

## Index

$2\pi$  counters 245, 246, 262, 263  
 $4\pi$  counters 245, 246, 262, 263, 336

**a**  
absolute disintegration rates, determination of 262, 263  
absorption bands 835, 852  
absorption coefficient 6, 207, 220–222, 225, 226, 252, 316, 384, 777  
absorption near edge structure (XANES) 578, 836, 842  
absorption spectroscopy 578, 835, 837, 852  
accelerator bombardments 301, 337  
accelerator-driven transmutation technology (ADTT) 547, 851  
accelerator mass spectrometry (AMS) 715, 716, 752, 757–761  
acoustic waves 835  
actinides 1, 95, 140, 302, 305, 416, 418, 453, 517, 541, 547, 548, 592, *see also* transactinides  
– colors of 624  
– coprecipitation of 325  
– electrodeposition of 543, 544  
– electron configurations of 621  
– ionic radii of 623  
– irradiation of 594  
– lattice symmetries of 627  
– longest-lived isotopes 620  
– oxidation states of 622  
– potential energy surface of 419  
– properties of 618–629  
– radioactive tracers of 644  
– redox potentials for 625  
– spectroscopy of 615–618  
adiabatic barrier 428, 430  
adiabatic cutoff 354

adsorption 191, 293, 295, 296, 326, 546, 637, 639, 653, 745, 772, 774, 776, 778, 822–824  
– enthalpy 636, 641, 661, 664, 666, 667  
aerosols 291, 326, 333, 635–637, 640, 660, 663, 722, 739, 816, 817, 827, 831, 872, 878, 879  
aging 726, 781, 833  
– process of 776, 779  
airborne radioactivity 264  
ALADIN-LAND collaboration 458  
A Large-Aperture Dipole Magnet (ALADIN) 348  
alpha decay, modes of 119–125  
– alpha-decay energies 126, 127  
– hindrance factors 125, 126  
alpha ( $\alpha$ )-particles  
– electronic stopping power of 211  
– emission of 125  
– energy loss rate 213  
– nuclear stopping power of 211  
– range of 209, 210  
– relative number of 209  
– scattering of 4, 378  
– specific ionization of 208  
– stopping power for 211  
alpha ( $\alpha$ )-radiation 6, 7, 207–214  
– decay of, *see* alpha decay, modes of  
– monoenergetic nature of 119  
– spectrometry 259  
Alternating-Gradient Synchrotron (AGS) 575  
aluminosilicate colloids 822  
Alvarez structure 570  
anisotropy 350, 353, 397, 400  
– angular distributions 183, 397  
– thermal expansion 521  
annihilation radiation 219, 249  
Annual Limits of Intake (ALI) 865

- anthracene 248, 250, 286  
 anticoincidence circuits, use of 250, 263, 264  
 anti-Compton spectrometers 263, 264  
 antimatter 19, 681  
 antineutrinos 7, 18, 47, 146, 149, 150, 160, 162, 163, 469, 496, 701  
 antiparticles 17, 18, 219  
 antiproton beams 577  
 archeometallurgy 752  
 artificial elements 585  
 – discovery of 33, 34  
 artificial radiation sources, radiation exposure by 872, 874  
 astrophysical S factor 688  
 asymmetry energy 42, 43, 45  
 asymptotic barrier shift 424, 426, 427  
 atomic collisions 3  
 atomic force microscopy (AFM) 843  
 atomic isobars 758  
 atomic mass spectrometry 39  
 atomic nucleus, discovery of 4–6  
 atomic number 2–5, 8, 27, 33–35, 39, 40, 45, 89, 91, 123, 129, 148, 154, 155, 209, 211, 212, 217–220, 223, 225, 233, 239, 252, 258, 259, 262, 268, 270, 334, 361, 407, 411, 413, 415, 465, 471–475, 498, 519, 576, 581–584, 586–590, 592, 594, 595, 598, 604–606, 618–623, 631, 677, 694, 705, 738, 745, 746, 770, 803, 804, 836, 876  
 atomic processes 2–4  
 atomic weights, of the isotopes 34–36, 39  
 atoms  
 – radii of 2  
 – schematic representation of 2  
 Auger electrons 8, 159, 180, 324, 474, 504, 616, 698, 751  
 Auger electron spectroscopy (AES) 751  
 Auger yield 474, 475  
 Automated Rapid Chemistry Apparatus (ARCA II) 642, 644, 645, 659  
 Automated Ion-exchange apparatus coupled with the Detection system  
 – for Alpha spectroscopy (AIDA) 642, 645  
 – schematic diagram of 646  
 autoradiography 266, 267, 297, 776, 777, 786, 787  
 Avogadro's number 191, 195, 212, 289, 292, 322, 729, 732, 775
- b**  
 backscattering 4, 217, 218, 237, 249, 262, 336, 745, 746, 750, 751, 803, 841, 850  
 Bardeen, Cooper, and Schrieffer (BCS theory), for superconductivity 105  
 barium fluoride ( $\text{BaF}_2$ ) 249  
 baryon number 18  
 Bass model fusion barrier 606  
 $\beta^+$ -delayed proton emission 131  
 Becquerel, Henri 23, 266  
 Berkeley experiments on element 595, 596  
 Berkeley Gas-Filled Separator (BGS) 636, 651  
 Bessel function 372, 399  
 beta decay  
 – Cabibbo–Kobayashi–Maskawa matrix 165–170  
 – electron capture-to-positron ratios in 158, 159  
 – Feynman diagrams of 165  
 – fundamental processes of 148–158  
 – massive vector bosons 164, 165  
 – muon 496  
 – nuclear matrix elements 160, 161  
 – parity non-conservation 162–164  
 – recoil energy due to 469  
 – transitions and selection rules, classification of 156  
 beta ( $\beta$ )-radiation 6, 7, 206  
 – absorption of 215, 219  
 – backscattering of 217, 218, 745  
 – decay of, *see* beta decay  
 – interaction of 214–219  
 – maximum energy of 219  
 – maximum range of 217  
 – recoil energy due to emission of 467  
 – stopping power of 217  
 Bethe–Bloch formula 212  
 “Big Bang” theory 680–682, 705  
 binding energy 2, 3, 9, 39–44, 75–77, 81, 83, 91, 94, 149, 158, 159, 171, 179, 223, 332, 387, 402, 472, 507, 512, 618, 619, 653, 836  
 – chemical 332, 465  
 – of fissioning nucleus 140  
 – nuclide masses and 39–47  
 –  $Q$  value 41  
 binomial distribution 276–280, 847  
 biogenic emissions 715  
 bismuth germanate 249  
 blackbody radiation 695, 834  
 Blair sharp-cutoff model 380, 381  
 B meson 19, 169  
 Bohr magneton 65, 888  
 Bohr model 3, 391  
 Bohr, Niels 5, 211, 601  
 Bohr radius 232, 233, 494, 888

Bohr's classical equation 211  
 Bohr's "independence hypothesis" 388,  
 389, 391, 392, 609  
 Bohr–Wheeler formalism 136  
 boiling-water (BWR) reactors 521, 525,  
 527, 534, 536  
 Boltzmann's constant 231, 308, 688  
 booster synchrotron 575  
 BOREXINO detector, Gran Sasso 703  
 Born approximation, for plane waves 406  
 "Borromean" nuclei 348  
 Bose–Einstein statistics 69  
 bosons 17–19, 89, 109, 164, 165, 167, 681  
 – massive vector 164, 165  
 boundary condition 375, 376  
 brachytherapy 316  
 branching radioactive decay 199, 200  
 breakup spectroscopy 347, 348, 353, 576  
 breeder reactor 513, 514, 522, 524, 525,  
 541, 547  
 Breit–Rabi formula 66  
 Breit–Wigner formula 310, 389, 391  
 bremsstrahlung photons 159, 407, 577  
 bubble chambers 268, 269

**c**

Cabibbo angle 167  
 Cabibbo–Kobayashi–Maskawa matrix  
 165–170  
 calcination 546  
 capillary electrophoresis with inductively-  
 coupled plasma mass spectrometry  
 (CE-ICP-MS) 835  
 carbon dating, *see* radiocarbon dating  
 carbon isotopes 716  
 carrier colloids, *see* *Fremdkolloide*  
 cathodic sputtering 302  
 cation exchange 587, 593, 596, 659, 660,  
 794  
 center-of-mass  
 – energies 363, 424  
 – motion 350  
 centrifugal force 114, 115, 400, 430, 520,  
 572  
 ceramic fuels 521, 523  
 Cerenkov detectors 698  
 Cerenkov radiation 219, 701  
 cermets 523  
 chain reaction 314, 408, 507, 508, 510, 511,  
 551, 562, 805, 806  
 channel coupling 429, 430, 432  
 charcoal filters 545  
 charge carriers 250–253, 809  
 charge compensation 842, 850

charge density distribution, in nucleus  
 59–61, 85  
 charge distribution 59–62, 67, 87, 95, 172,  
 178, 233, 333, 334, 441, 444, 451, 477, 478,  
 499  
 charged-particle accelerators  
 – cyclotrons 570–574  
 – direct voltage accelerators 565–568  
 – linear accelerators 568–570  
 – radioactive ion beams 576, 577  
 – synchrocyclotrons and synchrotrons  
 574–576  
 charged particles  
 – accelerators, *see* charged-particle  
 accelerators  
 – activation by 736, 737  
 – classical trajectories for 367  
 charge fluctuations 451  
 charge independence 76–80  
 charge-to-mass ratios 51, 53, 206, 342, 413  
 Chart of the Nuclides (2012) 56, 130, 146  
 chemical bonds  
 – affect of nuclear transmutations on 465,  
 466  
 – influence on  
 – half-lives 488, 489  
 – Mössbauer spectrometry 499–504  
 – radiation emission 490–498  
 chemical transmutation 769  
 chemisorption 292, 293, 823  
 Chernobyl accident 532–537, 815, 817, 831  
 "chop-leach" process 541  
 chronometers 711, 723  
 classical mechanics, elements from 12  
 Clebsch–Gordon coefficient 179  
*Clorella vulgaris* 796  
 cloud chambers 208, 268, 269  
 cluster radioactivity 9, 126–129, 268  
 Cockcroft–Walton accelerators 561, 565,  
 566  
 – schematic diagram of 566  
 cocrystallization 293, 294  
 coincidence circuits, use of 263  
 cold-fusion reactions 233, 594, 598–604,  
 606, 612  
 – decay chains measured in 603  
 collective dipole transitions 178  
 collective excitation 109–117, 385  
 collector ring (CR) 577  
 collinear laser spectroscopy 345  
 colloids 293, 297, 818–823, 825, 826, 833,  
 835–838, 840–846, 848, 850, 853, 854  
 – *Eigenkolloide* 298, 820, 821  
 – *Fremdkolloide* 298, 820, 821, 846

- formation of 299
- hydrophilic 298
- hydrophobic 298
- organic 298
- radiocolloids, *see* radiocolloids
- combined-function magnets 575
- Commission on Nomenclature in Inorganic Chemistry (CNIC) 33, 597
- complexation reaction 290, 852
- complexing agents 299, 326, 586, 587, 628, 816, 820–822, 878
- compound-nucleus deexcitation 407
- compound-nucleus reactions 385–403, 422–424, 430, 435
- Compton continuum 256, 263
- Compton distributions 249
- Compton effect 223–225, 474
- Compton scattering 224, 804, 805
- Compton wavelength 74, 384
- computed tomography (CT) 789
- configuration interaction (CI) 651
- conserved vector current, hypothesis of 166
- contamination monitors 270
- controlled thermonuclear reactors (CTRIs) 552–554
- coolants
  - disadvantages of water as 530
  - properties of 529
- coprecipitation 325, 336, 541, 546, 586, 731, 745, 822, 823, 825, 836
- of radioactive substances 293, 295
- Coriolis coupling 97
- Coriolis force 97, 113, 114
- corrosion 266, 300, 521, 522, 530, 532, 545, 546, 776, 790, 801
- cosmic rays 8, 14, 25, 27, 36, 235, 264, 267, 268, 496, 591, 618, 680, 698, 701, 702, 704–706
  - effects in meteorites 706, 707
  - flux 707
  - galactic cosmic-ray (GCR) fluence 707
  - radionuclides from 706
  - spectrum 707
- cosmochemistry 1, 677, 708, 711, 739, 755, 761
  - general aspects of 680
- cosmogenic radionuclides 26, 712–717, 813
  - applicable for dating 713
- Coulomb barrier 58, 80, 111, 119, 362, 367, 396, 409, 438, 440, 453, 590, 688, 696, 736
- Coulomb energy 42, 45, 76, 79, 132, 133, 135, 400
- Coulomb excitation 110–117, 170, 177, 339, 344, 348, 423, 424, 426
- Coulomb field, of atomic nucleus 214, 225
- Coulomb forces 4, 12, 400, 423
- Coulomb potential 73, 84, 85, 91, 94, 123, 125, 130, 366
- Coulomb radius 380
- Coulomb repulsion 42, 135, 143, 228, 362, 750
- Coulomb scattering 5, 7, 58, 214, 366, 372, 375
  - geometrical situation in 369
  - phases of 370
- Coulomb trajectories 442
  - in center-of-mass system 364–368
- coulometric titration (CT) 846
- counting, low-level 263, 264
- cryo on-line detector (COLD) 660, 664
- crystalline silicon, energy levels of
  - with acceptor level 252
  - schematic diagram of 251
- curium 456, 549, 591–593
- current-current coupling 165
- current density 305, 368, 369, 372
- cyclotrons 51, 323, 324, 570–574, 595, 596, 600, 636, 663, 748, 783, 788, 790
  - frequency 51–53
  - irradiation 591
  - resonance curve 52
  - resonance frequency 572
- d**
- de Broglie wavelength 14, 15, 35, 75, 123, 367
  - vs. particle kinetic energy for a few particles 15
- decay constant 11, 120, 121, 123, 124, 129, 150, 152, 174, 175, 177, 180, 189, 192, 199, 306, 322, 337, 488, 489, 495, 512, 589, 724, 726, 740, 828
- decay curve 176, 198, 235, 243, 337, 338, 495, 497, 590, 591, 851
- decay energy 8, 9, 16, 41, 119, 120, 126, 133, 148, 149, 158, 159, 161, 171, 172, 189, 313
- decay rate 119, 125, 191, 192, 199, 281, 287, 288, 337, 371, 386, 850, 852
- deep inelastic collision (DIC) 423, 432, 440–457
  - element distributions for 454
- “deflection function” scaling 442
- degrees of freedom 275, 424, 434, 451, 465
- density functional theory (DFT) 630, 653, 661, 664
- Derived Air Concentration (DAC) 867

- detectors
- contamination monitors 270
  - film badges 270
  - gas-filled, *see* gas-filled detectors
  - Large Area Neutron Detector (LAND) 264
  - pocket ion chambers 270
  - portable counters and survey meters 269
  - scintillation 248–250, 257, 259, 264
  - semiconductor 250–257, 264
  - solid-state 219
  - solid-state nuclear track detectors (SSNTDs) 128
  - surface barrier (SSB) 254, 257
  - thermoluminescence dosimeters 270
  - track detectors, *see* track detectors
  - used in health physics 269–271
  - whole-body counters 271
- deuterons 76, 228, 318, 319, 323, 404, 405, 409, 560, 561, 572, 588, 590, 591, 681, 734, 735
- binding energy of 75
  - excited state of 78
  - ground state of 77
  - photodisintegration of 407
  - properties of 73
  - quadrupole moment of 74
- diamagnetic compounds 495
- DIAmide EXtraction (DIAMEX) process 548
- dibutylphosphoric acid (DBP) 542
- dielectric track detectors 267, 268
- diffusion 254, 255, 268, 293, 300, 441, 444, 450, 452–455, 481, 491, 511, 520, 553, 641, 664, 667, 721, 755, 772, 774, 776–778, 801, 878
- diffusion coefficient 444, 453–455, 774, 776–778
- dimers 624, 842, 850
- di-nuclear system 423, 442, 449
- dipole magnets 54, 333, 334, 346–348, 520, 575
- dipole moment 67, 175, 407
- Dirac–Coulomb–Breit (DCB) Hamiltonian 651
- Dirac equation 65, 651
- direct reactions 385, 404–407, 418
- direct voltage accelerators 565–568
- disproportionation reactions 624, 833, 837–839
- dissipation–fluctuation theorem 432
- dissolved organic carbon (DOC) 822
- dissolved organic matter 715, 822
- distorted wave Born approximation (DWBA) 406, 407
- distortion energy 135, 136
- DNA analysis, using radionuclides 785, 786
- doping 253, 852
- Doppler correction 344
- Doppler effect 176, 348, 500
- Doppler shift 176, 339
- Doppler velocity 502
- dosimetry 244, 268, 270, 861–864
- double-sided position-sensitive Si detector (DSSD) 616
- double-sided silicon strip detector (DSSSD) 344
- DS discrete variational method (DS-DVM), for atomic calculations 653
- Dubna Gas-Filled Recoil Separator (DGFRS) 604, 613, 614
- dynamic converters, principles of 809, 810
- e**
- eigencolloids 846
- eigenfunctions 86, 179, 370, 372, 451
- Eigenkolloide* 298, 820, 821
- eigenmotions 50
- Einstein's relation  $E = mc^2$  39
- elastic scattering 364, 423
- angular distributions for 378
  - Blair model predictions 381
  - kinematics of 750
  - in nuclear reactions 372–379
  - optical theorem 383–385
  - and reaction cross-section 379–383
  - schematic dependence of 58
- electric deflectors 333
- electric dipole moments (EDMs) 19, 68
- electric dipoles 62, 68, 112, 115, 226
- transitions 178, 754
- electric discharges 485, 807
- electric energy 808–810
- electric monopole interaction 501
- electric quadrupole moments 67–69, 94, 95, 178, 345, 490, 491
- electrode gap 569
- electrodeposition 302, 305, 336, 543, 544
- electrolysis cell 303
- electrolytic decomposition 714
- electrolytic deposition, of radionuclides 325, 777
- electromagnetic excitation 111, 115, 348, 354, 355
- electromagnetic force 11, 18, 19, 76

- electromagnetic radiation
  - Annual Limits of Intake (ALI) 865
  - biological effects in, *see also* radiotoxicity
  - cell 867, 868
  - humans, animals, and plants 868–872
  - collective dose concept 874
  - committed dose concept 874
  - Derived Air Concentration (DAC) 867
  - dose-effect curves 871
  - doses and dose rates 862
  - dosimetry 861–864
  - environment, monitoring of 879
  - external sources of 864, 865
  - internal sources of 865–867
  - non-occupational exposure 872
  - recommended dose limits 875
  - safety recommendations 872–875
  - safety regulations 875–879
  - weighting factors 862–864
- electromagnetic transitions 112, 115, 140, 142, 170–185
  - angular correlations 183–185
  - internal conversion coefficients 179–183
  - multipole order and selection rules 172–174
  - probabilities 174–179
- electromagnetic waves 570
- electromagnets 571, 573
- electron capture (EC) 7, 45, 163, 199, 313, 321, 471, 474, 488, 490, 499, 787, 795
- electron configurations, prediction of 2, 491, 587, 618, 621, 624, 630–632, 651, 770
- electron cyclotron resonance (ECR) 570
- electron density 4, 62, 212, 215, 488, 490, 495, 496, 653, 804
- electron-electron interaction 745
- electron exchange reactions, transition states in 771
- electron momentum distribution 16
- electron number density 211, 212
- electrons 2
  - antiparticles of 219
  - Auger electrons 8, 159, 180
  - binding energy of 223
  - capture-to-positron ratios 158, 159
  - helicity of 163
  - mass of 4, 39, 52
  - photoelectrons 223
- electron scattering 60–62, 165
  - angular distribution of 61
  - charge distributions, measurement of 61
- electron shells 3, 7, 8, 48, 66, 84, 85, 91, 131, 158, 185, 215, 220, 221, 223, 232, 233, 334, 465, 487, 488, 587, 592, 612, 630, 751
  - contraction of 473
  - expansion of 472
  - influence of nuclear transmutations on 471
  - magnetic interaction energy 64
  - Russel-Saunders coupling 63
- electron spin resonance (ESR) 712
- electrophilic labeling 323
- electrostatic generators 567
- elementary particles, short-lived 232, 233
- elements in the stars, synthesis of 683
  - evolution of
  - earth 686, 687
  - stars 684–686
  - helium burning 690
  - hydrogen burning 688–690
  - nuclei with
  - $A < 60$  690, 691
  - $A > 60$  691–696
  - thermonuclear reaction rates for 687, 688
- Emergency Core Cooling System (ECCS) 535
- emulsions, photographic 266, 267, 418, 497
- endoergic reactions 361
- energy absorption 361, 861, 862
- energy damping 441
- energy dispersive X-ray spectrometry (EDS) 305
- energy dissipation 301
- energy dose 787, 861, 863
- energy gain 39, 40, 512, 575
- energy gaps 49, 89, 91, 105, 106, 251, 252, 836
- energy loss 211, 213, 214, 216, 228, 251, 254, 259, 301, 306, 332, 342, 343, 346–348, 364, 386, 404, 443, 445, 446, 576, 750, 759, 760
- energy straggling 214, *see also* range straggling
- energy-weighted sum rule, *see* Thomas-Reiche-Kuhn (TRK) sum rule
- entropy 83, 84, 296, 300, 639, 640, 768
- epithermal flux 308, 310
- epithermal neutrons 265, 310, 311, 316, 510, 734, 740
- equation of state (EOS) 422
- etching 267, 268, 680, 725
- Euler's formula 374
- evaporation 84, 112, 113, 143, 257, 265, 294, 295, 302, 332–334, 336, 338, 339, 387, 393, 394, 395, 397, 403, 407, 409, 411, 413,

- 414, 421, 430–433, 450, 453, 458, 491, 546, 597, 600, 601, 603, 604, 606–609, 636, 662, 666, 677, 878  
 evaporation residue (EVR) 84, 143, 332–334, 338, 387, 393, 431–433, 453, 491, 600, 601, 604, 606–609, 636, 662, 666  
 – implantation 339  
 excimer pumped laser system 852  
 excitation energy 83, 84, 97–99, 105, 112, 143, 147, 170, 172, 178, 179, 206, 231, 348, 354, 387, 391, 393–398, 404, 407–410, 421, 429, 431, 435, 436, 440, 447, 450, 458, 465, 469, 470, 472, 473, 476, 479, 500, 594, 598, 607, 608, 617, 850, 867  
 excited nucleon 404  
 excited quasi-stationary state 386  
 excited states 8, 37, 49, 70, 78, 79, 97, 102, 104, 105, 109, 111, 120, 125, 129, 131, 144, 152, 157, 170, 171, 180, 220, 247, 305, 313, 340, 348, 387, 421, 427–429, 472, 473, 487, 489, 491, 499–502, 504, 616, 691, 697, 698, 753, 837  
 excitons 404  
 exoergic reactions 42, 361, 469, 470  
 experimental storage ring (ESR) 50, 53, 54, 131, 346, 576, 577  
 extended X-ray absorption fine structure (EXAFS) 551, 578, 836, 841, 842, 846–849
- f**  
 Facility for Antiproton and Ion Research (FAIR) 577  
 Fano factor 287  
 Faraday cup 306, 307, 386, 760  
 fast breeder reactors 514, 525, 541  
 Fermi constant 161, 165, 166  
 Fermi–Dirac statistics 69  
 Fermi distribution 60  
 Fermi energy 82, 104, 105, 107, 114, 219, 394, 449  
 Fermi function 151, 152, 158  
 Fermi gas model, of non-interacting particles 82–84, 394  
 Fermi level 616  
 Fermi matrix element 160, 161  
 Fermi momentum 82, 445  
 fermions 17, 18, 35, 65, 109, 148, 149, 165, 166  
 Fermi’s golden rule 150  
 Feynman graph, for gluon exchange 75  
 film badges 270  
 fine-grain emulsions 266  
 fissility parameter 134, 135, 400, 611  
 fission fragment anisotropies 400  
 fission isomers 138, 140, 141, 339, 418, 754  
 fission products 131, 143, 144, 149, 268, 315, 331, 342, 343, 411, 414, 415, 418, 422, 507, 510, 514, 517, 521, 525, 530, 531, 537–549, 551, 554, 555, 586, 590, 680, 761, 813, 815, 817, 832  
 – disintegration rate of 539  
 – effects of 537, 538  
 – long-lived 538  
 fission tracks 596, 636, 712, 725, 726  
 fission yield 147, 343, 410, 412, 512, 517, 585, 586, 813  
 flow counter 245, 256, 878  
 fluorescence emission 23, 837, 850, 852, 854  
 fluorescence spectroscopy 837, 852  
 fluorescence yield 159, 474, 475  
 flux density 66, 67, 185, 219, 312, 315, 538, 547, 559, 589, 705, 726, 732, 733, 735, 746, 868  
 flux depression 301  
 flux monitors 265  
 flux trap 563  
 Fock–Space (FS) DCB CC method, for atomic calculations 651  
 Fokker–Planck transport equation 452  
 Food and Agricultural Organization (FAO) 807  
 food irradiation, safety of 807  
 forbidden gap 251  
 force carriers 12, 17, 19, 20, 74  
 Formvar (plastic) 302, 336  
 Fourier transform-ion cyclotron resonance (FT-ICR) 52, 53  
 fractional crystallization 24, 325  
 fragment separator (FRS) 53, 345, 347, 348, 576  
 Fraunhofer diffraction 382, 383  
 free electrons 223, 226, 239, 242, 250, 552, 625, 689  
 free positrons 494, 495  
*Fremdkolloide* 298, 820, 821, 846  
 frequency-doubled dye laser 852  
 frequency-modulated (FM) cyclotrons 574  
 frequency modulation 574  
 Fresnel diffraction 382, 383  
 fuel cycle 1, 507, 512–517, 540  
 fuel elements  
 – “chop–leach” process 541  
 – design of 520–524  
 – storage of 540  
 – used in pressurized-water reactors 524  
 fuel rods 521, 523, 524, 545

- Fukushima Dai-ichi nuclear power plant 535–537
- full width at half maximum (FWHM) 53, 285–287, 386, 413, 852
- fundamental forces, in nuclear chemistry 11, 12, 18
- fusion probability, definition of 430–432, 434, 606
- g**
- galactic cosmic-ray (GCR) fluence 707
- gamma ( $\gamma$ )-emitters 257, 259, 305, 339, 747, 803, 877
- gamma ( $\gamma$ )-radiation 6, 7, 206, 220–226
- absorption of 220, 221, 225, 226
  - activation by 738
  - application for thickness measurement 804
  - backscattering of 746
  - Compton effect 223–225
  - difference with X-rays 220
  - elastic scattering of 746
  - emission of 8, 112, 170, 219, 220, 468, 469
  - energy range of 220
  - energy transfer 226
  - half-thickness of 221, 222
  - mass absorption coefficient for 222
  - measurement of 251, 253
  - monoenergetic 220
  - partial absorption coefficients of 225
  - photoelectric effect 223
  - photonuclear reactions 226
  - recoil energy due to emission of 468
  - scattering of 223, 226
  - spectrometry 259, 305, 451, 489, 562
  - standards 260
  - total absorption coefficient of 225, 226
  - treatment of sludge by 807
  - types of interactions of photons in 221, 223
- gamma ( $\gamma$ ) spin rotation ( $\gamma$ SR) 491
- Gamow peak 688
- Gamow factor 123, 130, 688
- Gamow–Gurney–Condon approach 123, 129
- Gamow–Teller matrix element 160, 161
- Gamow–Teller transitions, selection rule for 161
- gas amplification 242
- gas chromatography (GC) 258, 326, 478, 485, 636–639, 641, 642, 654, 657, 796
- gas-cooled reactors (GCRs) 522, 525, 527, 528
- gas diffusion 520
- gas-filled detectors 239–243, 264
- Geiger–Müller counters 246, 247
  - ionization chambers 243, 244
  - non-counted pulses at 240
  - proportional counters 244–246
  - pulse height 241
  - schematic representation of 240
  - time-projection chamber (TPC) 243
- gas-filled separators 303, 333, 334, 338, 606, 636, 651, 666
- gas ionization chamber 342
- Gaussian distribution 214, 281, 282, 399, 412, 428, 444
- Geiger–Müller counters 239, 243, 244, 246, 247, 256, 262, 269, 637, 879
- measurement of various kinds of radiation 257
- Geiger–Nuttall rules, for radioactive decay 120, 121
- gels 298, 785
- geochemical isotope thermometry 678
- Gerassimov–Drell–Hearn (GDH) sum rule 66
- giant dipole resonance (GDR) 62, 348, 354, 407, 451
- giant resonances 110–117, 178
- Gibbs free energy 296, 632, 634, 768
- gigaelectronvolts 422, 578, 706, 707
- glow discharge mass spectrometry (GDMS) 752
- Glückauf equation, of chromatography 647, 648
- gluon 18, 74, 75, 459, 460, 681
- Goldhaber–Teller model 407
- Goshal experiments 386, 391
- grain boundaries 777
- graphite 230, 311, 497, 511, 513,
- 521–525, 530, 532, 533, 547, 562, 641, 794
- graphite-moderated reactors 521, 524, 525, 530, 534
- grazing collision 382, 405, 423
- grazing trajectory 366
- ground state 37, 49, 77–79, 92–97, 105, 109, 112, 120, 125, 129, 139–142, 152, 171, 179, 182, 247, 313, 340, 341, 350, 351, 379, 396, 401, 416–418, 428, 489, 500–502, 504, 604, 607, 609, 616, 621, 622, 630, 651, 653, 690, 697, 746, 753
- shell effects 450
- ground-state transition 125, 129, 340, 341, 604
- gyromagnetic ratio 65

***h***

hadronic current 166, 167  
 hadrons 18, 59, 165–167, 459  
   – examples for 19  
 Hahn suction frit 336  
 half-life 8, 11, 27, 34, 55, 122, 190, 195,  
   714, 718, 808, 828  
   – biological 831, 865  
   – decay constant 123  
   – decay curve 235  
   – dependence on chemical bonding 488,  
   489  
   – determination of 337–339  
   – effective 865  
   – logarithm of 619  
   – of mother and daughter nuclide 197  
   – of pions 701  
   – similar 198  
   – for spontaneous fission 133, 134  
 halo nuclei 62, 348, 349  
   – electromagnetic dissociation of 353  
 Hamilton function 160, 164  
 Hamilton operator 150, 165, 166  
 Harkin’s rule 586, 618  
 harmonic oscillator 49, 52, 58, 59, 86–89,  
   97, 98, 137, 139, 451  
   – eigenfunctions 451  
 Hartree–Fock procedure 85, 86, 93, 94,  
   630  
 heat transfer 323, 521, 530, 805  
 heavy-ion collisions 354, 422, 423, 457,  
   459  
   – classification of 423  
   – relativistic 457–460  
 heavy-ion-induced fusion 553  
 heavy ions 34, 50, 111, 112, 115, 131, 264,  
   267, 302, 303, 318, 333, 335, 338, 342, 343,  
   354, 381, 382, 383, 422–424, 427, 430, 455,  
   490–492, 554, 568, 570, 573, 575, 588, 590,  
   595, 596, 600, 604, 606, 630, 635, 680, 737,  
   884  
   – deep inelastic collisions 440–457  
   – fusion reactions 424–434, 491  
   – quasi-fission 434–440  
   – relativistic collisions 457–460  
   – synchrotron 53, 345, 576  
 heavy residues 332  
 heavy-water reactors (HWRs) 513  
 Heisenberg uncertainty principle 15, 16,  
   19, 150, 226, 387, 499  
 helium burning 684, 690  
 Hertz dipole 175  
 Hertzsprung–Russell (HR) diagram 684,  
   685, 707

heterogeneous exchange reactions 744,  
   745, 774, 776, 796, 824, 825  
 high-active waste (HAW) 544  
 high-energy accelerators 269, 576  
 high-energy density 459  
 high-energy reactions 385, 418–422  
 high-energy storage ring (HESR) 577  
 High-Flux Beam Reactor (HFBR) 562  
 High-Flux Isotope Reactor (HFIR) 563  
 high level radioactive waste (HLRW) 832  
 high-level waste (HLW) 544–547, 585, 813,  
   815, 823, 825  
   – transmutation of 547  
 high-performance liquid chromatography  
   (HPLC) 326, 642, 644  
 high-spin states 110–117  
 high-temperature gas-cooled reactors  
   (HTGRs) 522, 525, 526, 528  
 homologs, investigation of 842–850  
 hot atom chemistry 465, 884  
 hot atoms 465, 477–479, 481, 485, 792, 884  
 hot fusion 233, 302, 594, 600, 606, 612  
 hot-fusion reactions 594–598, 606, 612  
 Hubble constant 681  
 Hubble time 680  
 hydrogen and hydrogen-like atoms,  
   properties of 232  
 hydrogen burning 682, 688–691, 696  
 hydrogen-like atoms 3, 232  
 hydrolysis 293, 545, 551, 624, 628, 659,  
   660, 818, 820, 821, 822, 834–838, 840, 841,  
   845–847, 850, 852–854  
   – monomeric 847  
   – mononuclear 846  
   – of radionuclide 299  
 hyperon decay 165, 166  
 hyperthyroidism, therapeutic treatment of  
   870  
 hypsochromic shifts 852

***i***

imaging plates (IPs) 305  
 inductively coupled plasma mass  
   spectrometry (ICP-MS) 752, 835  
 inelastic collision 2, 228, 423, 424, 440,  
   476, 609  
 inelastic scattering 115, 231, 316, 339, 385,  
   423, 428, 429, 435, 748  
 inert gas 544, 772, 838, 852  
 infinitely dilute resonance integrals 310  
 inorganic scintillators 249  
 instrumental activation analysis 730, 741  
 instrumental neutron activation analysis  
   (INAA) 741

- Integrated Measuring and Information System (IMIS) 879
- interacting boson approximation (IBA) 108–110, 609
- intermediate-mass fragments (IMFs) 126, 385, 420, 422, 458, 885
- intermediate vector bosons 17, 18
- internal conversion (IC) 8, 171–173, 179–183, 340, 471, 474, 475, 616
- internal fluorescence 474
- International Atomic Energy Agency (IAEA) 532, 807, 876
- International Commission on Radiological Protection (ICRP) 862, 872, 875
- International Thermonuclear Reactor Experiment (ITER) 552
- International Union of Pure and Applied Chemistry (IUPAC) 33, 34
- interstellar matter 680, 704–705
- intramolecular bonds 476
- intrinsic colloids, *see* *Eigenkolloide*
- ion beams 50, 302, 345, 568, 573
- radioanalysis with 748–752
- ion bombardment 404, 409, 748, 759
- ion dose 861, 862, 864
- ion exchange 290, 292, 293, 296, 299, 324, 326, 329, 531, 542, 545, 546, 587, 821–823, 826, 835
- separation of radionuclides by 328
- ion-exchange chromatography 326
- ionic strength of reaction 837
- ion implantation 254
- ionization chambers 8, 240–244, 250, 256–258, 265, 269, 270, 306, 342, 591, 595, 732, 759, 760
- measurement of various kinds of radiation 257
- solid-state, *see* semiconductor detectors
- ionization potential 48, 212, 232, 494, 497, 630, 753–756
- ionizing radiation 9, 205, 206, 239, 243, 250, 264, 286, 418, 466, 805, 861, 874
- ion optical system 346
- isobaric analog resonances 80
- isobaric interferences 752, 753, 759
- isobars 37, 38, 45, 76, 78, 126, 538, 582, 754, 758–760, 848
- isochronous cyclotrons 573
- isochronous mass spectrometry (IMS) 53
- isomeric transition (IT) 29, 37, 93, 172, 176, 331, 469, 474, 476–478, 489, 787, 887
- energies of 474
- isomer shift 499, 504
- isospin 76–80, 115, 136, 164, 352, 401, 613
- isothermal gas chromatography (IC) 326, 637, 639, 654, 657
- isotones 37, 38, 48, 129, 130, 884
- isotope dilution 337, 718, 741–743, 784, 785
- principle of 741
- isotope dilution analysis (IDA) 741–743
- isotope ratio (IR) 551, 677–689, 712, 716, 718, 721, 724, 726, 730, 742, 752, 760
- isotopes 29, 38
- atomic mass of 39
- atomic weights of 34, 35
- chart of nuclides and 34–38
- exchange reactions 767–769, 773
- – determination of surface area by 775
- radioisotopes, *see* radioisotopes
- isotopic nuclides, chemical separation of 481
- isotropic harmonic oscillator 88, 137
- shell-model states in 89
- j**
- Joint European Torus (JET) 552
- k**
- Kamiokande detector, Japan 685, 699, 701–703
- Kamiokande experiment 699
- KamLAND spectrum 703, 704
- kaon 19, 169, 232, 459
- kaon mass, as function of nuclear density 459
- Kimura equation 837, 850
- “kinematic coincidence” experiments 414
- kinetic energy 13–15, 35, 50, 75, 76, 82, 85, 111, 120, 124, 146, 147, 159, 171, 179, 213, 214, 227, 231, 254, 309, 332, 342, 343, 347, 348, 350, 362–364, 367, 375, 377, 386, 387, 393, 396, 407, 413–415, 432, 434, 436, 443, 445, 465, 469, 470, 476, 477, 479, 481, 500, 501, 507, 520, 553, 572, 700, 836
- Knight shift 491, 493
- K-shell fluorescence 159
- Kurie plot 151–153, 340
- l**
- labeled compounds 191, 298, 299, 484, 742, 758, 783, 785, 787, 789–797, 801, 803, 885, 886, *see also* recoil labeling and self-labeling
- Lamor frequency 66, 185, 491, 493
- Langevin equation 455, 457
- lanthanides 95, 114, 328, 543, 547–551, 818

- electron configurations of 621
  - ionic radii of 588, 623
  - oxidation states of 588
  - radioactive tracers of 644
  - relative abundances of 586
  - valence states of 587
  - Large-Area Neutron Detector (LAND) 264, 347–349, 352, 458, 576
  - large-area time-of-flight detector 333
  - Large Hadron Collider (LHC) 575
  - Large Magellanic Cloud (LMC) 685
  - laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) 752
  - Laser-Induced Breakdown Detection (LIBD) 834, 835, 840, 843, 846, 850
  - laser-induced fusion 553
  - laser-induced photoacoustic spectroscopy (LIPAS) 835, 840
  - lattice defects 252, 253, 466, 479, 496, 531, 725
  - law of conservation of momentum 223, 466, 467, 476
  - Lawson criterion 553
  - Lawson limit 552
  - Legendre polynomials 67, 135, 136, 185
  - leptons 16, 18, 150, 151, 160, 161, 164–166, 701
    - properties of 17
  - leukemia 788, 868–871
  - level densities 82–84, 105, 106, 137, 394–400, 608–610, 692
  - Lewis bases 550
  - ligands 4, 324, 481, 501, 548–551, 624, 625, 628, 660, 770, 771, 818, 819, 821, 824, 834, 837, 847, 850–853
  - light-ion scattering 383
  - light mirror nuclei
    - binding energies of 76
    - ground state of 79
    - properties of 77
  - light-water reactors (LWR) 521, 540, 832
  - limits of detection (LOD) 739, 752, 755
  - linear accelerators 61, 547, 568–571, 738
    - basic design of 569
    - phase stability in 569
  - linear energy transfer (LET) 206, 268, 418, 863, 867
  - liquid-drop model energy 44, 45, 47, 106, 126, 129, 130, 133, 134, 135, 137, 140, 143, 144, 178, 400, 401, 416, 436, 611, 612
  - liquid-drop potential 451
  - liquid-drop scaling 433
  - liquid emulsions 266
  - liquid–gas phase transition 422, 458
  - liquid–liquid extraction 650, 744
  - liquid scintillation 248–250, 257, 265, 266, 286, 336, 650, 715, 801, 839, 853
  - liquid scintillation counting (LSC) 249, 250, 336, 650, 715, 801, 839, 853
  - liquid-to-gas transition 457, 458
  - LOHENGREN separator 342
  - Lorentz contraction 354
  - Lorentz curve 389, 390
  - Lorentz factor 12, 211, 354
  - Lorentz transformation 13
  - low-active waste (LAW) 544
  - low-level waste (LLW) 544, 547
  - luminescence 306, 807
  - luminous substances, radiative decomposition of 809
  - luminophores 809
- m**
- Mach cone 219
  - McIntyre smooth cutoff model 380, 381
  - McKay equation 768, 773
  - macromolecular compounds 806
  - magic numbers 48, 49, 89, 91, 93, 107, 137, 138, 396, 416, 418, 613, 615, 677, 694
  - magnetic deflection 342, 343
  - magnetic flux density 66, 185, 219
  - magnetic moment 93, 491
    - dipole 65–67, 227, 345
    - of muon 497
  - magnetic spectrometer 128, 219, 220, 340, 386, 449
  - magnetic splitting 503
  - magnetic  $\gamma$ SR spectra 491
  - magnetrons 51, 64
  - Majorana neutrino 47
  - Manhattan project 371
  - many-body perturbation theory (MBPT) 651
  - mass action, law of 296, 632, 634
  - mass energy 5, 13
  - mass number 8, 27, 29, 35, 37, 39, 40, 45, 46, 50, 81, 84, 92, 105, 106, 119, 127, 147, 148, 212, 228, 268, 312, 322, 362, 402, 407, 412, 418, 420, 434, 435, 438, 440, 449, 455, 467, 468, 470, 480, 519, 538, 604, 608, 681, 692–694, 759
  - mass spectrometry 34, 39, 47, 49–55, 337, 345, 411, 418, 477, 680, 707, 715, 716, 718, 742, 751
    - accelerator 757–761
    - inductively-coupled plasma 835
    - nano-electrospray 847

- precision 49–55
  - radioisotope 752
  - resonance ionization 752–757
  - time-of-flight 836
  - mass transfer 442
  - material flux 801
  - Mattauch–Herzog mass spectrograph 50
  - Mattauch's rule 582
  - maximum likelihood method 282, 283
  - Maxwell–Boltzmann energy distribution 308, 394, 687, 688
  - Maxwell distribution 231, 308, 309
  - Maxwell equations 172, 183
  - Maxwellian function 231, 310
  - Maxwellian neutrons 310
  - Maxwell velocity distribution 552
  - medium-active waste (MAW) 544
  - medium-level waste (MLW) 544, 547
  - megaelectronvolts 134, 171, 217, 230, 347, 348, 354, 387, 390, 391, 421–423, 433, 465, 568, 750, 758
  - megawatt days (MWd) 513
  - Mendeleev, Dmitri 33
  - mesons 18, 25, 62, 74, 86, 93, 162, 169, 267, 459, 460, 496, 497, 681, 705
    - decay of 19, 169
  - metal coating 336, 803, 836
  - metal-ligand complex 851
  - Meyer, Lothar 33
  - microautoradiography 266
  - microwave spectroscopy 68, 704
  - Mikheyev–Smirnov–Wolfenstein large mixing angle model 703
  - moderators, properties of 529
  - molecular isobars 753, 759
  - molecular plating 302, 303, 305
  - mole numbers 294, 772, 773, 796
  - monazite 26, 824
  - monoclonal antibodies 788
  - monoenergetic bremsstrahlung 220
  - monoenergetic neutron flux 309
  - monoenergetic protons, emission of 9
  - monoenergetic radiation 747
    - pulse heights for 285, 286
  - monomers 250, 806, 820, 847, 848
  - mononuclear complexes
    - dihydroxo 842
    - hydroxide 853
  - Monte Carlo simulation (MCS) 350, 421, 638, 640, 641, 661, 664, 667
  - Moseley, Henry 4
  - Mössbauer effect 503
  - Mössbauer spectroscopy 177, 481, 482, 487, 499–504
  - multi-nucleon transfer reactions 455, 457, 663
  - muon decay 161, 165, 496, 498, 701
  - muon neutrinos 17, 166, 701–703
  - muons 14, 16, 26, 232, 233, 496–498, 700, 701, 705, 706
    - magnetic moment of 497
    - spin depolarization 497
    - spin rotation technique 497
  - Myers and Swiatecki mass formula 433
- n**
- nano-electrospray mass spectrometry 847
  - nanoelectrospray mass spectrometry technique (ESI-MS) 836
  - natural decay series, applicable for dating 120, 195, 711, 712, 720–723, 813
  - naturally occurring unstable elements, discovery of 33
  - natural radioactivity 48, 57, 199, 581, 680, 731, 813
    - measurement of 27
  - nebula 684–686, 704
  - Nernst's distribution law 294
  - neutrino–electron elastic scattering 703
  - neutrino–nucleon scattering 165
  - neutron activation analysis (NAA) 305, 561, 680, 730, 732–735, 740
  - neutron flux 265, 300, 305, 308–312, 314–316, 512, 525, 538, 547, 551, 555, 559, 561, 562, 589, 685, 691, 692, 723, 726, 733, 735, 746, 868
  - neutron gas 83
  - neutron generators 511, 560, 561, 565, 732, 734, 746
  - neutron-induced fission 231, 265, 407, 409–411, 413, 414, 422, 547, 582, 680, 725, 726
  - neutron polarization, degree of 169
  - neutrons 2, 35
    - counting efficiency for 265
    - detection of 232, 264, 265
    - diffraction 562
    - elastic scattering of 229
    - emission of 227–232
    - energy ranges 227
    - epithermal 265, 510
    - fast 227, 265, 315, 509, 510
    - interaction with electrons 227
    - irradiation 312, 313, 478, 481, 483, 484, 525, 543, 559, 586, 588–590, 592, 620, 808
    - measurement of 264, 265
    - resonance 227, 310, 395

- scattering 166, 375, 561
- shielding 735
- spectrometry 260
- thermal 83, 227, 265, 509, 510
- thermal agitation energies 231
- ultracold 169, 227, 228, 525
- wavefunction of 228
- neutron yields, of neutron sources 416, 559–561, 734, 735
- new experimental storage ring (NESR) 577
- N,N'-diethyl-2-(2-hexyloxy-ethyl)-malone amide (DMDOHEMA) 548
- structure of 549
- noble gases, radioactive 778
- production of 779
- Nordheim number 93
- Nuclear and Industrial Safety Agency (NISA) 536
- nuclear angular momenta 63–65, 183
- nuclear backscattering 750
- nuclear bombarding particles, sources of
  - charged-particle accelerators
  - cyclotrons 570–574
  - direct voltage accelerators 565–568
  - linear accelerators 568–570
  - radioactive ion beams 576, 577
  - synchrocyclotrons and synchrotrons 574–576
  - neutron generators 560, 561
  - neutron sources 559, 560
  - photon sources 577, 578
  - research reactors 561–563
- nuclear chemistry, physical concepts
  - classical mechanics 12
  - de Broglie wavelength 14, 15
  - force carriers 19, 20
  - fundamental forces 11, 12
  - Heisenberg uncertainty principle 15, 16
  - particle physics 16–19
  - relativistic mechanics 12–14
- nuclear collisions 332, 361, 362, 458, 459, 496
- nuclear decay, *see* radioactive decay
- nuclear disaster
  - Chernobyl accident 532–537, 815, 831
  - Fukushima Dai-ichi nuclear power plant 535–537
- nuclear emulsions 266
- photographic films with 267
- Nuclear Energy Agency (NEA) database 854
- nuclear explosions 27, 585, 589, 593, 684, 686, 692, 712, 713, 715, 716, 726, 817, 831, 868, 870
- nuclear explosives 525, 554, 555
- dirty weapons 555
- nuclear fission 8, 41, 397, 398, 818, *see also* nuclear fusion
- chain reaction 508
- discovery of 588
- effects of 537, 538
- energy production by 507
- energy released by thermal neutrons during 414
- energy spectra of 415
- excess reactivity 510
- nuclear forces 57, 59, 63, 73–77, 81, 84, 86, 89, 104, 143, 366, 372, 379, 384, 423, 427, 430, 433
- nuclear fuel cycle 1, 512–517, 761, 832
- nuclear fuels 512–517, 832, *see also* spent fuels
- lattice defects 531
- metals considered as cladding materials for 523
- reprocessing of 537–544, 545, 585
- nuclear fusion 138, 423, 680, *see also* nuclear fission
- controlled reaction, parameters for 552
- sub-barrier enhancement 424
- tunneling 425
- nuclear instability 119
- nuclear magnetic moment 65, 487, 488, 498
- nuclear magnetic resonance (NMR) 66, 487, 488
- nuclear magnetons 64, 65, 488, 888
- nuclear matrix elements 160, 161
- nuclear matter 81, 82
- evaporation of 458
- liquid-to-gas transition of 457
- phases of 457–460
- nuclear medicine 300, 316, 319, 324, 325, 329, 341, 585, 790, 794, 795, 869, 870, 875
- positron emitters used in 320
- radionuclides used in 783, 787–789
- reactor-produced radionuclides 317
- nuclear poisoning 538
- nuclear potential 49, 73–76, 84, 89, 94, 121, 130, 375, 380, 406, 426, 613
- nuclear power plants 525, 532, 534, 535
- nuclear power station 525, 545
- nuclear radiation
  - absorption of 207, 215, 745, 746, 803–805
  - activity and counting rate of 235–239
  - backscattering of 803
  - behavior in magnetic field 207

- beta radiation 214–219
- elementary particles, short-lived 232, 233
- energy production by 807–810
- gamma radiation 220–226
- general properties of 205–207
- heavy charged particles 207–214
- measurement of
  - absolute disintegration rates 262, 263
  - activity and counting rate 235–239
  - choice of detectors for 256–258
  - coincidence and anticoincidence circuits for 263
  - detectors used in health physics for 269–271
  - gas-filled detectors 239–247
  - low-level counting 263, 264
  - neutron detection and 264, 265
  - scintillation detectors 248–250
  - semiconductor detectors 250–256
  - spectrometry methods for 259–262
  - track detectors for 266–269
- neutrons, emission of 227–232
- scattering of 745, 746, 803–805
- nuclear radii 57–63, 87, 124, 501
- nuclear reactions
  - center-of-mass system 363, 364
  - chemical effects of 477
  - collision kinematics of 362–364
  - coulomb trajectories in 364–368
  - cross-sections 368–372
  - difference with chemical reactions 361, 362
  - elastic scattering 372–379
  - - and reaction cross-section 379–383
  - excitation functions for 384
  - grazing trajectory 366
  - heavy ions 422–424
  - - deep inelastic collisions 440–457
  - - fusion reactions 424–434
  - - quasi-fission 434–440
  - - relativistic collisions 457–460
  - investigation of 386
  - models for 385
  - - compound-nucleus model 386–403
  - - direct reactions 404–407
  - - fission 407–418
  - - high-energy reactions 418–422
  - - investigation 386
  - - photonuclear reactions 407
  - - precompound decay 403, 404
  - optical model for 383–385
  - radiation-induced 805–807
  - radioactive products found after 482
  - rate of production 370
- nuclear reactors 553, 554, 559, 687, 783
  - Calder Hall type 522, 525
  - controlled thermonuclear reactors (CTR)s 552–554
  - dismantling of 545
  - energy production by 525
  - most widely used 526
  - natural reactors at Oklo 551
  - neutron-induced reactions in 312
  - neutron spectrum in 308, 734
  - radionuclides, production of 311–316
  - types of 524–532
- nuclear resonance absorption 170
- nuclear spectroscopy 80, 119, 182, 339, 346, 426
- nuclear structure
  - charge independence and isospin 76–80
  - collective excitations in 110–117
  - and collective motion in nuclei 94–101
  - fermi gas model of 82–84
  - forces associated with 73–76
  - interacting boson approximation in 108–110
  - macroscopic–microscopic model of 106–108
  - Nilsson model of 101–103
  - nuclear matter associated with 81, 82
  - pairing force and quasi-particles 104–106
  - rotational and vibrational states 100
  - shell model of 84–94
    - spin-orbit splitting, energy levels of 90
  - nuclear transmutations
    - - excitation effects 471–476
    - - gases and liquids 476–479
    - - general aspects of 465, 466
    - - recoil effects 466–471
    - - recoil labeling and self-labeling 484, 485
    - - solids 479–482
    - - Szilard–Chalmers reactions 482–484
  - nuclear vapor 422, 458
  - nuclear waste repositories 832, 833
  - nucleon–nucleon collisions 421
  - nucleon–nucleon interaction 42, 86, 116
  - nucleon–nucleon potential 74, 76, 86
  - nucleon–nucleon scattering 73, 76, 385
  - nucleosynthesis 681, 682, 690–692, 707
  - nucleus– $\alpha$ -particle system, potential energy for 122
  - nucleus–nucleus collisions 459, 460
  - nucleus, schematic representation of 2
  - nuclides
    - angular momentum of deformed 97
    - $\beta$ -decays of 46
    - binding energy 39–47

- charts of 34–38
- collective motion in 94–101
- electric moment for 68
- excited states of 70
- ground states of 70
- liquid-drop model of 47
- magnetic moments of 66
- proton–neutron model of 36
- radionuclides, *see* radionuclides
- surface diffuseness of 58
- Woods–Saxon potential of 59–60
  
- o**
- oligomers 846
- one-body dissipation 437, 449
- optical diffraction 57, 58
- optical microscopes 267, 725
- orbital angular momentum 3, 12, 49, 63, 66, 87, 91, 102, 125, 155, 156, 162, 405, 438, 440, 487
- orbital electron 7, 8, 158, 179, 213, 689
- organic compounds, self-labeling of 484, 485
- oscillator frequency 574
- Ostwald ripening 295, 776
- oxidation-state distributions 839, 841
- oxidation states 4, 818, 837
- oxidizing agents 590, 592, 628, 837
- oxyhydroxo colloids 841
  
- p**
- pairing energy 43–47, 119, 129, 395, 408
- paper chromatography 258
- partially conserved axial vector currents, hypothesis of 166
- particle–hole excitation 385
- particle-induced X-ray emission (PIXE) 260, 748, 750
- particle physics, standard model of 16–19, 161, 700, 703
- particle trajectories, Coulomb effects on 382
- Passivated Ion-implanted Planar Silicon (PIPS) detectors 640
- Pauli exclusion principle 18, 49, 69, 82, 104, 108, 421
- Penning traps 50–52, 344, 345
- schematic of 51
- periodic safety assessments (PSAs) 537
- Periodic Table of the Elements 1, 33–35, 582, 586, 630–632, 813
- perturbed angular correlations (PAC) 185, 490
- phase boundary 460, 772, 804
- phase oscillations 574
- phase shift 58, 374, 375, 377–379
- phase space factor 16, 150
- phase stability 569, 570, 574
- principle of 575
- phase transition 113, 422, 457, 458, 459, 620
- phonon 87, 89, 91, 98, 99, 227, 287, 354, 451, 452
- phonon energy 451, 452
- phosphorescence 23
- photocathodes 248, 249, 286
- photoelectric effect 158, 223–225, 252
- photoelectrons 244, 246, 249, 286, 578, 836
- energy of 223
- photoelectron spectroscopy 578
- photoelements 809
- photoexcitation 738
- photofission reactions 407
- photographic emulsions 266, 267, 418, 497
- photographic films, with nuclear emulsions 267, 270
- photomultipliers 248–250, 264, 270, 701, 751
- photon energy 115, 223, 224, 321, 502
- photon–photon interaction 226
- photons 8, 11–15, 18–20, 66, 115, 164, 173, 205–207, 219–226, 230, 233, 246–249, 256, 263, 286, 287, 313, 321, 324, 329, 347, 354, 407, 468, 470–472, 474, 476, 479, 491, 494, 499, 500, 577, 578, 682, 683, 691, 730, 734, 751, 753, 754, 756, 789, 790, 804, 805, 836, 850, 863, 868, 885
- activation by 738, 739
- high-energy 738
- sources 577, 578
- tagged 577
- photonicuclear reactions 223, 226, 407, 695
- photopeaks 226, 249, 256, 263, 286
- photo-stimulated luminescence (PSL) 306
- pH values 293, 843, 845
- pions
  - Compton wavelength of 74
  - decay 165, 170, 496, 701
  - half-life of 701
  - reabsorption of 407
- pitchblende 24, 26, 783
- Planck constant 3, 887
- plasma cooling 834
- plasma density 553
- plastic deformations 521
- plastic scintillators 250

- plutonium 33, 513, 514, 517, 521, 524, 525, 534, 541, 542, 548, 549, 551, 554, 583, 591, 620, 621, 624, 627, 755–758, 833, 843  
 – metallurgical properties of 521  
 – as nuclear fuel 521  
 – plutonium cycle 542  
 – redox chemistry 854  
 pocket ionization chambers 270  
 Poisson distribution 280–281, 286, 287  
 polonium, discovery of 24, 25  
 polyetherketone (PEEK) 303, 305  
 polynuclear hydroxide complexes 818, 820, 836, 846  
 polyvinyl acetate–polyvinyl chloride copolymer 302  
 portable counters and survey meters 269  
 positron annihilation 491, 495, 577  
 positron emission tomography (PET) 316, 324, 329, 783, 788, 790  
 positronium (Ps) 232, 233, 494–496  
 – annihilation, rate constant for 495  
 – reactivity of various compounds with 496  
 positrons 7, 8, 158, 172, 173, 219, 225, 232, 316–320, 324, 329, 491, 494, 495, 497, 577, 681, 697, 783, 788, 790, 795  
 potential energy surface (PES) 432, 446, 449–450, 455  
 potential scattering 378, 389, 390  
 ppi chain 689  
 precipitation 24, 25, 290, 293–295, 325, 336, 518, 520, 541, 545–547, 586, 587, 593, 716, 722, 731, 744, 745, 776, 820, 822, 823, 825, 826, 831, 833, 836, 853  
 precision mass spectrometry 34, 49–55  
 precompound decay 385, 403–404  
 pressurized light-water reactor 832  
 pressurized-water (PWR) reactors 521, 523, 525, 528, 531, 534  
 – fuel element used in 524  
 primordial radioelements 34, 37  
 prolate deformation 102  
 promethium 582, 585–588  
 prompt gamma activation analysis (PGAA) 562, 734, 748  
 proportional counters 242–247, 250, 256–258, 263, 265, 270, 286, 336, 342, 698, 700, 715, 879  
 – measurement of various kinds of radiation 257  
 proton-induced gamma emission (PIGME) 748, 752  
 proton–proton collision 459  
 proton radioactivity 9, 129–130, 132  
 –  $\beta^+$ -delayed proton emission 131  
 – energy requirements for 129  
 protons 2, 9, 18, 25, 35, 36, 42, 43, 57, 62, 63, 68, 75–78, 82, 83, 89, 91, 103, 106, 109, 115, 116, 124, 135, 173, 205, 206, 228, 230, 264, 265, 301, 307, 318, 319, 323, 324, 343, 344, 361, 388, 392, 395, 403, 407, 409, 411, 417, 418, 420, 446, 470, 471, 561, 565, 571, 575, 615, 680–685, 688, 696, 698, 705–707, 712, 716, 734, 746, 748, 750, 791, 794, 795, 824, 842, 885  
 – inelastic scattering of 748  
 – magnetic dipole moment of 65  
 – separation energies of 43  
 proton synchrotron (PS) 575  
 Prout's hypothesis 35  
 pseudocolloids, *see Fremdkolloide*  
 pseudoscalars 160, 163  
 pulse-height analysis system, schematic diagram of 259  
 pulse-height distributions, statistics of 285–287  
 PUREX process 541, 542, 545, 547–550, 625  
 Pygmy resonance 354, 355  
 pyrometallurgy  
 – concept of 543  
 – for electrodeposition of actinides 544
- q**
- quadrupole moment 74, 94, 95, 112, 141, 178, 179, 345, 490, 491, 501  
 – electric 67–69  
 – experimental and theoretical 141  
 quantum chromodynamics (QCD) 74, 459  
 quantum electrodynamics (QED) 651  
 quantum mechanics 2  
 – scattering 372  
 – sharp cutoff 380  
 – tunneling 189, 228  
 – zero-point motion 451  
 quantum number 3, 45, 63–65, 69, 77, 78, 87, 89, 101–104, 158, 165–167, 179, 181, 184, 339, 353, 398, 488, 616, 617  
 quark–gluon plasma (QGP) 422, 457, 459, 682  
 quarks 18, 74, 164, 165, 167–169, 422, 457, 459, 681, 701  
 – composition of 19  
 – properties of 16, 17  
 quasi-elastic transfer reactions (QE) 405, 423, 434

- quasi-fission (QF) reactions 402, 423, 432, 434–440  
 – angular distributions of 437  
 quasi-particle random-phase approximation (QRPA) 354, 355  
 quasi-particles 104–106, 354, 385, 616, 618  
 quenching 250, 336, 352, 850–852  
 $Q$  value 41, 42, 126, 127, 148, 189, 339, 361, 362, 364, 406, 448, 466, 469, 470, 507
- r**
- radiation annealing 481  
 radiation decomposition 301, 482, 484, 531, 546, 797  
 radiation dosimetry, *see* dosimetry  
 radiation emission, impact of chemical environment on 490–498  
 radioactive decay 3, 27, 41, 807, 808  
 – branching 199, 200  
 – characteristics of 8  
 – energy of 189–191  
 – Geiger–Nuttall rules for 120, 121  
 – half-life  
 – of mother and daughter nuclide 197  
 – similar 198  
 – laws of 9, 11, 189–191, 201  
 – modes of  
   – alpha decay 119–126  
   – beta decay 148–170  
   – cluster radioactivity 126–129  
   – electromagnetic transitions 170–185  
   – nuclear instability and nuclear spectroscopy 119  
   – proton radioactivity 129–131  
   – spontaneous fission 132–147  
 – photomultipliers 250  
 – radioactive equilibria 191–193  
 – attainment of 193  
 – secular 193–195  
 – transient 196, 197  
 – successive transformations in 200–202  
 – time dependence 10, 11  
 – types of 6–11  
 radioactive disequilibria 712, 724–725, 818  
 radioactive equilibrium 191–193  
 – attainment of 193  
 – secular 193–195  
 – transient 196, 197  
 radioactive ion beams 576, 577  
 radioactive substances 24, 25, 191  
 – chemical separation of 258  
 – detection limits of 729  
 – effects of radiation from 326, 870  
 – handling of 801  
 – methods for confinement of 792  
 – microamounts of 292–297  
 – in nature 26–29  
 – risk of contamination 801  
 – special regulations 875–879  
 radioactive tracers 299, 644, 730, 742, 784, 803  
 radioactive transmutations 680  
 radioactive waste 544–551, 752, 813, 876, 877, 879, *see also* spent fuels  
 – handling of 878  
 – reprocessing of 543  
 – safe disposal of 537, 739, 832  
 – storage of 525, 818  
 radioactivity  
 – decay of, *see* radioactive decay  
 – discovery of 23–26  
 – measurement of  
   – experimental applications for 283–285  
   – maximum likelihood method for 282, 283  
   – probability and probability distributions for 275–281  
   – pulse-height distributions for 285–287  
   – random variables, distribution of 273–275  
   – upper limits when no counts are observed 287, 288  
 – sources of 813–815  
 radioanalysis  
 – of absorption and scattering of radiation 745, 746  
 – accelerator mass spectrometry (AMS) 757–761  
 – of activation by  
   – charged particles 736, 737  
   – photons 728–739  
 – applications of radiotracers for 745  
 – on basis of inherent radioactivity 730–732  
 – general aspects of 729, 730  
 – with ion beams 748–752  
 – isotope dilution analysis (IDA) 741–743  
 – neutron activation analysis (NAA) 732–735  
 – radioisotope mass spectrometry 752  
 – radiometric methods for 743–745  
 – resonance ionization mass spectrometry (RIMS) 752–757  
 – special features of 739–741  
 – X-ray fluorescence analysis 746–748  
 radiocarbon dating 27, 706, 755, 758  
 – cosmogenic radionuclides applicable for 712–717

- fission tracks 725, 726
- general aspect of 711, 712
- natural decay series 720–723
- radioactive disequilibria and 724, 725
- stable isotopes, ratios of 723, 724
- terrestrial mother/daughter nuclide pairs suitable for 717–719
- radiochemical detectors 698
- radiochemical neutron activation analysis (RNAA) 741
- radiocolloids 293, 297–299, 818, 819, 821, 822
- autoradiograph of 297
- generation of 298
- radioecology 784, 827, 829
- radioelements 34
  - actinides and transactinides, spectroscopy of 615–618
  - $^{48}\text{Ca}$ -induced fusion reactions 604–606
  - chemical separation of 593
  - cold-fusion reactions 598–604
  - cross-sections 606–610
  - hot-fusion reactions 594–598
  - natural and artificial 581–585
  - production of 588–594
  - promethium 585–588
  - superheavy elements, nuclear structure of 610–615
  - technetium 585–588
- radio frequency oscillator 569
- radio frequency (rf) power 570
- radio-gas chromatography 258
- radiographic imaging (RI) 305
- radioimmunoassay 785
- radioimmunotherapy 316
- radioisotope mass spectrometry 752
- radioisotopes 191, 472, 477, 729, 752, 754, 755, 758, 761, 783, 795, 813, 819, 821, 822, 827, 830
  - carrier-free 292
  - non-isotopic carriers for 290
  - production of 300
  - short-lived 338
- radiolysis 542, 546, 622, 867
  - formation of hydrogen by 531
- radiolytic decomposition 816
- radiometric titration 730, 744, 745
- radionuclide farms 796
- radionuclide generators 315, 321, 329–331, 341, 543, 788, 795, 801
  - development of 783
- radionuclides 226
  - absolute activities of 263
  - application of, for thickness measurements 804
- artificial 831
- batteries 807–809
- in biosphere 826–832
- chemistry of
  - beam intensity and fluxes 306–308
  - decay-scheme studies 339–341
  - for determination of half-lives 337–339
  - epithermal neutrons and resonances 310, 311
  - in-beam nuclear reaction studies 342–355
  - microamounts 292–297
  - neutron spectrum in nuclear reactors 308
  - preparation of samples, for activity measurements 336, 337
  - radiocolloids 297–299
  - reaction rates in thermal reactors 311
  - role of carriers in 289–291
  - short-lived radionuclides 289–291
  - specific activity 291, 292
  - target preparation 300–306
  - thermal neutrons 308–310
  - tracer techniques 299, 300
  - use of recoil momenta and 331–336
- concentration factors, in ecosystems 830
- from cosmic rays 706
- counting rate of 235–237
- decay curves of 235
- detection limits of 730
- disintegration rate of 189, 190
- distribution of, in animals 829
- dose rate constants 865
- electrolytic deposition of 325
- in geo- and cosmochemistry
  - abundance of Li, Be, and B 707, 708
  - cosmic radiation 705, 706
  - cosmic-ray effects in meteorites 706, 707
  - early stages of the universe 681–683
  - general aspects 680
  - interstellar matter 704, 705
  - natural abundances of elements 677–680
  - radionuclides from cosmic rays 706
  - solar neutrino problem 696–704
  - synthesis of the elements in the stars 683–696
- in geosphere
  - interactions with solid components 823–826
  - radioactivity, sources of 813–815
  - reactions with components of natural waters 818–823
  - solubility 816–818

- half-lives of 190, 814, 815
- in human body 828, 866
- of heavy elements 291
- of high specific activity 291, 292
- hydrolysis of 299
- identification of 259
- in life sciences
- ecological studies 784
- labeled compounds 790–797
- nuclear medicine 783, 787–789
- physiological and metabolic studies 786, 787
- positron emission tomography (PET) 790
- radioanalysis 784–786
- single-photon emission computed tomography (SPECT) 789, 790
- long-lived impurity 238
- mass of 289
- metabolism of 827
- microamounts of 292–297
- migration of 1
- natural abundances of 677–680
- natural radionuclides 831
- observed ratio 830
- primordial 34, 37
- production by
- accelerators 318–324
- nuclear reactors 311–316
- radionuclide generators 329–331
- separation techniques 324–328
- as radiation sources in X-ray fluorescence analysis 746–748
- radiotoxicity of 865, 866
- ratio of the activities of 687
- short-lived 289–291
- impurity 237
- sorption of 293
- speciation techniques 832–837
- homologs Th(IV) and Zr(IV), investigation of 842–850
- redox reactions, hydrolysis, and colloid formation 837–842
- time-resolved laser-induced fluorescence 850–854
- specific activity 191
- technical and industrial applications of
- absorption and scattering of radiation 803–805
- energy production by nuclear radiation 807–810
- radiation-induced reactions 805–807
- radiotracer techniques 801–803
- terrestrial pairs of, applicable for dating 717–719
- transfer of, to meat (or milk) 830
- X-ray emitting 260
- radiopharmaceuticals 1, 572, 790, 795, *see also* nuclear medicine
- radiophotovoltaic conversion 808, 809
- radiophotovoltaic (photoelectric) radionuclide batteries 809
- radioreagents 744
- radiotherapy 316, 788, 868, 872
- radiotoxicity 742, 815, 865, *see also* radiotherapy
- of radionuclides and radioelements 866
- of spent fuel 548, 832
- radiotracers 743, 784, 786, 801–803
- application of 745, 765
- chemical equilibria and chemical bonding in 765, 766
- for diffusion and transport processes 776–778
- emanation techniques 778–781
- general aspects of 765
- reaction mechanisms in
- heterogeneous systems 772–776
- homogeneous systems 767–772
- radium 24, 27, 33, 410, 582, 722, 778, 783
- range straggling 212, 214, *see also* energy straggling
- rate constant 495, 634, 768, 770, 772, 773, 828, 864, 865
- Rayleigh scattering 223, 224, 226, 804, 805, 834
- reactor irradiations 300, 593
- real colloid, *see* *Eigenkolloide*
- recoil chemistry 465
- recoil energy 42, 120, 223, 331, 332, 337, 345, 363, 448, 449, 466–480, 484, 500, 778
- recoil labeling and self-labeling 484, 485, 797
- recoil transfer chamber (RTC) 636, 666
- recrystallization 293, 522, 721, 726, 774–776, 824, 825
- redox reactions 624, 771, 837–842
- reduced transition probability 111, 175, 176, 179
- reducing agents 590, 622, 626, 837
- relativistic heavy-ion collider (RHIC) 460, 575
- relativistic mechanics 12–14
- research reactors 149, 300, 311, 314, 514, 521, 524, 525, 561–563, 730
- resonance ionization laser ion source (RILIS) 344
- resonance ionization mass spectrometry (RIMS) 752–757
- setup for 756

- resonance neutrons 227, 308  
 resonance scattering 377, 378, 390  
 resonant ionization, principle of 753  
 retention 466, 474, 475, 481, 483, 635, 639,  
   640, 827  
 reversed-phase partition chromatography  
   (RPC) 326  
 REX-ISOLDE isotopes 344  
 ripening, mechanism of 776, *see also*  
   Ostwald ripening  
 rotating liquid-drop model (RLDM)  
   400–402, 430  
 Russel–Saunders coupling 63  
 Rutherford backscattering (RBS) 750–751  
 Rutherford, Ernest 4  
 Rutherford scattering 4–6, 57, 305,  
   372  
 Rydberg constant 3  
 Rydberg states 754, 756
- s**  
 Saddle point 136, 137, 397–402, 416, 430,  
   609, 610  
 saturation current 10, 241  
 scanning electron microscopy (SEM) 305,  
   834, 843  
 scattering amplitude 58, 375, 383  
 scattering length 227, 375  
 scattering phase 58, 370, 374, 375, 378  
 scattering resonance, *See* Lorentz curve  
 Schottky mass spectrometry (SMS) 53  
 Schrödinger equation 49, 84–86, 102, 121,  
   376, 378, 428  
 scintillating liquids 249  
 scintillation detectors 248–250, 259, 264,  
   739, 879  
   – measurement of various kinds of  
     radiation 257  
 Seaborg's actinide hypothesis 592  
 secondary-ion mass spectrometry (SIMS)  
   751  
 Selective Actinide EXtraction (SANEX)  
   process 548, 549  
 self-diffusion 300, 776, 777  
 self-labeling, of organic compounds 484,  
   485, 797  
 self-shielding 301  
 semiconductor detectors 176, 250–257,  
   263–265, 287, 337, 342, 739, 748, 750, 751,  
   760, 836  
 semiconductors  
   – depletion zone 253  
   – intrinsic 253  
   – n-type 253  
   – p–n barrier 253  
   – p-type 253, 809  
 semiconductor spectrometers 285  
 semiempirical mass equation 42, 45, 82,  
   133  
 Separator for Heavy-Ion reaction Products  
   (SHIP) 333, 600, 609  
 sharp cutoff, Blair model for 104, 380  
 shell-correction energies 138, 142, 396,  
   611, 612  
 shell corrections 106, 107, 137, 138, 140,  
   142, 143, 212, 396, 416, 418, 608, 611,  
   612  
 shell structure in nuclei 47–49  
 shock waves 705, 834  
 simple surface barrier (SSB) detectors 254,  
   257, 596, 752  
 sine wave 377, 378, 569  
 single-particle resonances 387  
 single-photon emission computed  
   tomography (SPECT) 324, 783, 789,  
   790  
 Si p–i–n diodes 255  
 SISAK system 650, 651  
 Slater determinant 85  
 slowing-down radiation 577  
 smooth cutoff, McIntyre model for 380,  
   381  
 solar neutrinos 150, 696–704  
 Solar Neutrino Units (SNUs) 698  
 Solar System 677, 680, 685, 686, 694, 708,  
   721, 723  
 solar wind 706  
 solid diffusion 774  
 solid scintillation 250  
 solid solutions 325, 721, 816, 823, 825  
 solid-state detectors 219, 226, 250, 597  
 solid-state ionization chambers, *see*  
   semiconductor detectors  
 solid-state nuclear track detectors (SSNTDs)  
   128  
 solid track detectors 250, 268  
 sols 298  
 solubility of radionuclides, in geosphere  
   816–818  
 solvent extraction 257, 290, 296, 325, 326,  
   541, 547, 743, 835, 839  
 Sommerfeld parameter 111, 365, 442  
 sorption 292, 293, 296, 298, 325, 336, 546,  
   659, 666, 794, 816, 821–826, 829, 834, 846,  
   850, 853  
 spallation 25, 264, 319, 342, 385, 420–422,  
   547, 561, 576, 706–708, 723  
 spark chambers 269

- spent fuels  
 –  $\beta$ -activity and heat production of 539  
 – composition of 540  
 – disposal of 537, 832  
 – radiotoxicity of 548, 832  
 – reprocessing of 537–544  
 – extraction procedures used for 542  
 spin-dipole resonance 62  
 spin fluctuations 491  
 spin-orbit coupling 64, 76, 89, 139, 384, 615, 630  
 spin-orbit interaction, effect of 49  
 spin-orbit splitting 89, 91, 351, 352, 615, 623  
 – energy levels of shell model with 90  
 spontaneous fission 126, 132–147, 594, 610, 680, 717, 725, 735  
 – fission yield as function of mass number for 147  
 – half-life for 133, 135, 146  
 – subsequent steps of 145  
 sputter-induced photon spectrometry (SIPS) 751  
 stable elements 842  
 – discovery of 33  
 standing waves 121, 570  
 Steinwedel-Jensen model, of giant dipole resonances 451  
 Stern-Gerlach experiment 66  
 Stirling's approximation 281  
 stripping reaction 404  
 substitution reactions 466, 477, 482  
 substoichiometric analysis, principle of 743  
 superconducting fragment separator (Super-FRS) 577  
 superconducting magnets 553, 575  
 superconductivity 113, 628  
 – BCS theory of 105  
 superheavy elements 53, 108, 142, 608, 609, 631  
 – chemical properties of 630  
 – isotopes of 455  
 – nuclear structure of 610–615  
 – shell structure of 668  
 – syntheses of 34, 563, 604, 606  
 supernova 684–686, 692, 695, 705  
 surface energy 42, 44, 45, 133, 135, 298, 400, 433  
 surface tension 42  
 swimming-pool reactors 529  
 synchrocyclotrons 571, 574–576  
 synchrotron oscillations 574  
 synchrotron rings 576  
 synchrotrons 53, 345, 553, 574–576, 578, 836  
 Szilard-Chalmers reactions 313, 470, 478, 482–484  
**t**  
 “tagged” photons 577  
 Taylor series 283  
 technetium 33, 538, 582, 585–588  
 tetramers 846–850  
 Th(IV) and Zr(IV) colloids, characterization of 843–850  
 thenoyltrifluoroacetone (TTA) 731  
 theory of relativity 12, 13  
 thermal annealing 481  
 thermal conversion 808  
 thermal diffusion 254  
 thermal electrons 250  
 thermal equilibrium 84, 308, 385, 387, 402, 438, 440, 681  
 thermal fluctuations 387  
 thermal flux 308–310  
 thermal ionization mass spectrometry (TIMS) 752  
 thermal neutron-induced fission 410, 411, 413, 414, 422, 547  
 thermal neutrons 83, 227, 231, 264, 265, 270, 301, 308–311, 313, 315, 316, 407, 408, 410–415, 422, 507, 508–513, 547, 555, 562, 591, 618, 726, 732–734, 736, 740, 746  
 – absorption of 469, 517  
 – flux density 312  
 thermal noise 250, 252, 253  
 thermal reactors 513, 514, 522, 530  
 – reaction rates in 311  
 thermionic conversion, principle of 809  
 thermochromatography (TC) 291, 326, 637, 638, 642, 657, 660, 664, 666, 795  
 thermodynamics, equilibrium-state 839  
 thermoluminescence 712  
 – dosimeters 270  
 thermonuclear explosions 593, 684, 692, 713  
 thermonuclear fusion 314  
 thermophotovoltaic batteries 809  
 thin-layer chromatography 258  
 Thomas-Reiche-Kuhn (TRK) sum rule 117, 354, 355  
 Thomson scattering 226  
 thorium minerals 26  
 three-photon annihilation 494  
 threshold energy 362, 618, 736, 795  
 time-of-flight-ion cyclotron resonance (ToF-ICR) 52, 53

time-of-flight mass spectrometer 755, 836, 847, 849  
 time-projection chamber (TPC) 243  
 time-resolved laser-induced fluorescence spectroscopy (TRLFS) 837, 850–854  
 Tokamaks 552  
 total center-of-mass kinetic energy (TKE) 434, 435  
 – element distributions as function of 445  
 total kinetic energy loss (TKEL) 364, 443, 447, 448  
 trace elements 742, 745, 748, 752, 784, 786, 823, 827  
 – activation of 739, 785  
 – chemical behavior of 819  
 – coprecipitation of 823  
 – diffusion coefficients of 777  
 – metabolism of 787  
 tracer techniques 299, 300, 745, 765, 766, 771, 776, 784, 786, 801  
 track counters 270  
 track detectors  
 – bubble chambers 268, 269  
 – cloud chambers (Wilson chambers) 268  
 – dielectric 267, 268  
 – for investigation of high-energy reactions 418  
 – photographic emulsions and autoradiography 266, 267  
 – solid-state nuclear track detectors (SSNTDs) 128  
 – spark chambers 269  
 transactinides 1  
 – chemical properties of 629, 630  
 – electronic configurations and oxidation states 630–632  
 – methods to investigate 632–653  
 – selected experimental results 653–668  
 – spectroscopy of 615–618  
 TransActinide Separator and Chemistry Apparatus (TASCA) 303, 304, 338, 636  
 transition energy 3, 67, 116, 501  
 translational velocity 363  
 transmission coefficient 121, 370, 374  
 transmission electron diffraction (TED) 843, 844  
 transmission electron microscopy (TEM) 834, 843  
 transuranic elements 34, 540, 813, 815  
 – production of 588–594  
 tributylphosphate (TBP) 542  
 tri-isoctyl amine (TiOA) 643  
 trimers 842, 850  
 trinitrotoluene (TNT) 508

triscarbonato complex 816  
 tritium 27, 314, 477, 484, 485, 553, 560, 561, 629, 713, 734, 735, 796, 801, 817  
 tumor-associated antibodies 316  
 two-nucleon system, states of 75, 78  
 two-photon annihilation 494

## **u**

ultracold neutrons (UCNs) 169, 227, 228, 525  
 UNILAC linear accelerator 570, 571, 576  
 United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 873  
 universal mass drift relaxation time 437, 438  
 uranic radiation 23  
 uranium and uranium compounds 26, 513, 514  
 – anisotropic thermal expansion of 521  
 – behavior in nuclear reactors 522  
 – long-lived members of 519  
 – modifications of 521  
 – as nuclear fuel 516, 519  
 – production of 517–520  
 – properties of 522  
 – recrystallization of 522  
 – separation scheme of 549  
 – uranium cycle 542  
 uranyl nitrate hexahydrate (UNH) 518, 542  
 UV-VIS absorption spectroscopy 837, 840, 852

## **v**

vacancy 3, 158, 179, 474, 496  
 vacuum evaporation 302  
 valence band 251, 252  
 valence electrons 48, 81, 251, 471, 498, 631, 771  
 Van Allen radiation belt 706  
 van de Graaff generators 565, 736  
 – schematic representation of 566, 568  
 – “tandem” principle 568  
 van der Waals repulsion 81  
 Viola systematics 434, 436, 441  
 vitrification 546  
 volume diffusion 777  
 volume energy 42, 45

## **w**

wave function 18, 63–64, 69, 75, 77, 79, 81, 82, 84–87, 94, 104, 121, 122, 129, 151, 155, 158, 160, 162, 175, 178, 227, 348, 350, 353, 372, 376, 384, 388, 398, 404, 428, 503, 630, 651

wave numbers 373, 376, 836  
Weisskopf formulas 175, 178  
Weisskopf units 175  
whole-body counters 271, 878  
“whole-number rule” 35  
Wien filters 333, 342  
Wilczinski diagram 441, 442, 444, 446  
Wilson chambers, *see* cloud chambers  
Wilzbach labeling 484  
Woods–Saxon potential, of nuclides 59, 60,  
  87, 102, 124, 384, 416  
World Health Organization (WHO) 807

**x**

X-ray fluorescence analysis (XFA) 260, 264  
– radionuclides as radiation sources in  
  746–748

– setup for 747  
X-rays 3, 180  
– absorption of 220  
– backscattering of 746  
– bremsstrahlung 206, 215  
– difference with gamma radiation 220  
– emission, due to nuclear decay 3, 8, 159,  
  260  
– emitters 260, 262  
– energies 4  
– energy range of 220  
– interactions of photons in 221, 223  
– scattering 804  
– spectrometry 250, 260

**y**

yrast line 112, 113, 394

