

## Index

### **a**

- absorber 213
  - gas 213
  - solid 213
  - thickness 219
- abundance
  - beryllium 561, 562
  - boron 562
  - carbon 382
  - cosmic rays 560
  - evolution 144–146
  - flow 157
  - forward or reverse flow 157
  - light elements 560
  - lithium 369, 559, 560
  - mole fraction 353
  - net flow 157
  - time-integrated net flow 352
- accelerator 207, 208
  - mass spectrometry 285
  - neutron production 210, 211
- accretion-induced collapse 453
- activation method 291, 343–345, 347
  - loss of radioactive nuclei 292
  - saturation 292, 347
- activity 42
- $\alpha p$ -process 491, 495, 497
- $\alpha$ -process 540
- angular correlation 262, 587, 588
  - alignment 588
  - attenuation factor 276, 601
  - coefficients 591
  - direct radiative capture 603
  - interference 594
  - isotropic 589
  - magnetic substates 588
  - mixed radiation 594
  - overlapping resonances 603

### **b** particle parameter 591

- pure radiation 591
- radiation 588
- radiation pattern 588
- secondary transition 602
- symmetric 590
- three-step process 598
- unobserved intermediate radiation 598
- well-defined parity 590
- angular distribution 82, 86, 590
- angular momentum coupling
  - examples 574
  - selection rules 135, 573
- antineutrino 59
- astrophysical S-factor 163–165, 173, 203
  - broad resonance 176
  - constant 165, 170, 180
  - definition 163
  - effective 173
  - energy-dependent 173–175
  - expansion 173, 177, 194
- Atkinson 1
- atomic K shell 223
- atomic number 2
- attenuation
  - neutrons 347
  - photons 228, 229, 234, 346
- Auger electrons 224

### **b**

- background
  - activity in materials 296, 298, 302
  - anticoincidence technique 298, 299, 310
  - beam-induced 242
  - bremsstrahlung 298, 306
  - charged particles 298–300
  - comparison of count rates 303, 310, 311
  - compilation of  $\gamma$ -ray energies 301

- background (*contd.*)
    - continuous 262
    - $\Delta E$ - $E$  technique 300
    - direct ionization by muons 303, 306
    - intrinsic detector activity 309
    - muon flux 309, 310
    - muon-induced 297, 300
    - neutron flux 309, 310
    - neutrons 309
    - neutron shielding 231, 232, 309
    - nuclear weapons testing 296
    - passive lead shield 302
    - photons 301
    - radon 296
    - sources 297
    - spontaneous fission 296
    - terrestrial 296
    - underground location 298, 304, 310
    - variation with time 298
  - backing 234
    - cleaning 234
    - contaminants 234
    - etching 234
    - material 234
    - resistive heating 234
  - beam
    - spot size 208
    - transport 208
  - $\beta$ -decay 58
    - allowed transition 63
    - average neutrino energy loss 60, 71
    - delayed particle decay 60, 531
    - density dependence of decay constant 66
    - energetics 59
    - Fermi theory 61
    - Fermi transition 65
    - forbidden transition 63
    - Gamow-Teller transition 65
    - laboratory decay constant 64
    - stellar decay constant 66, 67, 513
  - $\beta$ -limited CNO cycle 463
  - Bethe 1
  - big bang 5, 359, 552
    - abundance flows 556
    - nucleosynthesis 552, 555
  - binding energy 33
  - Boltzmann
    - constant 140
    - distribution 54, 151, 554
  - boundary condition parameter 119
  - Bragg peak 218, 219
  - Bragg's rule 220, 229
  - branching ratio
    - $\alpha$ -particle decay 258
  - nuclear reaction 262
  - photons 52, 267, 269, 271, 277
  - breakout from hot CNO cycles 487, 489, 492, 497
    - comparison of reaction rates 482
    - competition between reaction and  $\beta$ -decay 483
    - equilibrium abundance 484
    - sequences 480, 481, 491
  - Breit-Wigner formula 110, 114, 120–123, 130, 137, 177, 182, 194, 316, 340
  - bremsstrahlung 303
  - brown dwarfs 9, 14
  - burning front 453
- C**
- Cameron–Fowler mechanism 369
  - carbon burning 400
    - abundance evolution 404, 405
    - abundance flows 404, 405
    - branching ratios 402
    - $^{12}\text{C} + ^{12}\text{C}$  reaction 400
    - comparison of reaction rates 402, 403
    - $^{12}\text{C} + ^{16}\text{O}$  reaction 402
    - electron screening factor 404
    - experimental situation 406
    - explosive 449
    - final abundances 406
    - light particles 404
    - neutron excess parameter 404, 406
    - neutron source 404, 406
    - nuclear energy generation 403
    - primary reactions 400
    - secondary reactions 401
    - temperature dependence of  $^{12}\text{C} + ^{12}\text{C}$  rates 403
    - typical temperatures 401
  - central-limit theorem 246
  - Chandrasekhar limit 15, 24, 29, 438, 452
  - channel 83, 110, 116, 117, 126, 131
    - spin 574, 594
  - chart of the nuclides 3
  - chemical fractionation 4
  - CI carbonaceous chondrites 4
  - classical turning point 101, 102, 198
  - Clebsch–Gordan coefficient 573, 591
    - isospin 128
    - numerical value 573
    - symmetry properties 573
  - CNO cycles 15, 370
    - abundance evolution 378, 379
    - approach to steady state 378
    - branching ratios versus temperature 371, 372

- catalysts 370
- CNO1 cycle 370, 373, 461
- CNO2 cycle 371, 465
- CNO3 cycle 372
- CNO4 cycle 372
- cycle time 376
- evolution of energy generation rate 380
- experimental situation 382
- history 1
- neutrino energy loss 375
- nuclear energy generation 375, 376
- observational evidence 381
- reaction rates 373
- steady state abundances 374, 375
- steady state operation 374
- sum of abundances 374
- coincidence summing 271, 279, 347
  - decay scheme 272, 274
  - numerical correction method 274
  - summing-in 273
  - summing-out 273
  - visual inspection 274
- coincidence technique 304
  - scheme 304
  - setup 304
- collision
  - energy transfer 214
  - hard 214
  - maximum energy transfer 222
  - soft 214
- color-magnitude diagram 9
- common envelope phase 452
- competition cusp 137
- complex exponential 87, 88, 94, 137
- compound nucleus 125, 132
  - decay 127
  - formation 134
  - independence of formation and decay 134
  - level 125, 131, 187, 194
- Compton effect 225, 263
- angular distribution 226
  - Compton edge 226, 253, 263
  - continuum 263
  - maximum energy transfer 225
  - multiple scattering 263
  - probability 226, 227
  - recoil electron 225, 226
- conservation
  - angular momentum 118, 134, 573
  - charge 433
  - energy 225, 579
  - linear momentum 225, 579
  - mass 433
  - parity 134, 573
- contaminant 240, 241
- boron 240
- carbon 240
- fluorine 240
- continuity condition 88, 89, 95, 97
- continuum theory 132
- cosmic microwave background radiation 552
- cosmic radiation 297
  - flux 561
  - origin 561
- cosmic-ray spallation reaction 6, 369, 391, 559
  - cross section 560
  - nucleosynthesis 559
- cosmological parameters 553
- cosmological principle 553
- Coulomb
  - barrier 101, 115, 116, 137, 167, 168, 208, 349, 487
  - wave function 113, 114, 194, 196, 572, 595
- coupling constant
  - axial-vector 62
  - vector 62
- critical density 553
- cross section 163
  - absolute 328, 335
  - average 133, 135, 136, 138, 177, 202, 233
  - compound nucleus formation 134
  - continuum 202
  - definition 73
  - differential 75, 85
  - effective 341
  - elastic scattering 82, 85, 103, 107, 110
  - identical particles 182
  - interference 83, 110, 111, 203
  - maximum 132
  - Maxwellian-averaged 142, 179, 204, 205, 211, 503, 513
  - neutron 232
  - neutron capture 203, 204, 512
  - neutron capture on gold 345, 346
  - reaction 85, 103, 107, 109, 110, 118
  - relative 330
  - Rutherford 260, 336
  - total 75
  - $1/v$  law for neutrons 133, 177, 204, 232
- current density 75, 79, 83, 84, 88, 114, 142, 340
- d**
- dark energy 28
- dark matter 14
- de Broglie wavelength 76
  - numerical expression 317

- Debye–Hückel radius 197, 200  
 decay constant 144, 159  
   – definition 41  
   – effective 492  
   – identical particles 159  
   – ratio 149  
 $\delta$  electrons 214, 303  
 density  
   – of final states 62–64, 71  
   – mass 40  
   – number 40  
 detector 243  
   – charge collection 243  
   – energy calibration 257, 258  
   – energy resolution 245  
   – intrinsic response 244, 245  
   – pulse height 243  
   – pulse height variation 244  
   – threshold 245, 271  
 deuterium burning 13, 14, 359  
 Doppler broadening 338, 342  
 dripline  
   – neutron 37, 530  
   – proton 37, 480, 485–487
- e**  
 Eddington 1  
 effective stellar energy window  
   – charged-particle emission 181  
   – charged particles 166  
   – narrow resonances 187  
   – neutron emission 181, 182, 205  
   – neutrons 178, 179  
   – thermonuclear reaction 169  
 effective surface temperature 9  
 efficiency 246  
   – absolute 309  
   – calculation of total 269  
   – calibration for  $\gamma$ -rays 266  
   – intrinsic 246  
   – matching procedure for  $\gamma$ -rays 267  
   – peak 245, 246, 258, 259, 266, 267, 272  
   – summing 280  
   – total 245, 246, 269, 272  
 elastic scattering 35, 73, 78, 86, 129  
 charged particle on electron 346  
   – Coulomb 260  
   – experiment 259, 260  
   – interference 82  
   – multiple 342  
   – neutrons 89, 90, 93, 96, 98–100, 104, 105,  
     233  
   – protons 261  
   – resonance 111, 260, 336
- Rutherford 83, 113, 333, 335  
 electron  
   – density 69  
   – pickup 218  
 electron capture 59, 64, 68  
   – of  $^7\text{Be}$  363  
   – bound 68  
   – continuum 68, 364, 453  
   – laboratory decay constant 65  
   – of  $^{56}\text{Ni}$  492  
   – of  $^{59}\text{Ni}$  562  
   – stellar decay constant 69  
 electron degeneracy 15, 16, 22, 24  
   – brown dwarf 14  
   – factor 197, 199  
   – white dwarf 15  
 electronic noise 245  
 electron-positron annihilation 227, 263  
 electron screening 102, 197  
   – factor 197, 199–201, 206  
   – intermediate 199  
   – laboratory experiments 201  
   – narrow resonance 200  
   – potential 200  
   – strong 199  
   – weak 197, 199, 200  
 elementary charge 208  
 energy level diagram 36  
 energy loss 221, 223  
 energy transport in star 377  
 entropy 438, 441  
 e-process 432  
 equilibrium 147, 157, 158, 160, 205, 493  
   – condition 156, 157, 424  
 etched track detector 285  
 explosive burning 25  
 explosive hydrogen burning 460  
   – abundance evolution beyond CNO range  
     476, 477  
   – abundance evolution in CNO range 470,  
     473  
   – beyond CNO range 474  
   – branch point nuclei beyond CNO range  
     476  
   – branch point nuclei in CNO range 475, 480  
   – competition between reaction and  $\beta$ -decay  
     476  
   – experimental situation beyond CNO range  
     479  
   – final abundances beyond CNO range 477,  
     478  
   – final abundances in CNO range 471, 473  
   – nuclear energy generation 473, 474, 477,  
     478

- explosive hydrogen–helium burning 32, 480
  - abundance evolution 489, 491, 498, 499
  - abundance flows 488, 490, 496, 497
  - bottleneck nucleus 493
  - endpoint 489
  - experimental situation 499
  - nuclear energy generation 494, 495, 498, 499
- f**
  - Faraday cup 242, 243, 330
  - Fermi
    - function 63, 69
    - integral 64
  - Fermi’s Golden Rule 61
  - fluorine production 400
  - flux density 75
  - free particle 62, 76, 79, 80
    - wave number 570
  - freeze-out
    - $\alpha$ -rich 445, 452, 539
    - normal 445
  - ft-value 64
- g**
  - Galaxy
    - NGC 4526 621
    - age 7
    - halo 9
  - $\gamma$ -process 546
  - $\gamma$ -ray astronomy 8
    - $^{26}\text{Al}$  abundance 56, 450, 451, 478
    - annihilation radiation 474
    - $^{60}\text{Fe}$  abundance 451, 520
    - $^{44}\text{Ti}$  abundance 451
  - $\gamma$ -rays
    - absolute energy standards 264
    - absorption 270
    - attenuated Doppler shift 583
    - dipole or E2 rule 53
    - Doppler shift 49, 56, 266, 347, 581
    - multipolarity 49, 574
    - $4\pi$  detection method 279
    - primary branch 277
    - random summing 271
    - recoil shift 48, 347, 581
    - reduced transition probability 49
    - scattering 270
    - secondary branch 277
    - shielding 224, 229
    - sum peak 280
  - Gamow 1
  - Gamow factor 103, 114, 137, 163, 166, 167, 185, 192, 198
    - Gamow peak 167, 176, 185, 186, 189, 192, 196, 201, 369, 382, 388, 401, 406, 412, 474, 479
    - asymmetric shape 172
    - charged-particle emission 180
    - concept for narrow resonances 185, 187, 205
    - definition 166
    - $1/e$  width 169, 171
    - Gaussian approximation 168
    - location of maximum 166–168, 198
  - germanium detector 249
    - cooling 249
    - dead layer 249
    - energy calibration 266
    - energy resolution 249
    - high-purity 249
    - Monte Carlo simulation 249, 251, 268, 270, 272
    - pulse shape 249
  - globular cluster 8, 9, 21, 613
    - age 21
    - M 3 9, 613
    - M 10 9
- h**
  - half-life 41
  - Hauser–Feshbach
    - comparison of theory and experiment 202
    - formula 135, 137, 202
    - reliability of reaction rates 202
    - theory 152, 202, 352, 485, 500, 521, 551
  - helium
    - observations 554
    - primordial 554
  - helium burning 389, 390
    - abundance evolution 397–399
    - comparison of mean lifetimes 396
    - energy level diagram 391, 392
    - final abundances 398, 399
    - neutron excess parameter 399
    - nuclear energy generation 398
    - other reactions 399
    - reaction rate errors 398
    - temperature–density evolution 518, 519
    - typical hydrostatic conditions 390
    - weak s-process component 516
  - helium flash 32, 393
  - Hertzsprung–Russell diagram 10
    - evolutionary track 11, 17
    - M 3 9
    - red clump 21
    - solar neighborhood 9, 10
    - turn-off point 11, 16

- Hertzsprung–Russell diagram 9
- Hipparcos 10
- hot bottom burning 22
- hot CNO cycles 461, 462
  - abundance evolution 466–468
  - $\beta$ -limited 463, 468
  - branch point nucleus 464, 465
  - competition between reaction and  $\beta$ -decay 465
  - experimental situation 474
  - hot CNO1 cycle 463, 476
  - hot CNO2 cycle 465
  - hot CNO3 cycle 466
  - nuclear energy generation 469
  - time until H exhaustion 469, 470
  - transition from CNO1 to HCNO1 cycle 463
- Hoyle 2
- Hubble parameter 553
- Hubble's constant 553
- hydrostatic equilibrium 11, 13, 349
- hydrostatic hydrogen burning 353
  - abundance evolution beyond CNO range 386, 387
  - beyond CNO range 383
  - branch point nuclei beyond CNO range 385
  - branch point nuclei in CNO range 371
  - competition between reaction and  $\beta$ -decay 384
  - experimental situation beyond CNO range 388
  - observed abundances beyond CNO range 388
  - reaction rates beyond CNO range 386
- i*
- implantation
  - accelerating voltage 236
  - diffusion velocity 237
  - incident dose 237
  - lifetime of foils 237
  - saturation 237
  - self-sputtering 237
  - sputtering 237
  - substrate dead layer 237
  - target or sample 236–238
- inner Lagrangian point 27
- in-scattering effect 342
- instability strip 17, 20
- intensity
  - background 244
  - balance of cascading photons 267, 278
  - error 244
- overlapping peaks 244
- peak 244
- total 244
- interaction
  - nucleon-nucleon 77
  - radius 119
  - residual 125
  - strong nuclear 24, 77
  - weak 57
- interaction of radiation with matter 212, 213
  - charged particles 213
  - deflection of charged particles 213
  - energy distribution function 223
  - energy distribution function for charged particles 222
  - energy loss of charged particles 213, 346
  - energy straggling 261
  - neutron cross section 231
  - neutrons 230
  - photons 223, 227
  - range straggling 218, 326
  - recombination 214
- internal
  - conversion 48, 578
  - pair formation 48, 391, 578
- ion beam
  - charge integration 241, 242, 314
  - charge state 243
  - collimation 208
  - current 208
  - defining aperture 242
  - definition of energy 209
  - energy calibration 209, 210
  - energy calibration constant 209
  - energy spread 208
  - energy variability 208
  - power deposited in target 242
  - iron peak 5–7, 23, 32
- isobar 3
- isomer 54, 57
- isomeric state 54, 56, 57, 67
  - equilibration 55, 57
- isotone 3
- isotope 3
- k*
- K absorption edge 225
- K capture 59
- kinematics 259
  - after collision 584
  - binary interaction 579
  - center-of-mass frame 583
  - before collision 583
  - emission cone 211, 345, 582

- endothermic reaction 211, 581
- exothermic reaction 580
- inverse 285, 288, 347
- laboratory frame 579, 583
- population of excited state 582
- radiative capture 581
- relativistic effects 580
- transformation of angles 585
- transformation of solid angles 586
- Klein–Nishina formula 226
- Kronecker symbol 140, 144
  
- I***
- Legendre polynomial 80, 82, 84, 276, 590
  - associated 569
  - expressions 570
- level shift 114, 118, 119
- lifetime
  - effective of  $^{26}\text{Al}$  57
  - mean 41, 144, 145
  - total 145
- linear absorption coefficient 228
- liquid scintillator detector 253
  - efficiency 255
  - neutrons 254
  - pulse shape discrimination 255
- lithium problem 558
- logarithmic derivative 106, 108, 113, 117, 119, 127, 132
- luminosity 9
  
- m***
- magic numbers 2, 44, 45, 501, 503, 507, 523, 528
- magnet analyzer 209
  - calibration 209
- mass
  - atomic 37
  - excess 37
  - fraction 40
  - gaps 2, 3, 389
  - nuclear 33
  - number 2
  - relative atomic 38
  - thickness 229
- mass attenuation coefficient 224, 229, 230
  - compound 229
  - geometrical considerations 229
- matrix element
  - Fermi 62
  - Gamow-Teller 62
  
- Maxwell–Boltzmann distribution 140, 141, 166, 167, 178, 180, 193, 201, 211, 212, 341, 345
- energy maximum 142
  - velocity maximum 142
- mean effective energy 312
- mean free path
  - neutrons 232, 309
  - photons 229
- measurement
  - direct 207
  - indirect 187, 207, 388, 474, 479
- metallicity 8
- microchannel plate detector 256
  - avalanche 256
  - intrinsic efficiency 256
  - ion feedback 256
  - multiplication factor 256
  - sensitivity 256
  - timing property 256
- minimum ionizing particles 216, 298
- mixing ratio 594
  - channel spin 577, 594
  - $\gamma$ -ray 53, 578, 594
  - orbital angular momentum 577, 594
  - sign convention 594
- mole fraction 40, 438, 441
- Monte Carlo simulation
  - attenuation factor 276, 602
  - $\gamma$ -ray background 303
  - $\gamma$ -ray spectrum 264
  - neutron detector efficiency 284
  - neutron scattering 342
  - peak efficiency 266
  - summing of  $\gamma$ -rays 280
  - total efficiency 270, 272
- muon peak 299, 303
  
- n***
- Nal(Tl) detector 252
  - energy resolution 252
  - hygroscopy 252
- neon burning 407
  - abundance evolution 410, 411
  - abundance flows 410, 411
  - comparison of reaction rates 407, 408
  - energy level diagram 408, 409
  - experimental situation 412
  - explosive 449, 547
  - final abundances 412
  - light particles 410
  - neutron excess parameter 410
  - nuclear energy generation 409, 566
  - photodisintegration 407

- neon burning (*contd.*)
    - secondary reactions 407
    - stellar  $\beta$ -decay constant 410
    - temperature dependence of energy generation 410
    - typical temperatures 408
  - neutrino 7
    - burst 438, 439
    - capture 59
    - escape from star 23, 58, 60, 61, 162, 350, 355, 433
    - interactions 438, 440, 441
    - sphere 438, 440
  - neutron
    - absorber 283, 309
    - attenuation 233, 292
    - beam 210
    - beam energy resolution 211
    - decay 58
    - elastic scattering 231
    - excess parameter 58
    - exposure 506
    - fast 231
    - flux 506
    - half-life 501
    - moderator 231, 282, 283, 309
    - multiple scattering 292
    - slow 231
    - thermal 231, 281
    - transmission 232, 233
    - transmission for compound 233
  - nuclear
    - level density 136, 202, 552
    - matrix element 48, 62, 64, 65, 69
    - radius 119
    - spectroscopy 256
  - nuclear burning 11
    - core 349
    - duration 350, 351
    - shell 349
    - stages 349
  - nuclear energy generation 168, 349
    - comparison of pp1 chain and CNO1 cycle 376, 377
    - rate 161, 162
    - temperature dependence 170
    - total 162
  - nuclear reaction 35, 73
    - direct capture 356, 395
    - endothermic 36
    - energetics 35, 36
    - exothermic 36
    - experiment 260, 261, 337
    - forward and reverse 147, 148
  - identical particles 144, 146
  - network 146, 349, 378
  - neutron capture 7, 351
  - neutron production 211
  - radiative capture 35, 150, 207
  - three-particle 146
  - nuclear spin 46
  - nuclear state
    - decay probability 126
    - formation probability 126
    - natural parity 575
    - single-particle 125, 126
    - unnatural parity 395, 575
    - virtual 125
  - nuclear statistical equilibrium 432, 438, 539, 546, 566
    - composition of matter 433–436
    - explosion 445
    - light particles 434, 435
    - time to reach equilibrium 436, 437
  - nucleon
    - fraction 41
    - number 2
  - nuclide 2
  - $\nu p$ -process 442
  - $\nu$ -process 441
- o**
- one-level, many-channel approximation 118
  - orthogonality 84
  - oxygen burning 412
    - abundance evolution 417, 418
    - abundance flows 416, 417
    - branching ratios 415
    - comparison of decay constants 413
    - comparison of reaction rates 415
    - electron screening factor 416
    - experimental situation 414, 419
    - explosive 449
    - explosive temperature–density evolution 549, 550
    - final abundances 418
    - light particles 419
    - neutron excess parameter 418
    - nuclear energy generation 416
    - $^{16}\text{O} + ^{16}\text{O}$  reaction 412, 414
    - primary reactions 412
    - secondary reactions 413
    - stellar  $\beta$ -decay constant 419
    - temperature dependence of  $^{16}\text{O} + ^{16}\text{O}$  rate 416
    - typical temperatures 413
    - weak interactions 418

**p**

- pairing effect 47, 526, 545
- pair production 61, 225, 227, 263
  - probability 227
  - Z-dependence 227
- parity 570, 573
- partial wave 80–82, 86
- partial width 110–112, 126
  - charged particle 184
  - entrance channel 116
  - formal 120
  - $\gamma$ -ray 50, 52, 122, 184, 277
  - neutron 114, 177, 184
  - observed 120, 130, 131, 137, 195
  - particle 112, 114, 118, 126
  - proton 122, 130, 131
  - reaction 114, 116
  - single-particle 128
- particle
  - current 74
  - density 79, 88
  - flux 73, 88, 126
- partition function 54
  - normalized 151, 155, 159, 161, 352, 418
- Pauli exclusion principle 14, 42, 43
- peak
  - back-scattering 264
  - double-escape 263, 266
  - full-energy 263, 264, 282
  - single-escape 263, 266
- penetration factor 113–115, 119, 128, 190, 194, 196, 602
  - charged particles 114–116
  - neutrons 114, 115
- pep reaction 356
- phase shift 81–83, 85, 86, 89–92, 98, 103, 106, 107, 112, 133, 135, 595
  - Coulomb 113, 595
  - energy derivative 112, 120
  - hard-sphere 595
- phase space 71, 75
- photodisintegration reaction 35, 141, 142, 144, 150, 157, 180, 480
  - decay constant 143, 155, 191
  - temperature dependence of decay constant 181
- photoelectric effect 223, 262
  - photoelectron 223
  - probability 224
  - Z-dependence 224
- photon density 143
- Planck radiation law 143
- plane wave 62, 78, 79, 88, 94
- plastic scintillator detector 253
  - anticoincidence shield 254, 283
  - Compton edge 254
  - muon peak 254
  - room background spectrum 253, 254
  - shapes 253
- Poisson distribution 244
- positron
  - capture 68
  - emission 59, 60
- potential
  - average 125
  - central 77, 81, 569
  - centripetal 115, 137, 178, 570
  - Coulomb 83, 101, 102, 214, 572
  - effective 77
  - global parameters 202
  - local parameters 202
  - nuclear 83, 85, 86, 111
  - optical model 133, 552
  - screened Coulomb 197, 198, 206
  - single-particle 104, 105, 111, 127, 129
  - square-well 86, 92, 101–104
  - square-well plus square-barrier 93, 94, 104, 164
  - Woods-Saxon 44, 105, 129
- pp chains 15, 353, 355
  - $^2\text{H}$  abundance evolution 357, 359
  - $^3\text{He}$  abundance evolution 357, 359
  - comparison of mean lifetimes 361, 362
  - competition 365, 368
  - experimental situation 369
  - history 1
  - neutrino energy loss 364
  - nuclear energy generation 362, 364, 367, 368
  - pp1 chain 356
  - pp1 chain operation in Sun 368
  - pp2 chain 363
  - pp3 chain 364
- p-process 542
  - abundance flows 550
  - branching condition 546
  - branch point nucleus 551, 568
  - decay constant 547
  - experimental situation 551
  - final abundances 551
  - hot photon environment 544
  - network calculation 549
  - p-nucleus 504, 542
  - sites 547, 549
  - solar system abundances 542
  - underproduction of nuclides 548, 551

- presolar grains 4
  - primordial deuterium abundance 359
  - proportional counter 255, 282
    - charge carriers 255
    - gas mixture 255
    - ionization avalanche 255
    - moderated 281, 283
    - neutron detection 255
    - quencher 255
    - response function 281
  - pulse height deficit 258
  - pulse height spectrum 244, 245
    - americium source 248
    - charged particles 336
    - coincidence 306
    - elastic scattering 259, 260
    - europium source 249, 250
    - heavy ions 290
    - neutrons 281
    - nuclear reaction 261
    - photons 262, 278
    - room background 264
  - pulse pileup 271
  
  - q**
  - quantum number
    - magnetic 80, 118, 569, 573, 588
    - orbital angular momentum 569, 574
  - quasi-equilibrium 157, 419
    - cluster 424
    - explosion 446
  - Q-value 36, 38, 157, 161, 580
  
  - r**
  - Racah coefficient 591
  - radioactive ion beams 286, 474, 479, 499
    - batch mode technique 286
    - fragmentation 286
    - ISOL technique 286, 287
    - production 289
    - target chemistry 287
  - radioactive source
    - absolute activity 275
    - $\alpha$ -particle 257
    - $\gamma$ -ray 264
    - neutron 283–285
  - radius parameter 119, 196
  - range
    - mean 218, 219, 257
    - in silicon 218, 220
  - reaction rate 139, 144
    - broad resonance 176, 192, 193, 195
    - cutoff factor 174
    - cutoff temperature 175, 176
  - definition 140
  - elevated temperatures 150
  - equilibrium 150
  - errors 188, 352, 383, 485
  - evaluation 352
  - identical particles 161
  - influence of excited states 190
  - laboratory 151, 155
  - narrow resonance 183, 194, 195
  - neutrons 142
  - nonresonant charged-particle-induced 165, 170, 173, 194
  - nonresonant neutron-induced 177–179, 205
  - numerical integration 163, 176, 193, 194, 205
  - particle-induced 163
  - per particle pair 141
  - ratio 149
  - stellar 151, 154, 155, 189
  - stellar ratio 155
  - temperature dependence 170, 176
  - temperature dependence for narrow resonance 183, 184
  - total 201, 202
- reciprocity theorem 76, 77, 116, 134, 147, 159, 180
- recoil separator 289
- recommended upper limit (RUL) 51
- reduced width 112, 114, 117, 120, 122, 125, 128
- dimensionless single-particle 128, 129, 138
- observed 120
- resonance
  - absolute energy 210
  - absolute strength 329, 333
  - broad 165, 177, 201
  - energy 91, 92, 109, 112
  - energy derivative of phase shift 129
  - formal energy 114
  - formal theory 117
  - interference 122, 203
  - isolated 117, 118, 182, 338
  - narrow 112, 121, 210
  - observed energy 114, 119
  - overlapping 122, 134, 177, 202, 400, 412
  - phase shift 112, 118, 120
  - phenomenon 90, 92, 98–101, 104
  - recommended strength 334
  - relative strength 330
  - single-particle 104, 124, 125
  - strength 183–185, 195, 201, 316
  - subthreshold 121–124, 194, 201, 389, 394, 395

- total width 110, 210
- unobserved 389
- weak 382, 389
- R-function 117
- R-matrix theory 117, 395
  - pole 117
- Roche lobe 27, 453
- rp-process 487, 489, 495, 497, 499
- r-process 502, 504
  - boulevard 535
  - classical model 531, 532
  - comparison of observed and calculated abundances 534
  - constant temperature 532
  - dynamic model 537
  - equilibrium 524
  - experimental situation 541
  - fission 531
  - fission cycle 531
  - global description 534
  - nuclear mass model 532
  - nuclear properties 531
  - nucleochronology 531
  - path 528, 530
  - r-only nuclide 504
  - solar abundance peak 522, 531
  - solar system abundances 522
  - steady flow approximation 528, 533, 534, 541, 568
  - stellar abundances 537
  - superposition of components 534
  - temperature-density conditions 533
  - waiting point approximation 528, 530, 533, 568
- Rutherford formula 336
  
- s**
- Saha statistical equation 156, 158, 426, 433, 524, 566
- Salpeter 2
- sample 234
  - composition 241
  - gas 239
  - hygroscopy 241
  - material 235
  - neutron attenuation 239
  - neutron scattering 239
  - oxidization 241
  - self-supporting 235, 345
  - thickness 239
- scattering
  - inelastic 35, 159, 231
  - photon 229, 231
- scattering amplitude 79, 82, 83
  - hardsphere 107, 110
  - resonance 107, 109
- Schottky barrier 248
- Schrödinger equation 78, 86, 88
- Schrödinger equation 569
- scintillation detector
  - anode 252
  - BaF<sub>2</sub> 252
  - BGO 252
  - components 252
  - critical angle 251
  - dynode 250
  - energy calibration 266
  - fast response 251
  - fast timing 253
  - fluorescence 250
  - light guide 253
  - optical fibers 253
  - organic 253
  - phosphorescence 250
  - photocathode 250
  - photomultiplier tube 250, 252
  - reflective surface 251
  - transparency 250
- secondary electron emission 242, 243, 330
- selection rules
  - $\beta$ -decay 65
  - $\gamma$ -rays 49, 50, 577
- self-absorption of radiation 292
- self-regulating equation 357, 359, 506, 528
- semiconductor detector 246
  - bias voltage 247
  - charge carriers 247
  - energy resolution 247
  - junction 246
  - linear response 247
  - material 247
  - radiation damage 247
- separation energy 37
- shell model 42, 128, 130
  - configuration mixing 47
  - independent motion of nucleons 43
  - single-particle states 45
  - spin-orbit coupling 44
  - valence nucleon 47
- shift factor 113–115, 119, 120
- silicon burning 420
  - abundance evolution 422, 423
  - abundance flows 422, 423
  - comparison of decay constants 420, 421
  - complete 445
  - effective rate of <sup>28</sup>Si conversion 429
  - electron capture 424

- silicon burning (*contd.*)
  - evolution of quasi-equilibrium clusters 425, 426
  - experimental situation 432
  - final abundances 422
  - incomplete 447
  - light particles 422, 428, 566
  - neutron excess parameter 422, 424
  - nuclear energy generation 430
  - photodisintegration 422
  - quasi-equilibrium abundance 428
  - quasi-equilibrium cluster 422, 423
  - reaction chains 426, 427
  - typical temperatures 420
- silicon detector
  - ion implantation 248
  - junction 248
  - spectrum 248
  - surface barrier 248
- single-particle
  - eigenfunction 127
  - Hamiltonian 125, 126
- solar system abundance 4, 6
  - heavy nuclides 501
  - origin of nuclides 563
  - peaks 2, 5, 501
- Sommerfeld parameter 103
- spectroscopy
  - charged particle 257
  - factor 48, 128, 130, 131
  - $\gamma$ -ray 262
  - neutron 280
  - notation 44
- spherical
  - Bessel function 80, 113, 571
  - harmonics 80, 106, 127, 570
  - Neumann function 113, 571
  - wave 78, 79, 106, 108
- Spite plateau 558, 562
- spontaneous fission 283, 302
- s-process 20, 23, 503
  - abundance evolution 567
  - basic building blocks 505
  - bottleneck 510
  - branching 512
  - carbon burning 516
  - classical model 511, 513
  - compilation of neutron cross sections 521
  - constant temperature 506, 511
  - experimental situation 520
  - exponential distribution of neutron exposures 509
  - final abundances 518
  - flow pattern 518
- local equilibrium approximation 507
- main component 510, 514
- network calculation 518
- neutron poison 517, 518, 521
- neutron source 514–516, 520
- seed nuclei 510
- s-only nuclide 504
- stellar sites 514, 515
- strong component 511, 516
- termination point 505
- weak component 511, 516, 518, 548
- stars
  - asymptotic giant branch 11, 514
  - Betelgeuse 23
  - binary 12
  - binary system 26
  - carbon flash 22
  - carbon-oxygen white dwarf 20
  - carbon star 20
  - Cat's Eye Nebula 20, 616
  - classical Cepheid variable 21
  - classical nova 30, 470, 471, 473, 475, 478, 623
  - contact binary 27
  - core collapse 434, 438
  - Dumbbell Nebula 20, 615
  - early asymptotic giant branch 18
  - energy loss 61
  - evolutionary stages 13
  - first dredge-up 16
  - halo giant 538
  - helium flash 18
  - helium shell flash 22
  - helium white dwarf 15
  - high-mass X-ray binary 31
  - horizontal branch 11, 18, 20, 613
  - low-mass X-ray binary 32
  - main sequence 9, 10, 613
  - massive 17, 56
  - mass-luminosity relation 12
  - M dwarf 15
  - neon nova 623
  - neutron star 31, 619
  - neutron star merger 539
  - Nova Cygni 1992 31, 623
  - onion shell structure 24
  - oxygen-neon white dwarf 22, 623
  - planetary nebula 20, 22, 615, 616
  - planetary nebula nucleus 20
  - population I 8
  - population II 8
  - post asymptotic giant branch 19
  - pre-main sequence 12
  - proto-neutron star 25

- Proxima Centauri 15
- red clump 9
- red dwarf 9, 15
- red giant 613
- red giant branch 9, 11, 16
- Rigel 23
- RR Lyrae variable 21
- second dredge-up 22
- Sirius B 9
- structure of massive star 23, 24
- sub-Chandrasekhar white dwarf 30, 549
- subdwarf 9, 21
- subgiant branch 9, 11, 16
- super asymptotic giant branch 22
- supergiant 9, 23, 618
- thermal helium pulse 515
- thermally pulsing asymptotic giant branch 19
- thermal pulse 19
- third dredge-up 20, 22, 514
- T Tauri 14
- Tycho G 29
- type I X-ray burst 32, 495, 499, 544
- type II X-ray burst 32
- white dwarf 9, 15, 623
- Wolf-Rayet 24, 56, 617
- X-ray binary 31
- X-ray pulsar 32
- zero age main sequence 14
- statistical
  - data analysis 244
  - fluctuations 245
  - weight 54, 76
- steady state 147, 157
- stellar enhancement factor 152, 352, 418, 513, 522
- stellar evolution 11
  - temperature-density conditions 350, 351
- stellar rate ground state fraction 152
- stellar wind 22
- stopping cross section 214
- stopping power 215, 217, 311
  - Bethe–Bloch formula 215, 216
  - center-of-mass frame 315, 333
  - compilation 216
  - compound 220
  - effective 314, 320, 330, 332
  - electronic 215
  - interpolation 216
  - linear 214
  - LSS theory 215, 216
  - mass 214
  - nuclear 215
  - SRIM 216, 217, 314
  - tabulation 216
  - theoretical calculation 215
  - thin absorber 346
  - total 216
  - uncertainties 216
- sum peak method 275
- angular correlation 276
- Sun 614
  - age 7
  - central temperature 353, 368
  - evolution 16, 17
  - neutrinos 8
- super bubble 563
- supernova
  - Cassiopeia A 452
  - classification 25, 28
  - companion star 29
  - cosmological distance indicator 28
  - cosmology 28
  - Crab Nebula 26, 619
  - deflagration 30
  - delayed detonation 30
  - delayed shock model 439
  - detonation 29
  - double-degenerate model 29, 452
  - gain radius 439, 440
  - light curve 8, 26, 27, 451, 452
  - neutrino-driven wind 440–442, 539
  - neutrinos 451
  - 1987A 8, 26, 451, 618
  - 1994D 27, 28, 621
  - normal type Ia 28
  - observations 451
  - peculiar type Ia 28
  - Phillips relation 28
  - rate 26
  - redshift 28
  - reverse shock 441
  - revival of shock 25, 439
  - shock radius 440
  - shock wave 25, 434, 439, 443, 450
  - single-degenerate model 29, 452
  - thermonuclear 29, 452
  - 2011fe 29
  - Tycho 29, 622
  - type Ia 27, 70, 452, 622
  - type Ia progenitor 29
  - type Ib/Ic 25, 56
  - type II 25, 56, 58, 562, 618
  - white dwarf merger 453
- t**
- target 234
  - active nuclei 313, 326

- target (*contd.*)
    - anodized 325, 327
    - beamstop 234, 242, 261
    - blistering 239
    - chamber 241, 242
    - composition 236, 330
    - compound 236
    - contaminant 261, 262
    - cooling 242
    - degradation 209, 234
    - evaporated 235, 328, 330, 336
    - finite thickness 321
    - gas cell 238
    - gaseous 237, 288, 289
    - gas jet 239
    - gas thickness 239
    - heating 209
    - hydrogen 288
    - implanted 261, 326, 327
    - inactive nuclei 236, 313
    - infinitely thick 318
    - isotopic enrichment 236
    - oxidization 330
    - preparation 235
    - radioactive 285
    - random orientation of nuclei 588
    - self-supporting 235
    - sputtering 235
    - stability 239
    - stoichiometry 330, 337
    - thickness 239, 312, 328
    - transmission 235, 259, 260
    - windowless gas 238
  - technetium 2, 7, 20
  - thermal
    - equilibrium 56, 57, 71
    - excitation 53, 66, 67, 150, 151, 154, 191, 422
    - population probability 54, 67
    - velocity 142
  - thermally stable hydrogen–helium burning 499
  - thermonuclear
    - explosion 172
    - reaction 140
    - runaway 18, 22, 29, 32
  - Thomas approximation 119, 182
  - threshold energy 143, 148, 181, 581
  - time-of-flight method 293
    - components 294
    - detector 295
    - neutron energy 294
    - neutron energy resolution 294, 295
  - time-reversal invariance 76
  - total width 114, 118, 127, 318
  - compound state 126
  - observed 120
  - transfer reaction 122, 130
  - transmission 234
    - area above curve 339
    - coefficient 88, 89, 94, 96, 98, 100, 102, 114, 132, 133, 135, 137, 198
    - Coulomb barrier 103, 163, 184, 354, 357
    - curve 342, 343
    - modified coefficient 198, 206
    - neutrons 339, 341
    - probability 87, 98–100, 164, 177
    - thin sample 339
  - triple- $\alpha$  reaction 160, 391, 442, 491, 492, 494
    - decay constant 161, 393
    - electron screening 200
    - equilibrium 161
    - experimental situation 393
    - history 2
    - nuclear energy generation 393
    - temperature dependence of decay constant 393, 565
  - tunnel effect 1, 96, 116, 149, 167, 197
  - two-particle capture
    - direct 158
    - sequential 158, 160, 486, 497, 499, 500, 567
- u**
- uncertainty principle 78
  - universe
    - accelerating expansion 554
    - baryon-to-photon ratio 553
    - critical density 553
    - dark matter 554
    - primordial nucleosynthesis 552
    - temperature and density evolution 555
    - weak interactions 554
  - Urca process 70
- v**
- von Weizsäcker 1
- w**
- waiting point nucleus 442, 443, 486, 491, 492, 494, 497, 526, 546
  - wall effect 281
  - wave function 569
    - derivative 91, 92, 95
    - matching 91, 92, 98–100, 106
    - node 91, 93, 99–101
    - radial 570
    - slope 106

- Weisskopf
  - estimate 50
  - unit 51
- width fluctuation correction 135, 136
- WMAP 553
- Wronskian 571
- x**
- X-ray photons 224
- y**
- yield
  - angle-integrated 602
  - area under curve 322, 326, 329, 331, 334, 340
  - beam resolution 322, 323
  - broad resonance 328
  - curve for charged particles 311, 338
  - curve for neutrons 342, 343
  - curve plateau 318
  - definition 311
  - differential 313, 329
  - Doppler broadening 326
  - experimental 325, 327–329
  - finite target thickness 326
  - general expression 319
  - maximum 317, 318, 321
  - neutron-induced 339
  - nonresonant 312–314, 319
  - resonant 316, 317, 319, 320
  - shape of curve 324
  - slowly varying cross section 313, 315
  - straggling 322, 323
  - target compound 313
  - thin sample 339
  - thin target 312, 319, 348
  - total 329





