

Index

a

- absorption processes 33–51
 - Beer–Lambert law 39–42, 51
 - carbon nanostructures 95
 - chemical sensing 463, 474
 - electronic transitions 33–39, 56
 - environmental effects 113
 - fluorescence microscopy 332, 333
 - fluorescence polarization 181–183, 191–198
 - Franck–Condon principle 47–49
 - harmonic generation 49–51
 - human eyes 484–487
 - hydrogen bonding 119–122
 - metal compounds, complexes and clusters 96, 97, 100
 - multiphoton absorption 49–51
 - oscillator strength 42–45
 - pH dependence 174–177
 - quantum dots 38, 39, 103–105
 - selection rules 46, 47
 - steady-state spectrofluorometry 272–274
 - transition probabilities 39–47
- N*-acetyl-L-tryptophanamide (NATA) 547
- acid–basic properties of water 175–177
- acridines 80, 522
- acridine orange 522
- ACRYLODAN 381
- actinide complexes 98
- active optical sensors 460
- additivity law of anisotropy 188–190
- adenosine triphosphate (ATP) 441, 443, 488–490
- advanced glycation end (AGE) products 483
- aerodynamics applications 401–404
- AFM, *see* atomic force microscopy
- AGE, *see* advanced glycation end

- alcohols 78
- aldehydes 78, 79
- 7-alkoxycoumarins 123, 124
- amines 78
- amino acids 461, 481–488, 524–525
- 4-amino-7-methylcoumarin 126
- 4-aminophthalimide 113, 114, 121
- amplitude-averaged decay times 291
- angular distribution of emission transition moments 190, 191
- 2-anilinonaphthalene 120, 121
- 1-anilino-8-naphthalene sulfonate (1,8-ANS) 524
- anion sensors 437–445
- anisotropic rotation 200, 203–206
- 1,8-ANS, *see* 1-anilino-8-naphthalene sulfonate
- anthracenes 167, 168, 273, 524
- anthroyl phosphatidylcholine 122
- antibunching 350, 352–355, 368
- APD, *see* avalanche photodiodes
- argyrimidine 486
- aromatic hydrocarbons
 - absorption processes 43–45
 - fluorescence emission 55, 75–80, 136
 - structure and characteristics 524–526
- art conservation applications 515–518
- artificial membranes 396, 397
- arylmethane dyes 528
- astrophysics applications 461
- asymmetric rotors and ellipsoids 204, 205
- atomic force microscopy (AFM) 329
- ATP, *see* adenosine triphosphate
- auramine O 91, 528
- autocorrelation functions 208, 209, 350–355, 358, 359

- autofluorescence 480–490, 501
 – absorption and fluorescence in human eyes 484–487
 – amino acids 481–488
 – characteristics and classification 480, 481
 – chlorophylls 490
 – coenzymes 488–490
 – detection 479
 – fluorescence microscopy 333, 334
 – food sciences applications 511–513
 – steady-state spectrofluoroscopy 265, 274, 275
 avalanche photodiodes (APD) 330, 336
 average decay times 291
 azarenes 80
 azulene 369, 370
- b**
- banana ripening 513
 band broadening effects 49, 109, 110
 barium borate (BBO) 296
 barium tetracyanoplatinate 96
 base protonation in excited states 178
 BBD (oxazole ligand) 538
 BBO (oxazole ligand) 538
BBO, see barium borate
 beam aperture 279
 Becquerel, Edmond 8, 10, 11, 13, 17
 Becquerel function 309–312
 beer 513
 Beer–Lambert law 39–42, 51, 69
 benz[a]anthracene 136
 9,9'-bianthryl 90
 bifluorophoric compounds 390–392
 biodeterogens 462
 biological membranes 248, 249, 396, 397
 bioluminescence 483, 487, 488
 biomedical applications, *see* life sciences applications
 biosensors 410
 bipyridyl ligands 98–101, 155
 bis-viologens 451
 blinking phenomena 368, 371, 372
 blood 428, 513
n-BMA, *see* *n*-butyl methacrylate
 BODIPY fluorophores 86, 87, 494, 495, 529–530
 body fluids 513, 514
 Boltzmann law 55
 Born–Haber cycle 159
 boronic acid-based sensors 449, 451
 Brewster, Sir David 7, 14, 15
 broadening effects 49, 109, 110
- Brownian rotation 200, 201, 208
 bunching 350
n-butyl methacrylate (*n*-BMA) 388
- c**
- calibrated tungsten lamps 269
 calixarenes 422, 423, 432, 436
 carbazoles 81
 carbon dioxide sensors 456
 carbon dots 93–96, 501
 carbon nanostructures 38, 93–96
 carbon nanotubes (CNT) 93–96
 carboxylate sensors 443, 444
 carboxylic acids 79
 cation sensors 426, 428–436
 chelating ligands 98–101
 chemical kinetic studies 356–359
 chemical sensing 409–478
 – anion sensors 436–445
 – applications 428, 429, 454–456, 461, 462
 – approaches of fluorescence sensing 410, 411
 – classification of pH indicators 413
 – collisional quenching approach 411, 437, 438, 453–455
 – continuous variations method 472–474
 – cooperativity 471
 – derivatization approach 411
 – design principles 420–427
 – displacement approach 410, 411, 444–445
 – dual-wavelength measurements 463–465, 469, 470
 – excimers 427, 430, 434, 449
 – Förster resonance energy transfer 427, 430, 432
 – gasses 453–458
 – ion and molecule recognition 420–458
 – ionic strength 414
 – main fluorescent pH indicators 417–420
 – metal ions 427–436, 465–473
 – neutral molecules 445–453
 – pH indicators 412–420, 462–465
 – photoinduced charge transfer 424, 425, 429, 433, 436
 – photoinduced electron transfer 413, 420, 424, 425, 429–431, 436, 449–453
 – photoinduced photon transfer 413
 – photophysical signal transduction 424–426
 – principles and techniques 409–410, 412–417
 – ratiometric measurements 417
 – recognition units and signaling units 420–424
 – remote sensing by LIDAR 460, 461

- reversible binding approach 410–412, 437–445
 - reversible reaction approach 410–412
 - sensing devices 458–460
 - single-wavelength measurements 462, 467–469
 - spectrophotometric and spectrofluorometric titrations 462–473
 - stoichiometry and stability constants 465–473
 - topologies 422, 423
 - chi-square methods 306, 307
 - chlorophylls
 - autofluorescence 490
 - excitation energy transfer 251, 252
 - fluorescence emission 96–98
 - food sciences applications 512, 513
 - chromoionophores 428
 - chromophore assemblies 250–252
 - circular polarization luminescence (CPL) 183
 - citrate sensors 446, 447
 - cobalt complexes 444, 445
 - coenzymes 488–490
 - Collins-Kimball's theory 149, 150
 - collisional quenching 411, 437, 456
 - colorimetry 428
 - compressed hyperbola 309–312
 - concentration depolarization 279
 - confocal fluorescence microscopy 327, 329–331, 363, 364, 367–370
 - confocal microspectrofluorimetry 517
 - conformational disorder 93
 - conjugated polymers (CP) 92, 93
 - conjugated systems 37, 38
 - conservation applications 515–518
 - continuous light sources 300–302
 - continuous variations method 471–473
 - cooperativity 471
 - copper complexes 444, 445
 - core-shell semiconductors 103–105
 - coronands 429
 - correction factors 268, 269
 - Coulombic interactions 217, 221–223, 242
 - coumarins
 - chemical sensing 418
 - fluorescence emission 81, 82, 123, 124, 126
 - structure and characteristics 531–533
 - counterfeit detection 514, 515, 517
 - coupling strength 223–233
 - CP, *see* conjugated polymers
 - CPL, *see* circular polarization luminescence
 - cresyl violet 536
 - critical care analysis 454, 455
 - cross-correlation FCS 360
 - crown ethers 428
 - cryptands
 - chemical sensing 428, 436, 443, 445, 446
 - fluorescence emission 101, 102
 - cryptocyanine 534
 - crystal violet 528
 - cultural heritage applications 515–518
 - Curie symmetry principle 184, 185, 277
 - cw lasers 300, 301
 - Cy3 (Cy3-18) 534
 - Cy5 (Cy5-18) 534
 - Cy7 (Cy7-18) 534
 - 9-cyanoanthracene 524
 - cyanines 85, 86, 534, 535
 - cyclodextrins
 - chemical sensing 421, 445–449
 - excitation energy transfer 253–255
- d**
- δ-pulse responses 287–290
 - dairy products 512
 - DANCA 381
 - dansyl chloride 494
 - DAPI 546
 - data analysis
 - global analysis 307
 - Kohlrausch function and Becquerel function 309–312
 - phase-modulation fluorimetry 306, 309
 - pulse fluorimetry 305, 306, 308
 - quality and fit 306, 307
 - time-resolved fluorescence spectroscopy 305–312
 - DCM, *see* 4-dicyanomethylene-2-methyl-6-(*p*-dimethylaminostyryl)-4H-pyran
 - DDI, *see* 1,1'-diethyl-2,2'-dicarbocyanine iodide
 - de-excitation pathways 20, 21
 - *see also* intermolecular photophysical processes
 - decay time measurements 10–12
 - deconvolution 290, 294, 322
 - delayed fluorescence 60, 399, 400
 - Dexter's formulation 233
 - DHFR, *see* dihydrofolate reductase
 - dibenzofurans 81
 - dibenzothiophenes 81
 - dichlorofluorescein disodium 542
 - 4-dicyanomethylene-2-methyl-6-(*p*-dimethylaminostyryl)-4H-pyran (DCM) 546, 547
 - dielectric solute–solvent interactions 111

- 1,1'-diethyl-2,2'-dicarbocyanine iodide (DDI)
535
- diffusion-controlled reactions 145, 146,
149–151, 389
- diffusional processes 132, 243–246
- dihydrofolate reductase (DHFR) 496
- dimensionality 247–249
- 4-N,N-dimethylaminobenzonitrile (DMABN)
88–90, 383, 386, 387
- 2,4-dinitrotoluene (2,4-DNT) 456
- dioxygen, *see* oxygen molecule
- diphenylanthracene 273, 524
- diphenylhexatriene 203
- dipole–dipole interactions 16, 17
- direct fluorometric detection 409
- directed nonradiative energy transfer 252
- discriminators 292, 293
- distance-dependent rate constants 150, 151
- DL-PSP, *see* dual luminophore
- pressure-sensitive paints
- DMABN, *see*
4-N,N-dimethylaminobenzonitrile
- DNA sequencing 365, 366
- DNA structures 257
- 2,4-DNT, *see* 2,4-dinitrotoluene
- donor–acceptor interactions 216–218,
229–232, 235–242
- Doolittle equation 132–134, 391, 392
- double-beam spectrophotometers 41
- dual focus FCS 356
- dual luminophore pressure-sensitive paints
(DL-PSP) 404
- dual-color fluorescence cross-correlation
spectroscopy (FCCS) 360
- dynamic quenching
- fluorescence emission 144, 146–152,
154–159
 - probes 389
 - time-resolved fluorescence spectroscopy
299
 - *see also* collisional quenching
- e**
- edible oils 512, 513
- Einstein, Albert 11, 12
- Einstein coefficients 44, 45, 59
- electrochemical sensors 458
- electron-donating substituents 78
- electron-withdrawing substituents 78, 79
- electronic transitions 33–39
- fluorescence emission 53–60, 98–100
 - transition probabilities 39–47
- electronics applications 401
- electro-optic modulators 300–302
- ellipsoids 204, 205
- EMA, *see* ethyl methacrylate
- emission anisotropy 184–207
- additivity law of anisotropy 188–190
 - angular distribution of emission transition
moments 190, 191
 - excitation energy transfer 230–232
 - fundamental and limiting anisotropies
193, 194
 - instantaneous anisotropy 187–189, 203,
204
 - motionless molecules with random
orientation 191–199
 - multiphoton excitation 196–199
 - nonparallel absorption of emission
transition moments 192–196
 - parallel absorption of emission transition
moments 191, 192
 - polarization ratio 184–187
 - probes 385, 396, 397
 - rotational motion effects 199–207
 - single-molecule fluorescence spectroscopy
363
 - steady-state anisotropy 188, 189, 202,
203, 206
 - steady-state spectrofluorometry 277–282
 - time-resolved fluorescence spectroscopy
314–318
 - totally asymmetric rotors and ellipsoids
204, 205
- emission inner filter effects 272–274
- emission transition moments 190–196
- empirical scales of polarity 124–129
- multiparameter approach 126–128
 - polarity-induced changes 129
 - single-parameter approach 124–126
 - solvatochromic shifts 124–128
 - vibronic band intensities 129–131
- energy migration 210, 250–252
- ensemble averaging 367, 368
- enzymes 496
- eosin Y 541
- epifluorescence microscopy 328
- equilibrium constants 465–467
- erythrosin B 541
- ethidium bromide 496
- ethyl methacrylate (EMA) 388
- eupromium complexes 401
- excimers
- chemical sensing 427, 430, 432, 446, 449
 - fluorescence emission 144, 162–168
 - probes 385, 389–392
- exciplexes
- fluorescence emission 144, 162, 163, 167,
168
 - probes 399

excitation energy transfer 213–261
 – applications 252–257
 – classical description of energy transfer 214–216
 – Coulombic interactions 217, 221–223
 – coupling strength 223–233
 – definitions 213, 214
 – dimensionality 247–249
 – distinction between radiative and nonradiative 218, 219
 – donor–acceptor ensembles 243–250
 – donor–acceptor interactions 216–218, 229–232, 235–242
 – energy migration 250–252
 – heterotransfer 213, 219
 – homotransfer 213, 219
 – intermolecular orbital overlap 221–223
 – long-range dipole–dipole transfer 226–233
 – nonradiative energy transfer 214–219, 221–234
 – polarization of acceptor emission 230–232
 – quantum mechanics of donor–acceptor interactions 216–218
 – radiative energy transfer 214–221
 – red-edge effect 252–255
 – restricted geometries 250
 – selection rules 233, 234
 – single molecule studies 242
 – strong coupling 223–226
 – supramolecular distance determination 235–243
 – transfer rates 226
 – very weak coupling 223–233
 – viscosity effects 243–246
 – *see also* resonance energy transfer
 excitation inner filter effects 271, 272
 excitation spectra
 – chemical sensing 416, 420, 434
 – steady-state spectrofluorometry 268, 278, 279, 281, 282
 excitation transport, *see* energy migration
 excited-state lifetimes 61–64, 66, 67, 312–314
 exciton diffusion 38, 39
 explosives sensors 456, 457
 exponential distance dependence 150
 exponential series method 309

f
 FAD, *see* flavin adenine dinucleotide
 FAMC, *see* few-atom noble metal clusters
 FCCS, *see* fluorescence cross-correlation spectroscopy

FCS, *see* fluorescence correlation spectroscopy
 Fermi's golden rule 218
 few-atom noble metal clusters (FAMC) 103
 FIA, *see* fluoroimmunoassays
 fingerprints 513, 514
 FITC, *see* fluorescein isothiocyanate
 flash lamps 292
 flavin adenine dinucleotide (FAD) 488–490
 FLCS, *see* fluorescence lifetime correlation spectroscopy
 FLIM, *see* fluorescence lifetime imaging
 fluidity 384–398
 fluorescein isothiocyanate (FITC) 494
 fluorescins
 – chemical sensing 416, 420, 444–446, 455, 456
 – fluorescence correlation spectroscopy 359
 – fluorescence emission 84, 92
 – fluorescence labeling 494, 495
 – fluorescence polarization 193, 194
 – structure and characteristics 541, 542
 fluorescence
 – de-excitation pathways 20, 21, 141–159
 – decay time measurements 10–12
 – definitions 19
 – early applications 17–19
 – historical development 2–25
 – photoluminescence 19, 20
 – probes, indicators, labels and tracers 21–23
 – spatial and temporal resolution 23–25
 fluorescence correlation spectroscopy (FCS) 349–360
 – applications 356–358
 – autocorrelation functions 350–355, 358, 359
 – bunching and antibunching 350, 352–355
 – chemical kinetic studies 356–359
 – conceptual basis and instrumentation 349–355
 – cross-correlation methods 360
 – rotational diffusion coefficients 359
 – single-molecule fluorescence spectroscopy 364
 – temporal fluctuations in fluorescence intensity 350, 351
 – translational diffusion coefficients 355–359
 fluorescence cross-correlation spectroscopy (FCCS) 360

- fluorescence emission
 - acidic-basic properties of water 175–177
 - aromatic hydrocarbons 55, 75–80
 - band broadening effects 109, 110
 - base protonation in excited states 178, 179
 - Boltzmann law 55
 - carbon nanostructures 93–96
 - characteristics 53–74
 - chemical sensing 416, 420, 463–474
 - conjugated polymers 92, 93
 - correction factors 268, 269, 280
 - decay of fluorescence intensity 64
 - delayed fluorescence 60
 - determination of excited-state pK^* 172–174
 - diffusion-controlled reactions 145, 146, 149–151
 - dynamic quenching 144, 146–152, 154–159
 - electron-donating substituents 78
 - electron-withdrawing substituents 78, 79
 - electronic transitions 53–60, 98–100
 - emission spectra 67–71
 - empirical scales of solvent polarity 124–129
 - environmental effects 109–139
 - excimers 144, 162–167
 - exciplexes 144, 162, 163, 167
 - excitation spectra 67, 68, 71
 - excited-state lifetimes 61–64, 66, 67
 - extent of π -electron system 75–77
 - fluorescence labeling 492
 - gas phase 137
 - ground-state nonfluorescent complexes 153, 154
 - heterocyclic compounds 76, 77, 80–87
 - heterogeneously emitting systems 158, 159
 - human eyes 484–487
 - hydrogen bonding 119–122, 125, 126
 - intermolecular photophysical processes 141–179
 - internal conversion 56, 61
 - internal heavy atom effect 77
 - internal rotation 87–92, 132–135
 - intersystem crossing 57–62, 64–66, 96
 - lowest-lying transition 75–77
 - metal compounds, complexes and clusters 96–103
 - micellar aggregation numbers 154–157
 - nonradiative de-excitation 60
 - nonradiative energy transfer 144, 150, 151
 - organic compounds 55, 64, 65
 - organic molecules 75–93
 - pH dependence 174–178
 - phenomenological approaches 143–146
 - phosphorescence spectra 54, 60, 64–66
 - photoinduced charge transfer 112–114
 - photoinduced electron transfer 144, 159–162
 - photoinduced ICT 87–92
 - photoinduced proton transfer 168–179
 - polarity-induced changes 123, 124, 129
 - probes 400
 - quantum dots and quantum rods 103–105
 - quantum yields 64–66, 70–73, 143, 171
 - radiative deactivation 56, 57, 61, 62
 - red-edge effects 109, 110
 - solid matrices at low temperature 135–137
 - solvation dynamics 115, 116
 - solvatochromic shifts 111, 117–120, 124–128
 - solvent effects 110–129
 - solvent relaxation 112–116
 - sphere of effective quenching 152, 153, 157
 - spontaneous and simultaneous emissions 57, 58
 - static quenching 144, 152–159
 - steady-state fluorescence intensity 67, 68, 152, 166, 170
 - Stern–Volmer kinetics 146–148
 - Stokes shifts 57, 72–74
 - structural effects 75–107
 - substituted aromatic hydrocarbons 77–80
 - sulfonates 79, 80
 - temperature effects 66, 67, 135–137
 - time evolution of fluorescence intensity 113, 170
 - transient effects 148–152, 157, 158, 167
 - triplet–triplet transitions 61
 - vibronic band intensities 129
 - viscosity effects 129–135
 - wavelength and wavenumber scales 71, 72
 - *see also* emission anisotropy
- fluorescence labeling 21–23, 491–502
 - applications 497, 498, 500
 - detection 479, 480
 - fluorescent proteins 491–493
 - fluoroimmunoassays 498
 - organic molecules 493–497
 - quantum dots and nanoparticles 497–501
 - requirements and constraints 480

- fluorescence lifetime correlation spectroscopy (FLCS) 360
- fluorescence lifetime imaging (FLIM) 327, 340–345, 399, 489, 490
- fluorescence microscopy 327–348
 - applications 334, 342–345
 - autofluorescence 489, 490
 - biomedical applications 334
 - confocal 327, 329–331, 363, 364, 367–370
 - far-field techniques 327, 337–340
 - fluorescence lifetime imaging 327, 340–345, 399, 489, 490
 - fluorescence polarization 333
 - frequency-domain 327, 331, 333, 342
 - photoactivated localization microscopy 339
 - polar plots 344, 345
 - scanning near-field optical microscopy 327, 329, 333–337, 343, 366, 367
 - single-molecule fluorescence spectroscopy 363–370
 - stimulated emission depletion 327, 338, 339
 - stochastic optical reconstruction microscopy 327, 339
 - super-resolution techniques 327, 333–340, 343
 - time-domain 327, 331, 333, 341
 - two-photon excitation 327, 331–334, 343, 366
 - wide-field 327, 328, 329
- fluorescence microthermography 401
- fluorescence polarization 181–212
 - additivity law of anisotropy 188–190
 - angular distribution of emission transition moments 190, 191
 - applications 207–210
 - characterization of polarization state 184–187
 - emission anisotropy 184–207, 230–232, 277–282, 314–318, 385, 396, 397
 - energy migration 210
 - excitation energy transfer 230–232
 - fluorescence microscopy 333
 - fundamental and limiting anisotropies 193, 194
 - historical development 14, 15
 - homogeneous isotropic media 393–395
 - horizontally polarized excitation 186, 187, 277, 281
 - instantaneous anisotropy 187–189, 203, 204
 - lipid bilayers and liquid crystals 206–209
 - motionless molecules with random orientation 191–199
 - multiphoton excitation 196–199
 - natural light 181, 182, 187
 - nonparallel absorption of emission transition moments 192–196
 - ordered systems 395
 - parallel absorption of emission transition moments 191, 192
 - photoselection of absorbing molecules 181–183
 - polarization ratio 184–187
 - polarized light 181–183, 184–187
 - probes 385, 390, 393–398
 - rotational motion effects 199–207
 - steady-state anisotropy 188, 189, 202, 203, 206
 - steady-state fluorescence intensity 281, 282
 - steady-state spectrofluorometry 277–282
 - time-resolved fluorescence spectroscopy 314–318
 - totally asymmetric rotors and ellipsoids 204, 205
 - vertically polarized excitation 184–186, 277, 281
- fluorescence polarization immunoassays (FPIA) 210
- fluorescence quenching, *see* intermolecular photophysical processes
- fluorescence staining 479
- fluorescence standards 268–272
- fluorescence up-conversion
 - environmental effects 114, 116
 - excitation energy transfer 255
 - time-resolved fluorescence spectroscopy 285, 295–297
- fluorescent probes, *see* probes
- fluorescent proteins (FP) 491–493
- fluorescent whitening agents (FWA) 507, 508
- fluoroimmunoassays (FIA) 498
- fluorionophores 428
- fluorspar 8–10
- focused laser beams 361, 362
- food sciences applications 511–513
- forensics applications 513, 514
- formaldehyde 37
- Förster cycle 172, 173
- Förster radius 216, 226–233, 244
- Förster, Theodor 16

- Förster-type resonance energy transfer (FRET)
- applications 252–257
 - chemical sensing 427, 432, 436
 - dimensionality 247–249
 - donor-acceptor ensembles 243–250
 - donor-acceptor interactions 235–242
 - energy migration 250–252
 - excitation energy transfer 221, 231–233
 - fluorescence labeling 498, 501
 - fluorescence microscopy 343
 - historical development 16, 17
 - metal compounds, complexes and clusters 102
 - red-edge effect 252–255
 - restricted geometries 250
 - single-molecule fluorescence spectroscopy 369, 370
 - steady-state methods 236–238
 - supramolecular distance determination 235–243
 - three dimensional 243–246
 - time-resolved methods 238, 239, 240
 - viscosity effects 243–246
- Förster's theory for supramolecular distances 242, 243
- Fourier transforms 289, 290
- FP, *see* fluorescent proteins
- FPIA, *see* fluorescence polarization immunoassays
- fractal structures 249
- Franck–Condon principle
- absorption processes 46, 47–49
 - fluorescence emission 53–55, 112, 113
- free rotation 199–206
- free volume diffusion 132, 133
- frequency doubling/tripling 49–51
- frequency-domain fluorescence microscopy 327, 331, 333, 343
- FRET, *see* Förster-type resonance energy transfer
- friction coefficients 133
- fullerenes
- absorption processes 38
 - fluorescence emission 93–96
 - probes 399–401
 - structure and characteristics 527
- fundamental anisotropies 193, 194
- FWA, *see* fluorescent whitening agents
- g**
- gas phase fluorescence 137, 138
- Gaviola, Enrique 12
- GFP, *see* green fluorescent protein
- global analysis 307
- glucose sensors 450, 451
- glycopeptides 240–242
- green fluorescent protein (GFP) 483, 487, 488, 491
- ground-state nonfluorescent complexes 153, 154
- h**
- hairpin structures 257
- halide ion sensors 437
- harmonic generation 49–51
- harmonic responses 287–290
- Henderson–Hasselbalch equation 412, 463
- Herschel, John 7
- heterocyclic compounds 76, 77, 80–87
- heterogeneously emitting systems 158, 159
- heterotransfer 213, 219, 250
- highest occupied molecular orbitals (HOMO) 34, 36, 159, 425
- hindered rotation 199, 200, 206–209
- historic monuments 462
- historical development
- de-excitation pathways 20, 21
 - decay time measurements 10–12
 - early applications of fluorescence 17–19
 - early observations 3–10
 - fluorescence and phosphorescence 2–25
 - fluorescence polarization 14, 15
 - Perrin–Jablonski diagrams 12–14
 - photoluminescence 3, 19, 20
 - probes, indicators, labels and tracers 21–23
 - resonance energy transfer 16, 17
 - spatial and temporal resolution 23, 24
- HITCI 535
- HOMO, *see* highest occupied molecular orbitals
- homogeneous broadening 49, 109, 110
- homogeneous isotropic media 393–395
- homogeneous time-resolved fluorescence (HTRF) 498
- homotransfer 213, 219, 250, 251
- horizontally polarized excitation 186, 187, 277, 281
- HPTS 526
- HTRF, *see* homogeneous time-resolved fluorescence
- human eyes 484–487
- hydrogen bonding
- absorption processes 119–122
 - fluorescence emission 119–122, 126, 127
 - probes 379
- hydroquinones 154
- 3-hydroxykynurenone 486
- hydroxyquinoline-based sensors 432, 435

i

- ICT, *see* intramolecular charge transfer
- imidazolium-based sensors 443
- indicators 21–23
- indirect fluorometric detection 409
- indocyanine green 535
- indoles
 - fluorescence emission 81, 145
 - fluorescence polarization 195, 197, 198
- inhomogeneous broadening 49, 109, 110
- inner filter effects 271–274, 302–304
- inorganic compounds
 - luminescence 1
 - photoluminescence 19, 20
 - pigments 515, 516
 - *see also* metal ions; transition metal complexes
- instantaneous anisotropy 187, 188, 189, 203, 204
- intensity-averaged decay times 291
- intermolecular excimer formation 385, 389, 390
- intermolecular orbital overlap 221–223
- intermolecular photophysical processes
 - acido-basic properties of water 175–177
 - autofluorescence 481
 - base protonation in excited states 178, 179
 - Collins-Kimball's theory 149, 150
 - de-excitation processes and quenching 20, 21, 141–159
 - determination of excited-state pK^* 172–174
 - diffusion-controlled reactions 145, 146, 149–151
 - distance-dependent rate constants 150, 151
 - dynamic quenching 144, 146–152, 154–159
 - excimers 144, 162–167
 - exciplexes 144, 162, 167, 168
 - fluorescence emission 141–179
 - fluorescence labeling 491, 492
 - Förster cycle 172, 173
 - general equations for excited-state deprotonation 169–171
 - ground-state nonfluorescent complexes 153, 154
 - heterogeneously emitting systems 158, 159
 - micellar aggregation numbers 154–157
 - nonradiative energy transfer 144, 150, 151
 - pH dependence 174–178
 - phenomenological approaches 143–146

- photoinduced electron transfer 144, 159–162
- photoinduced proton transfer 168–178
- probes 385, 389, 390
- single-molecule fluorescence spectroscopy 367–372
- Smoluchowski's theory 148, 149
- sphere of effective quenching 152, 153, 157
- static quenching 144, 152–159
- steady-state measurements 173, 174
- Stern–Volmer kinetics 146–148
- time-resolved measurements 174
- transient effects 148–152, 157, 158, 167
- intermolecular quenching 385, 389, 390
- internal conversion 56, 61
- internal heavy atom effect 77
- internal rotation 87–92, 132–134
- International Union of Pure and Applied Chemistry (IUPAC) 42
- intersystem crossing
 - absorption processes 46
 - fluorescence correlation spectroscopy 350
 - fluorescence emission 57–60, 61, 63–66, 96
 - historical development 13, 20
- intramolecular charge transfer (ICT) 87–92, 119
- intramolecular excimer formation 385, 390–392
- intramolecular folding 194
- intrinsic fluorescence, *see* autofluorescence
- ionic sensors 420–445
 - anion sensors 436–445
 - design principles 420–427
 - metal ions 427–435
- ionic strength 414
- IR 140 535
- iron complexes 100
- isotropic rotation 200, 201–203
- IUPAC, *see* International Union of Pure and Applied Chemistry

j

- Jablonski, Aleksander 12–14
- Jablonski diagrams 12–14, 53, 54
- Job's method 471–473

k

- Kamlet–Taft scale 125, 126
- KDP, *see* potassium dihydrogen phosphate
- ketones 78, 79
- kiton red 544
- Kohlrausch function 309–312

I

- lab-on-chips 459, 461
- labels, *see* fluorescence labeling
- Langmuir–Blodgett films 248
- lanthanide complexes
 - absorption processes 38
 - fluorescence emission 98, 100, 101
 - fluorescence labeling 498
 - forensics applications 514
- LAURDAN 381, 383
- least-squares methods 306, 307
- LED, *see* light emitting diodes
- leukocytes 482, 483
- LIDAR, *see* light detection and ranging
- life sciences applications
 - chemical sensing 427–429, 453–455, 460, 461
 - excitation energy transfer 256
 - fluorescence correlation spectroscopy 356–358
 - fluorescence labeling 497, 498, 500
 - fluorescence microscopy 334
 - probes 389, 396, 397, 398–400
 - single-molecule fluorescence spectroscopy 364–366, 372
- lifetime-based decomposition of spectra 318, 321, 322
- lifetime standards 312–314
- light detection and ranging (LIDAR) 460, 462
- light emitting diodes (LED) 292
- light-matter interactions 3
- light scattering
 - fluorescence microscopy 333, 334
 - single-molecule fluorescence spectroscopy 361
 - time-resolved fluorescence spectroscopy 304, 305
- Lignum nephriticum* 6, 7
- limiting anisotropies 193, 194
- line broadening effects 49, 109, 110
- linearly polarized light 181, 182
- lipid bilayers
 - excitation energy transfer 248, 249
 - fluorescence correlation spectroscopy 356
 - fluorescence polarization 206–209
 - probes 396, 397
- lipid–protein interactions 396, 397
- Lippert–Mataga equation 118, 382
- liquid crystals 206–209
- long-range dipole–dipole transfer 226–233
- lowest unoccupied molecular orbitals (LUMO) 34, 36, 159, 425

luminescence

- definitions and types 1, 2
- thermodynamics 11, 12
- luminescent diamonds 339
- LUMO, *see* lowest unoccupied molecular orbitals

m

- macromolecules
 - absorption processes 38
 - chemical sensing 421, 423, 427, 428, 442
 - excitation energy transfer 253–255
 - fluorescence emission 93–96
 - probes 399–401
 - spatial and temporal resolution 24
- magnesium complexes 96, 97
- magnetic particle testing (MT) 510, 511
- malachite green 90, 91, 528
- marine monitoring 462
- markers, *see* fluorescence labeling
- materials sciences applications 255, 507–510
- matlanine 7
- matrix isolation spectroscopy 137
- maximum entropy method (MEM) 309
- MCA, *see* multichannel analyzers
- meat products 512
- medical applications, *see* life sciences applications
- MEM, *see* maximum entropy method
- metal ions
 - chemical sensing 427–436, 465–473
 - fluorescence emission 96–103
 - *see also* transition metal complexes
- methyl 8-(2-anthroyl)-octanoate 121, 122
- methyl methacrylate (MMA) 388
- N-methylcarbazole 546
- methylene blue 540
- micelles
 - aggregation numbers 154–157
 - fluorescence correlation spectroscopy 357, 358
 - intermolecular photophysical processes 175–177
- microfabricated systems 460, 461
- microspectrofluorimetry 517
- microviscosity 133, 209, 384–398
- mitosis 494
- MMA, *see* methyl methacrylate
- MO, *see* molecular orbital
- molar absorption coefficients 42, 43
- molecular mobility 384–398

molecular orbital (MO) theory
 – absorption processes 33–37
 – chemical sensing 424
 – fluorescence emission 159
 molecular rotors 385, 386–389
 molecular sensors 420–458
 – anion sensors 436–445
 – design principles 420–426
 – gasses 453–458
 – metal ions 427–435
 – neutral molecules 445–453
 molecular thermometers 397
 Monardes, Nicolas 6, 7
 monochromators 265–271, 277, 278, 293, 300, 301
 Monte Carlo simulations 221
 MT, *see* magnetic particle testing
 multichannel analyzers (MCA) 293, 294, 336
 multichromophoric cyclodextrins 253–255
 multiphoton absorption 49–51
 multiphoton excitation 196–199

n

NADH, *see* nicotinamide adenine dinucleotide
 nanocrystalline semiconductors, *see* quantum dots
 naphthalene sulfonates 380
 naphthalenes 163, 380, 524
 naphthols 170, 174
 Napierian absorption coefficients 42
 NATA, *see* N-acetyl-L-tryptophanamide
 natural fluorescence, *see* autofluorescence
 natural light 181, 182, 187
 Nd:YAG lasers 460
 NDT, *see* nondestructive testing
 near-field scanning optical microscopy (NSOM) 25, 327, 329, 333–337, 343, 366, 367
 near-infrared (NIR) absorption 33, 34, 49, 105
 negatively cooperative binding 471
 neutral molecules 445–453
 nicotinamide adenine dinucleotide (NADH) 488–490
 Nile blue/Nile red 536
 nitric oxide sensors 456, 457
 nitro compounds 78, 79
 nitrogen-vacancy (NV) defects 95, 96
 noncooperative binding 471
 nondestructive testing (NDT) 508–510
 nonparallel absorption of emission transition moments 192–196

nonradiative de-excitation 60, 61
 nonradiative energy transfer
 – classical description of energy transfer 214–216
 – definition 213, 214
 – directed 252
 – distinction from radiative energy transfer 218, 219
 – excitation energy transfer 214–219, 221–234, 252
 – fluorescence emission 110, 144, 150, 151
 – *see also* resonance energy transfer
 NPO (oxazole ligand) 538
 NSOM, *see* near-field scanning optical microscopy
 nucleic acids 356
 nucleotide labeling 365, 366
 NV, *see* nitrogen-vacancy

o

oceanographic applications 428, 462
 OMA, *see* optical multichannel analyzers
 optical brighteners 507, 508
 optical Kerr-gating 285, 297
 optical multichannel analyzers (OMA) 336
 optical sensors 458, 459
 optical thermometers 399, 400
 organic compounds
 – absorption processes 33, 34, 37, 38, 43–45
 – art conservation applications 515, 516
 – chemical sensing 414, 415, 421, 423
 – excitation energy transfer 227
 – fluorescence emission 55, 64, 65, 75–93, 113, 114, 120, 121, 135, 136, 144, 154, 160, 162, 164, 168, 169
 – fluorescence labeling 493–497
 – fluorescence polarization 193, 194, 203
 – luminescence 1
 – photoluminescence 19, 20
 – probes 380–384, 386–388, 394
 organometallic compounds 2
 oscillator strength 42–45
 osmium complexes 99, 100
 otical highlighting 493
 oxazoles 538, 539
 oxazines 84, 85, 536, 537
 oxidative electron transfer 160
 oxygen molecule 35, 36
 – chemical sensing 452–456
 – probes 392, 400
 – quenching 66, 142, 275, 276, 392, 400
 – steady-state spectrofluorometry 275, 276

p

- PAH, *see* polycyclic aromatic hydrocarbons
 paintings 515–518
 palladium complexes 96
 PALM, *see* photoactivated localization microscopy
 parallel absorption of emission transition moments 191, 192
 partially polarized light 181, 182
 passive optical sensors 458, 459
 PBBO (oxazole ligand) 539
 PCT, *see* photoinduced charge transfer
 penetrant testing (PT) 509, 510
 pentosidine 483, 486
 Perrin equation 202, 203
 Perrin, Francis 10, 12–14, 16
 Perrin, Jean 14, 16
 Perrin–Jablonski diagrams 12–14, 53, 54
 perylenes 193, 194, 399, 400, 525
 PET, *see* photoinduced electron transfer
 pH dependence 174–177
 pH indicators 412–420
 - classification 413
 - coumarins 417
 - dual-wavelength measurements 463–465
 - fluoresceins 413, 420
 - ionic strength 414
 - photoinduced electron transfer 413, 420
 - photoinduced photon transfer 413
 - principles and techniques 412–417
 - pyranines 414, 415, 417, 419
 - ratiometric measurements 417, 429, 436, 437, 462–465
 - single-wavelength measurements 462, 463
 - SNAFL and SNARF 416, 419, 420
 - spectrophotometric and spectrofluorometric titrations 462–465
- phase-modulation fluorimetry 174, 298–302
 - basic equations 286–291
 - comparison of techniques 322, 323
 - continuous light source and electro-optic modulator 300–302
 - data analysis 306, 309
 - decay time measurements 298
 - excitation energy transfer 239
 - fluorescence polarization 202, 317
 - harmonic content of pulsed lasers 302
 - harmonic and δ -pulse responses 287–290
 - lifetime-based decomposition of spectra 321, 322
- principles of technique 285–288, 298–300
- single exponential and multiexponential decays 290, 291, 298–299
- time evolution of fluorescence spectra 318, 320
- phenanthrene 525
- phenolphthaleins 92
- phenylalanine 481, 482, 523
- 6-propionyl-2-(dimethylaminonaphthalene) (PRODAN) 523, 524
- phosphate sensors 440, 445
- phosphatidylcholines 122
- phosphatidylinositols 396, 397
- phospholipid bilayers
 - excitation energy transfer 248, 249
 - fluorescence correlation spectroscopy 356
 - fluorescence polarization 206–209
 - probes 396, 397
- phospholipid vesicles 248, 249, 384, 395
- phosphorescence
 - carbon nanostructures 95
 - decay time measurements 10–12
 - definitions 19
 - fluorescence emission 54, 60, 64–66
 - historical development 2–25
 - metal compounds, complexes and clusters 96
 - photoluminescence 19, 20
- phosphoroscopes 13
- photoactivated localization microscopy (PALM) 339, 340
- photobleaching 276, 331–333, 341, 363, 367, 368–371
- photoconversion 493
- photodiodes 266–268
- photoinduced charge transfer (PCT)
 - chemical sensing 424, 426, 430, 433, 437
 - fluorescence emission 112–114
 - polarity 380–384
 - probes 380–384
- photoinduced electron transfer (PET)
 - chemical sensing 416, 420, 424, 425, 430–432, 437, 449–453
 - fluorescence emission 144, 159–162
- photoinduced ICT 87–92
- photoinduced proton transfer 168–178
 - acid–base properties of water 175–177
 - base protonation in excited states 177, 178
 - chemical sensing 413, 416
 - determination of excited-state pK^* 172–174
 - Förster cycle 172, 173
 - general equations for excited-state deprotonation 170, 171

- pH dependence 174–177
- steady-state measurements 173, 174
- time-resolved measurements 174
- photoisomerization 90
- photoluminescence
 - historical development 19, 20
 - light-matter interactions 3
 - quantum dots 20
- photomultipliers 265, 267, 268, 270, 278, 293, 300–302
- photon burst detection 361, 362
- photophysical signal transduction 424–427
 - *see also* intermolecular photophysical processes
- photoselection of absorbing molecules 181–183
- photoswitching 493
- photosynthesis 251, 252
- photosynthetic antennae 255
- physical parameters 379–407
 - microviscosity, fluidity and molecular mobility 384–398
 - polarity 379–384
- picosecond diode laser heads 292
- pigments 515, 516
- platinum complexes 96
- Pockels cells 300–302
- point-spread function (PSF) 329, 337, 338
- polar plots 344, 345
- polarity 123–124, 128, 129, 379–384
- polarization effects
 - steady-state spectrofluorometry 265, 275
 - time-resolved fluorescence spectroscopy 304
 - *see also* fluorescence polarization
- polarization ratio 184–187
- polarized light 181–183, 184–187
- polyazaalkene-based sensors 440, 441
- polycyclic aromatic hydrocarbons (PAH) 75–80, 137
- polymer processing monitoring 399
- polymerization reactions 388
- POPOP (oxazole ligand) 539
- porphyrins
 - autofluorescence 480, 483, 490
 - chemical sensing 439, 440, 452, 453
 - fluorescence emission 96–98
 - food sciences applications 512
 - positively cooperative binding 471
- potassium dihydrogen phosphate (KDP) 296
- PPO (oxazole ligand) 539
- pressure effects 402–404
- pressure-sensitive paints (PSP) 401–404
- probes 21–24, 379–407
 - applications 388, 389, 396–397, 398–404
 - fluorescence emission 67, 70
 - fluorescence polarization 385, 390, 393–398
 - homogeneous isotropic media 393–395
 - intermolecular excimer formation 385, 389, 390
 - intramolecular excimer formation 385, 390–392
 - local physical parameters 379–407
 - microviscosity, fluidity and molecular mobility 384–398
 - molecular rotors 385, 386–389
 - ordered systems 395
 - photoinduced charge transfer 380–384
 - polarity 379–384
 - pressure effects 402–404
 - quenching 385, 389, 390
 - temperature effects 397–402
- PRODAN 380–383, 525
- proflavin 522
- proteins 356, 491–493
- PSF, *see* point-spread function
- PSP, *see* pressure-sensitive paints
- PT, *see* penetrant testing
- pulse fluorimetry 291–297
 - basic equations 286–291
 - comparison of techniques 322, 323
 - data analysis 305, 306, 308
 - fluorescence polarization 174, 202, 315–317
 - fluorescence up-conversion 285, 295–297
 - harmonic and δ -pulse responses 287–290
 - lifetime-based decomposition of spectra 321, 322
 - light sources 292
 - optical Kerr-gating 285, 297
 - principles of technique 285–288
 - single exponential and multiexponential decays 290, 291
 - single-photon timing technique 292–294, 322, 323
 - streak cameras 285, 294, 295
 - time evolution of fluorescence spectra 318, 320
- pulsed lasers 302, 356
- pulsed LEDs 292
- purines 154
- Py scale 129
- pyranines 176, 177, 414, 415, 417, 418, 526
- pyrenes
 - excitation energy transfer 234
 - fluorescence emission 123, 124, 128–130, 163, 164, 167

- probes 384, 390, 403
- structure and characteristics 525
- pyridines 80
- pyrimidines 154
- pyronenes 84
- pyronines 542
- pyrrole-based sensors 439, 440
- pyrromethenes, *see* BODIPY fluorophores

- q**
- quantum counters 266–268
- quantum dots (QD)
 - absorption processes 38, 39
 - fluorescence emission 103–105
 - fluorescence labeling 497–501
 - photoluminescence 20
 - single-molecule fluorescence spectroscopy 368, 371, 372
- quantum mechanics
 - absorption processes 43, 46
 - excitation energy transfer 216–218
- quantum rods (QR) 103–105
- quantum yields
 - excitation energy transfer 221
 - fluorescence emission 64–67, 70–73, 143, 171
 - probes 399, 400
 - steady-state spectrofluorometry 269–271
- p-phenylphenyl 526
- quenching, *see* intermolecular photophysical processes
- quinolines 80
- quinine sulfate 546
- quinones 154

- r**
- radiation density 59
- radiative deactivation 56, 57, 61, 62
- radiative energy transfer
 - applications 252–257
 - classical description of energy transfer 214–216
 - definition 213, 214
 - distinction from nonradiative energy transfer 218, 219
 - excitation energy transfer 214–221
- radioactive decay 63, 64
- Raman scattering 10, 304, 305, 361
- rapid diffusion limit 245, 246
- rapid lifetime imaging (RLI) 341
- rare-earth doped nanocrystals 501
- ratio metric measurements
 - chemical sensing 416, 417, 430, 436, 437, 463–465
 - probes 399, 401
- Rayleigh scattering 304, 305, 361
- recognition units 420–424
- red-edge effects 109, 110, 252–255
- reductive electron transfer 160
- Rehm–Weller equation 425
- remote sensing by LIDAR 460–462
- resins 516, 517
- resonance energy transfer (RET)
 - applications 252–257
 - chemical sensing 427, 432, 435
 - dimensionality 247–249
 - donor–acceptor ensembles 243–250
 - donor–acceptor interactions 235–242
 - energy migration 250–252
 - excitation energy transfer 221, 231–233
 - fluorescence labeling 498, 501
 - fluorescence microscopy 343
 - historical development 16, 17
 - metal compounds, complexes and clusters 102
 - red-edge effect 252–255
 - restricted geometries 250
 - single-molecule fluorescence spectroscopy 369, 370
 - steady-state methods 236–238
 - supramolecular distance determination 235–243
 - three dimensional 243–246
 - time-resolved methods 238, 239, 240
 - viscosity effects 243–246
- restricted geometries 250
- RET, *see* resonance energy transfer
- retail applications 514, 515
- rhodamines
 - chemical sensing 446, 447
 - excitation energy transfer 248, 249
 - fluorescence correlation spectroscopy 353, 357–359
 - fluorescence emission 83, 91, 92
 - fluorescence labeling 495
 - fluorescence polarization 193, 194, 196
 - penetrant testing 510
 - probes 398, 399
 - single-molecule fluorescence spectroscopy 363, 364, 367, 369, 370
 - steady-state spectrofluorometry 265, 280, 281
 - structure and characteristics 542–545
- riboflavin 512
- ripening of bananas 513
- RLI, *see* rapid lifetime imaging
- RNA structures 257
- rotational diffusion coefficients 359

- rotational motion effects
 – anisotropic rotation 200, 203–206
 – fluorescence polarization 199–207
 – free rotation 199–206
 – hindered rotation 199, 200, 206–209
 – isotropic rotation 200, 201–203
 rotors 204, 205
 rubrene 526
 ruthenium complexes 99, 100
- s**
- saccharides 449–451
 scanning near-field optical microscopy (SNOM) 25, 327, 329, 333–337, 343, 366, 367
SdP, *see* solvent dipolarity
 selection rules 46, 47
 self-absorption 272–274
 seminaphthofluoresceins (SNAFL) 416, 419, 420
 seminaphthorhodafluors (SNARF) 416, 419, 420
 sensing devices 458–460
 Shpol'skii spectroscopy 136, 137
 sialic acid 444
 signaling units 420, 421
 single-molecule fluorescence spectroscopy 360–372
 – applications 364–366, 371, 372
 – conceptual basis and instrumentation 360, 361
 – emission anisotropy 363
 – excitation energy transfer 242
 – flowing solution analyses 361–363
 – fluorescence emission 70
 – fluorescence microscopy 363–370
 – historical development 25
 – photophysics 367–372
 single-photon timing technique (SPT) 285, 292–294, 322, 323
 single-walled carbon nanotubes (SWNT) 95
 singlet–singlet energy transfer 222, 234
 site-selection spectroscopy 137
 Smoluchowski's theory 148, 149, 389
 SNAFL, *see* seminaphthofluoresceins
 SNARF, *see* seminaphthorhodafluors
 SNOM, *see* scanning near-field optical microscopy
 solar cells 255
 solid matrix fluorescence 134–137
 solvation dynamics 115, 116
 solvatochromic shifts 111, 117–120, 124–128
 solvent dipolarity (*SdP*) scale 127, 128
- solvent effects
 – empirical scales of polarity 124–129
 – fluorescence emission 110–129
 – hydrogen bonding 119–122, 125, 126
 – polarity-induced changes 123, 124, 128, 129
 – solvation dynamics 115, 116
 – solvatochromic shifts 111, 117–120, 124–128
 – solvent relaxation 112–116
 – vibronic band intensities 128, 129
 solvent polarizability (SP) scale 128
 solvent relaxation 112–116
 Soret absorption band 96, 97
 SP, *see* solvent polarizability
 SPA, *see* *N*-(3-sulfopropyl)acridinium
 spatial resolution 23, 24
 spatially heterogeneous systems 255
 spectral multiplexing 497
 sphere of effective quenching 152, 153, 157, 243
 spin-forbidden transitions 46, 47
 spontaneous emissions 57, 58
 SPT, *see* single-photon timing technique
 stability constants 465–473
 static limit 243
 static quenching 66, 144, 152–159
 steady-state anisotropy 188, 189, 202, 203, 206, 363
 steady-state fluorescence intensity 67, 68, 152, 166, 172, 281, 282
 steady-state spectrofluorometry 265–283
 – artifacts 271–276, 279
 – autofluorescence 265, 274, 275
 – correction factors 268, 269
 – emission anisotropy 277–282
 – emission spectra 268, 269, 280–282
 – excitation spectra 268, 278, 279, 281, 282
 – fluorescence intensity 281, 282
 – fluorescence standards 268–272
 – inner filter effects 271–274
 – operating principles 265–268, 277–279
 – oxygen quenching 275, 276
 – photobleaching 276
 – polarization effects 265, 275
 – probes 385, 395
 – quantum yields 269–271
 – test solutions 279–281
 STED, *see* stimulated emission depletion
 Stern–Volmer equation
 – chemical sensing 437, 438, 456
 – excitation energy transfer 245
 – fluorescence emission 146–148
 – probes 389, 403

- stilbenes 399, 507, 508
- stimulated emission depletion (STED) 327, 338, 339
- stimulated emissions 57, 58
- stochastic optical reconstruction microscopy (STORM) 327, 339, 340
- Stokes diffusion 130–132
- Stokes, George Gabriel 6–9, 15
- Stokes' law 11, 12, 56, 64
- Stokes shifts 57, 72, 118, 122, 173
- Stokes–Einstein relation
 - fluorescence emission 131, 133, 148, 167
 - fluorescence polarization 202
- STORM, *see* stochastic optical reconstruction microscopy
- straylight 279
- streak cameras 285, 294, 295
- streptavidin 499
- stretched exponential 309–312
- Strickler–Berg equation 63, 76
- strong coupling 223–226
- substituted aromatic hydrocarbons 77–80
- sulfonates 79, 80
- N-(3-sulfopropyl)acridinium 522
- sulforhodamines 544, 545
- superquenching 457
- supersonic jet technique 137
- supramolecular distance determination 235–243
 - distributions of donor–acceptor distances 239–242
 - Förster's theory 242, 243
 - single donor–acceptor distance 235–239
 - single molecule studies 242
- surface pressure mapping 403
- surface temperature mapping 401
- SWNT, *see* single-walled carbon nanotubes
- symmetry-forbidden transitions 46

- t**
- TAC, *see* time-to-amplitude converters
- tags, *see* fluorescence labeling
- temperature effects
 - fluorescence emission 66, 67, 135–138
 - probes 397–402
- temperature-sensitive paints 401, 402, 404
- temporal fluctuations in fluorescence intensity 350, 351
- p-terphenyl 526
- tetrachlorotetraiodofluorescein (TCTIF) 542
- tetramethylrhodamine (TMR) 545
- Texas red 494
- thermodynamics of luminescence 11, 12
- thiazines 540
- thionine 540
- thiourea-based sensors 438, 439
- TICT, *see* twisted intramolecular charge transfer
- time-domain fluorescence microscopy 327, 331, 333, 340–342
- time evolution of fluorescence spectra 318, 320
- time-resolved anisotropy 363
- time-resolved fluorescence spectroscopy 24, 25, 285–325
 - artifacts 302–305
 - basic equations 286–291, 314, 315
 - comparison of techniques 322, 323
 - continuous light source and electro-optic modulator 300–302
 - data analysis 305–312
 - emission anisotropy 187, 188, 189, 202
 - environmental effects 113, 114, 134
 - excitation energy transfer 238, 239, 240
 - excited-state lifetimes 312–314
 - fluorescence polarization 314–318, 385, 390, 395
 - fluorescence up-conversion 285, 295–297
 - harmonic content of pulsed lasers 302
 - harmonic and δ-pulse responses 287–290
 - inner filter effects 302–304
 - intermolecular photophysical processes 150, 174
 - Kohlrausch function and Becquerel function 309–312
 - lifetime-based decomposition of spectra 318, 321, 322
 - light scattering 304, 305
 - light sources 292, 300–302
 - optical Kerr-gating 285, 297
 - polarization effects 304
 - principles of techniques 285–287, 298–300
 - probes 385, 390, 395
 - reference compounds 318, 319
 - single exponential and multiexponential decays 290, 291, 298–299, 308–312
 - single-photon timing technique 285, 292–294, 322, 323
 - streak cameras 285, 294, 295
 - time evolution of fluorescence spectra 318, 320
 - wavelength–color effects 304
- time-to-amplitude converters (TAC) 292–294

titanium–sapphire lasers 50, 292, 332
 TNT, *see* 2,4,6-trinitrotoluene
 torsional vibrations 193
 totally asymmetric rotors and ellipsoids
 204, 205
 toxicology 428
 tracers 21–24, 70
 transient effects 148–152, 157, 158, 167
 transition metal complexes
 – absorption processes 38
 – chemical sensing 442–444, 454,
 465–474
 – excitation energy transfer 227
 – fluorescence emission 98–100
 transition moments 43–45
 transition probabilities 39–47
 translational diffusion coefficients 355–359
 triantennary glycopeptides 240–242
 2,4,6-trinitrotoluene (TNT) 456–458
 triphenylmethane dyes 90, 91
 triplet state kinetics 359
 triplet–triplet annihilations 60
 triplet–triplet energy transfer 60, 234
 trivial transfer 220
 tryptophans
 – autofluorescence 481, 482
 – fluorescence emission 81
 – fluorescence polarization 195
 – food sciences applications 512
 – structure and characteristics 523
 tumor early detection 500
 tungsten lamps 269
 turbidity 279
 twisted intramolecular charge transfer
 (TICT) 88–90, 119, 382, 383
 two-photon excitation fluorescence
 microscopy 327, 331–334, 343, 366
 tyrosine 481, 482, 523

u
 ultraviolet (UV) absorption 33, 34, 49,
 105
 ultraviolet (UV-A) sensitivity 485–487
 up-conversion, *see* fluorescence
 up-conversion

uranin 541
 uranium oxides 96
 urea-based sensors 438, 439
 urine analysis 427, 428
 uronic acid 444
 UV, *see* ultraviolet

v
 varnishes 517
 vegetation monitoring 461
 vertically polarized excitation 184–186, 277,
 281
 very weak coupling 223, 224, 225, 226–233
 vibronic band intensities 129
 viscosity effects
 – excitation energy transfer 243–246
 – fluorescence emission 129–133
 – probes 384–398
 visible absorption 33, 34
 vitamin A 512

w
 water molecules 175–177
 wavelength–color effects 304
 wavelength scales 70–73
 wavenumber scales 70–73
 weak coupling 223, 224, 226
 Weber, Gregorio 15, 16
 Weber's red-edge effect 109, 110, 252–255
 weighted residuals plots 307
 Weller's theory for exciplexes 118
 wide-field fluorescence microscopy 327,
 328, 329
 wobble-in-cone model 206, 207, 395, 397

x
 xanthenes 82–84, 193, 194, 541–545
 xenon lamps 300, 301

y
 YOYO-1 496

z
 zero-crossing detectors 302
 zinc complexes 96, 97, 443, 444, 453

