,  
 non-enzymatic oxidation of,  
 369  
 reaction of with bacterial  
 luciferase, 382  
 Free energy, 173,174,461  
 Franck-Condon factor, 119,484

## G

Gas,  
 non-reactive, 48  
 Green fluorescent protein,  
 391

## H

Hammett reaction constants, 316  
 Hemin, 217,218,220  
 Hetero-excimer,  
 chemiluminescence yield of,  
 181  
 dissociation, 169,172  
 formation of, 169,181  
 free enthalpy of, 176,177  
 thermal dissociation, 190  
 Hexamethylphosphoramide(HMPA),  
 133  
 Homonuclear diatomics, 116  
 Hydrazide, 223,231  
 Hydrogen,  
 atomic, 398,401,403,417  
 molecular, 401,409,412  
 Hydrogen peroxide, 211,217,218  
 excitation energy, 131  
 in luminol reaction, 427  
 Hydroxylation,  
 mechanisms of in bacterial  
 bioluminescence, 385  
 Hydrophobicity,  
 of firefly luciferase, 300  
 Hydrozoa,  
 bioluminescence of, 388  
 Hypochlorite, 431,447

## I

Illumination,  
 emergency, 451  
 Infra-red,  
 chemiluminescence in, 1,45  
 Intensities,  
 total emission, 65  
 Interferometer,  
 Fourier, 90  
 Intermediate II,  
 bacteria, 374  
 Internuclear distance,  
 of the nitrogen molecule, 106  
 Intersystem crossing, 154  
 Intrinsic efficiency,  
 of phototubes, 463  
 Inverse predissociation, 77  
 Iodine, 483



- radical cation spectra, 252
  - EPR signal of  $I^{++}$ , 251
  - reaction with luminol, 431, 441, 443
  - in CL titrations, 445
  - Iodine fluoride, 481
  - Ion diffusion,
    - in ECL, 193
  - Ion exchange, 439, 441
  - Ion pairs,
    - collision formation of free, 34
    - cross sections for forming  $K_2SO_4$ , 35
    - state in energy transfer, 40
  - Iron (II),
    - as catalyst of luminol CL, 243, 428
    - analysis for, 427, 439
  - Iron-pentacarbonyl, 415
  - IsoATP,
    - effect on emission color in firefly luminescence, 296
- J
- Jellyfish,
    - bioluminescence of, 363
- K
- $\alpha$ -keto- $\beta$ -methyl-n-valeric acid, 337, 338, 339
  - $\alpha$ -ketoperoxide,
    - intermediate in sea pansy luminescence, 350
  - Kirkwood-Onsager continuum model,
    - equivalent sphere radius from, 177
- L
- Lasers,
    - chemical, 44, 49, 64, 486, 487
  - Latia*,
    - bioluminescence of, 341, 342
  - Lovenella*,
    - bioluminescence of, 362
  - Lead,
    - tetramethyl, 416
  - Levels,
    - high vibrational, 70, 79
  - Lifetimes,
    - synthetic dioxetanes, 266
    - $O_2(^1\Delta_g)$ , 124
  - Light capacity,
    - for CL systems, 452
  - Light emission,
    - factors affecting color of in firefly luminescence, 293
  - Light inhibition,
    - in bioluminescence, 495
  - Lighting,
    - chemical systems, 451, 456, 458
  - Lightstick, 456
  - Limit,
    - predissociation, 77
  - Linear peroxide,
    - in firefly luminescence, 293
  - Lipids, 497
  - Liquid scintillation counter, 494
  - Lithium phosphide, 488
  - Local symmetry,
    - effect of in  $NO + O_3$ , 27
  - Lophine dimer, 333
  - Luciferase, 391, 493, 494, 495, 496
  - Luciferase structure,
    - effect on emission color in firefly luminescence, 294
  - Luciferin, 493, 495
    - binding sites on luciferase, 305
    - dimer, 331
    - firefly, 286
    - quantum yield and CL, 470
  - Luciferin sulfokinase, 362
  - Luciferyl adenylate chemiluminescence,
    - oxygen-18 studies, 350
  - Luciferyl adenylate,
    - formation of, 290
  - Luciferyl sulfate, 362
  - Luminol,
    - chemiluminescence of 209, 225,

- 226,231,235,238,245,427-432,492  
 Lumino1 diazaquinone, 211,213  
 Lumino1,  
   light capacity, 453  
 Lumisome,  
   cellular site of bioluminescence, 387  
   composition of, 391  
   emission kinetics, 389  
   emission spectra, 389  
 Lyman-Birge-Hopfield bands, 485
- M
- M-dependence, 89  
 M-effect,  
   the ratio of, 85  
   finding of, 87  
 Magnetic field effects,  
   in ECL, 194  
 Malate, 494  
   determination of, 472  
 Manganese (II), 429  
 Maxwell-Boltzmann Distribution,  
   the excited state population,  
   105  
 P-mercuribenzoate,  
   reaction with sulfhydryls in  
   firefly luciferase, 302  
 Mercury,  
   lowest triplet level, 107  
 Metal vapor,  
   light emission from, 101  
 Methoxide ion, 254  
 Methods,  
   low-pressure, 61  
   in IRCL, 44  
 N-methylacridone,  
   rate of formation of, 317  
 Methyl glyoxal, 363  
 5-methyl oxyluciferin, 325  
 2-methyl-5-phenylimidazo[1,2-a]-  
 pyrazin-3-one, 329  
 Methylene blue, 489  
 Methyne, 486  
 Micelles,  
   chemiluminescence in, 317  
 Microsomal chemiluminescence, 497
- Microwave discharge, 102  
 Migration,  
   H atom, 67  
*Mnemiopsis*,  
   bioluminescence of, 362  
 Model compounds,  
   in the study of bioluminescence, 313  
 Model,  
   vertical transition, 78  
 Modified oxidative mechanism,  
   in firefly luminescence, 292  
 Molecular beams,  
   fast alkali, 31  
   crossed Na and N<sub>2</sub>, 34  
   "seeded-jet" technique, 36
- N
- Naphthalene-2,3-dicarboxylic  
 hydrazide, 212  
 Nickel (II), 428,433,435,439,  
 442  
 Nitrogen,  
   afterglow, 107,485,487  
   electronically excited, 74  
   atomic, 398,403  
   molecular, 398,404,406,412  
   radiative recombination, 12,  
   15  
   theoretical description, 12  
 Non-exponential decay,  
   fluorescence of complex NO<sub>2</sub>,  
   94  
 Non-radiative processes, 111  
 Non-resonant transfer,  
   from a thermalized distribu-  
   tion, 105  
 Nitrogen dioxide (NO<sub>2</sub>), 90,395,  
 400,402,404,407,413,416  
   fluorescence spectrum, 93  
   electronic quenching, 85  
   photodissociation of, 94  
   pressure dependence of, 84  
   quantum calculations, 93  
   radiative lifetime of, 87  
   state correlation diagram for,  
   19,27  
 Nitrogen oxide (NO), 395,402,

- 407,412,416,486,487  
 spectra, 118  
 radiative recombination with  
 O,18
- O
- Obelia*,  
 bioluminescence of, 362,367
- Orbital symmetry,  
 in O+NO+M reaction, 21
- Orbiting resonances,  
 in radiative recombination,  
 11
- Overlap, 119
- Overton bands, 56
- Oxaloacetate,  
 determination of, 472,494
- Oxalic acid,  
 oxidation, 140
- Oxidative mechanism,  
 in firefly luminescence, 291
- Oxygen,  
 atomic, 395,408,411  
 molecular, 395,401,406,411,  
 415  
 in chemiluminescence, 265  
 in luminol CL, 430,441  
 radical anion, 223  
 requirement for in lumisome  
 bioluminescence, 389
- Oxygen-18, 337,338,339,367  
 in firefly luminescence, 292  
 methodology, in luminescence,  
 345,346,347,348  
 use of in mechanism studies  
 in chemi- and biolumines-  
 cence, 345
- Oxyluciferin,  
 firefly, 289
- Oxyluminesce, olefin, 249
- Ozone, 396,405,411,417,481,482
- P
- Parazoanthus*,  
 bioluminescence of, 362,367
- Pentacene, 178
- Pelagia*,  
 bioluminescence of, 362
- Perhydroxyl-radicals, 131  
 reaction with luminol, 430  
 434,447
- Peroxalic acid, 137
- Peroxy carbonates, 238
- Peroxydisulfate, 211
- Peroxlactones, 268,493
- $\alpha$ -peroxylactone intermediate,  
 in firefly luminescence, 354
- Phenylalanine, 365
- Phialidium*,  
 bioluminescence of, 362
- Phosphorus, 402,411
- Phosphides, 488
- Photochemiluminescence, 481,  
 488,490,492
- Photo-decomposition, 270
- Photodissociation,  
 of H<sub>2</sub>O, 19
- Photo-oxidation, 488
- Photinus pyralis*,  
 bioluminescence of, 285
- Photoprotein, 342,362,387,391,  
 495
- Photopic factor, 453
- Phthalic hydrazide, 210,232
- Phthaloyl peroxide,  
 sensitized chemiluminescence  
 of, 225
- pK<sub>a</sub>,  
 firefly luciferin, 287
- Polar solvent,  
 quenching in, 124
- Poly(ethylene 2,6 naphthalene-  
 dicarboxylate), 488
- Poisson distribution, 465,466
- Potassium iodide, 246
- Potassium iodide quenching, 245
- Preannihilation, 479
- Predissociation, 13,14,79,485
- Probabilities,  
 exchange, 54  
 transition, 55
- Process,  
 allowed, 129
- Processes,  
 spin forbidden, 77
- Product analysis, 69

- Ptilosarcus*,  
 bioluminescence of, 362,367  
 Pumping,  
 treanor type, 70  
 Purification,  
 of lumisomes, 390  
 Pyrazine nucleus, 255,365  
 Pyrophosphate, 494
- Q
- Quantum efficiency, 233  
 Quantum yields,  
 of aldehyde and FMNH<sub>2</sub> in  
 bacterial bioluminescence,  
 381,383  
 in hydrazide luminescence, 233  
 in BIQI<sup>++</sup> luminescence, 257,  
 259  
 in firefly luminescence, 453  
 of fluorescence, 462  
 in luminol luminescence, 232  
 Quenching,  
 in ECL, 194  
 hydrogen, 116  
 in laser emissions, 65  
 in IR chemiluminescence, 52  
 mechanism of, 121  
 physical, 112  
 by SO<sub>2</sub>, 66  
 Quinones, 490,491
- R
- Radiation,  
 magnetic and electrical  
 dipole, 78  
 Radiative recombination,  
 of atoms, 8  
 on a single potential curve,  
 8-11  
 probability of radiation, 9  
 emission rate coefficient, 9  
 classical approach, 9  
 in He, 10  
 in Ar+O, 11  
 in C+H, 11  
 via curve crossing, 11-15  
 in N+O, 12  
 phenomenological description,  
 14  
 as resonance scattering  
 process, 14  
 in N, 15  
 in triatomic systems, 16-20  
 in H+NO, 17  
 in O+NO, 18  
 in five-atom systems, 20  
 in O+NO+M, 20  
 Radicals,  
 carbonate, 139  
 Radical ions, 143  
 electrochemically generated,  
 193  
 recombination of, 96,144,179,  
 184,185  
 temperature dependence of CL,  
 189  
 Raschig rings, 134  
 Rates,  
 in population of vibrational  
 levels, 44  
 of BIQI<sup>++</sup> luminescence decay  
 258  
 in formation of CO, 46  
 in vibrational deactivation,  
 44  
 Rate coefficient, 52  
 Rate constants,  
 quenching of, 112  
 Reactors,  
 fast-flow, 395,396  
 Reactions,  
 photodissociation, 63  
 Recombination processes,  
 two body and three body, 74,  
 80,135  
 Red light emitter,  
 structure of in firefly  
 luminescence, 293  
 Reflectivity,  
 from ECL electrodes, 203  
 Relaxation,  
 of HCl and HF, 54  
 radiative, 47  
 rotational and vibrational  
 rates, 78  
 vibrational, 52,67

*Renilla*,  
 bioluminescence of, 341,361,  
 362,367  
 auto-oxidized luciferin, 362,  
 363  
*Renilla*-like luciferase, 367  
 luciferin, 367  
*Renilla* luciferin, 361,362,363,  
 364,365,366  
*Renilla* oxyluciferin, 367  
*Renilla reniformis*,  
 bioluminescence of, 361,387  
 Rhodamine-B, 406  
 Rotating ring-disk electrode,  
 ECL, 194  
 Rubrene, 178,225

S

S-route,  
 ECL, 194  
 Salcomine, 329  
 Schumann-Runge bands, 403,404  
 Scattering,  
 resonance, 79  
 Scotopic, 470  
 Sea pansy,  
 bioluminescence of, 361,493  
 Second-order rate constant,  
 for O+NO reaction, 96  
 Selection rules,  
 harmonic oscillator, 52  
 Semiquinone, 491  
 Shock tube, 400  
 Singlet oxygen, 265,481,482,483,  
 489,491,497,498  
 Solvent,  
 absorption, 124  
 aprotic, 132  
 quenching, 123  
 Spin change, 127  
 Spin-forbidden, 129  
 Stoichiometry,  
 in bacterial bioluminescence,  
 382  
 State distributions,  
 importance of, 44  
 States,  
 excited electronic, 74  
 Steady state, analysis, 46

analysis, 46  
 Stern-Volmer,  
 quenching, 493  
 relationship, 48  
 model, 91  
*Stylatula*, bioluminescence of,  
 362,367  
 Subunits,  
 bacterial luciferase, 370  
 firefly luciferase, 301  
 Sucrose gradient densities,  
 of lumisomes, 390  
 Sulfhydryl groups,  
 role of in firefly luciferase,  
 302  
 Sulfur, 403,409  
 Sulfur dioxide, 396,405,409,416,  
 447,486  
 Sulfur oxide, 396,416  
 Superoxide anion, 132,265  
 Superoxide dismutase, 497,498  
 Systems,  
 discharge flow, 74

T

Tetracene,  
 cation-anion annihilation  
 rate constants, 160  
 Tetramethoxy BIQ,  
 preparation of, 255  
 Tetramethyl-p-phenylenediamine  
 (TMPD),  
 in radical ion recombination,  
 183,184,185,186  
 Temperature dependence, 89  
 Temperature,  
 pH and metal ions, effect on  
 emission color in firefly  
 luminescence, 295  
 rotational-translational, 66  
 Thioglycolate, 325  
 Thiol groups,  
 modification of on bacterial  
 luciferase, 372  
 Threshold energy, 67  
 TMAE, 259  
 TPCK,  
 inhibitory effect on firefly  
 luciferase, 302

Trans-azodicarboxylates,  
chemiluminescence of, 225  
Transitions,  
collision induced, 52,80,118  
in  $O_2$ , 127  
triplet-singlet, 139  
Transition state energy,  
effect of substituents on,  
234  
Transvibronic reactions,  
in molecular beams, 29  
of alkali atoms, 30  
Triplet acetone,  
involvement in dioxetane  
decomposition, 270  
Triplet-singlet energy transfer,  
232  
Triplet-triplet annihilation,  
161,169,175,194,480  
Triethylamine,  
as catalyst of dioxetane  
decomposition, 271  
Tris(p-dimethylaminophenyl)amine  
(TPDA),  
in radical ion recombination  
systems, 183,184,185,187  
Trimethyl aluminum, 414  
2,6,8-triphenylimidazo[1,2-a]-  
pyrazin-3-one, 333  
Tri-p-tolylaminium perchlorate,  
yield and energies of some  
radical ion recombination  
reactions with, 178  
Trace element analysis, 427  
Trace elements, 473  
Triplet state emission, 489  
Tryptophan, 365  
Tyrosine, 365

## U

Unpaired electron, 119

## V

Vanadium, 428,431,439,447  
V.E.R.,  
modes of transformation, 92  
Vesicular nature,

of lumisomes, 391  
Vibraluminescence, 90  
Vibrational excitation, 45,119  
Vibrational frequency, 116  
Vibronic states,  
in triatomic system, 16  
density of in five-atom  
system, 20

## W

Water,  
as reactant in bioluminescence  
and chemiluminescence, 349,  
350  
effect on reaction rate in  
chemiluminescence, 352,353

## Y

Yellow-green emitter,  
structure of in firefly  
luminescence, 294

## Z

Zero point energy,  
of  $NO_2$ , 95