

Index

- AABW, 161, 162
 AAS, 317
 ab initio models, 51
 absorption of electromagnetic radiations, 282
 abundance distribution in the Sun, 250
 accessory mineral, 17
 accretion, 258
 achondrite, 19, 257
 acid and base
 dissociation, 138
 acidity, 138
 acoustic waves, 47, 51
 actinides, 7, 10
 activation energy, 104
 activity, 71
 adiabatic atmosphere, 325
 ADN, 174
 adsorption, 115, 297
 advancement
 reaction, 113
 advection, 101, 102, 131, 204
 porous flow, 111
 AES, 316
 AFC, 229
 AFM diagram, 31
 age
 geological time scale, 315
 age distribution
 in a well-mixed reservoir, 123
 well-mixed reservoir, 124
 age of the Earth, 265
 age vs. time, 78
 air temperature, 184
 Al, 20, 158, 225, 226, 251, 290
²⁶Al, 267, 270
²⁶Al–²⁶Mg, 258
 albite, 16, 144, 154, 155, 209, 292, 313
 oxygen isotope fractionation, 62
 algae, 156
 ALH84001, 278
 alkali basalt, 222
 alkali elements, 7
 alkaline earth elements, 7
 alkalinity, 148, 156
 consumption, 147
 definition, 140
 in seawater, 149
 production, 145
 alkalinity fluxes, 190
 alkenones, 181
 α isotope fractionation coefficient, 46
 α decay, 21
 α particle, 6
 Aluminum silicates, 211
 Amazonian, 276
 amino acids, 173
 ammonia, 210
 and the origin of life, 198
 amphibole, 16, 19, 29, 211,
 295, 296
 amphibolite, 211
 amphibolite facies, 211
 anammox, 181
 anatexis, 26, 212, 224
 andesite, 222, 224, 230, 233, 242
 and continental crust, 242
 anharmonic terms, 48
 anhydrite, 295, 298
 anorthite, 16, 155
 anorthosite, 272
 apatite, 295, 299
 Apollo, 272
 Ar, 123
³⁶Ar, 83
³⁹Ar–⁴⁰Ar method, 84
⁴⁰Ar, 83
 inventory and mantle convection, 239
 aragonite, 16, 295, 296
 Archean, 87, 223, 246, 297
 areas, 322
 argon excess, 83
 ARN, 174
 Arrhenius, 104, 114
 asteroid belt, 257, 262
 asthenosphere, 218, 230, 232, 233
 Atlantic vs. Pacific seawater, 161
 atmophile, 17
 atmosphere
 pressure and temperature, 325
 atmospheres, 279
 atmospheric ⁴⁰Ar, 83
 atmospheric temperature and pressure, 282

- ATP, 170, 174, 300
 autotroph, 170
 Avogadro number, 7
- B, 150
 B isotopes, 68
 Banded iron formations, 194
 barites, 193
 basalt, 19, 25, 29, 32–34, 63, 190, 209–211, 221, 222, 225, 229, 230
 altered, 233
 oceanic plateaus, 244
 basalts, 272
 Batchelor, 133
¹⁰Be, 79
 becquerel, 71
 benthic foraminifera, 187
 beryllium-10, 79
 β decay, 21
 BIF, 194, 297
 Bigeleisen and Meyer, 55
 binding energy, 32, 250
 for isotopes, 47
 mass dependence, 51
 biogenic rocks and materials, 168
 Biogeochemical catastrophes, 191
 biogeochemistry, 168
 biological activity, 147, 161
 biomarker, 172
 biomarkers, 181
 biominerals, 172, 176
 biotite, 16, 88, 290
 bioturbation, 178, 297
 Birimian, 243
 birth and death processes, 123
 black smoker, 206, 209, 210, 294, 299
 blueschist facies, 211
 Boltzmann, 55, 104, 114
 Boltzmann distribution, 53
 bond
 force constant of, 52
 heavy isotopes, 51
 stiffness, 52
 bonding, 11
 boric acid, 150
 Born–Oppenheimer approximation, 8
 Bowen, 297
 Bq, 71
 branching
 decay, 22
 breakup (continents), 220
 brines, 206
 Brownian motion, 105
 brucite
 D–H substitution in, 51
 BSE, 233, 262, 303
- buffer, 312
 accessory phases, 35
 during partial melting, 34
 buffer (P_{O_2}), 203
 bulk partition coefficient, 32
- C, 203, 251, 263, 300
 C component, 234
¹⁴C, 78, 127
 C4 vs. C3 ($\delta^{13}C$), 65
 Ca, 20, 225, 230, 244, 251, 294
 Ca isotopes, 68
 Ca/Al ratio, 295
 CAI, 271
 calcite, 16, 147, 295
 Canyon Diablo, 266
 Canyon Diablo Troilite, 66
 cap carbonates, 197
 carbohydrates, 173
 carbon isotopes, 64, 66
 atmosphere, 65
 Earth, 64
 in plants, 65
 in seawater, 66
 mantle material, 66
 carbonaceous chondrite, 261
 carbonate, 16, 19, 26, 31, 73, 79, 113, 139, 143, 145, 148, 155, 161, 188, 189, 278, 293, 295, 296, 300
 mantle, 224
 solubility, 140
 ⁸⁷Sr/⁸⁶Sr of marine carbonates, 185, 190
 carbonate preservation, 186
 carbonate saturation, 150
 carbonate system, 148
 carbonates
 dissolved (C isotopes), 64
 speciation, 143
 carbonatite, 224
 carbonic anhydrase, 182
 Caribbean, 243
 CCD, 161, 186
 CDT, 66
 cellulose, 173, 174
 chain
 radioactive decay, 81
 chalcophile, 17
 chalcopyrite, 210
 charge, 16, 18
 chart of the nuclides, 5, 252
 chemical potential, 310
 chemotroph, 171
 chert, 289
 chirality, 171
 chitin, 173
 chlorophyll, 174, 182
 chondrite, 19
 chondrites, 248

- chondrules, 248
 chromatography, 110, 321
 chromite, 34
 circum-Antarctic current, 162
 Cl, 20, 123, 158, 297
 Cl and charge balance, 207
 Clapeyron, 313
 classification
 Goldschmidt, 7
 classification (geochemical), 17
 clathrates, 170
 clay, 19, 20, 79, 92, 125, 144, 147, 154, 161, 211, 221, 225, 289, 292, 293, 295–297
 deep-sea, 236
 clay minerals, 16, 25
 Clementine, 272
 climate, 185
 clinopyroxene, 16
 closed system, 72, 86
 closure, 28, 307
 closure temperature, 106
 mantle vs. crust, 212
 closure vs. resetting, 213
 CO in the solar nebula, 256
 CO₂
 atmospheric, 186
 consumption, 145
 volcanic emissions, 189
 coal, 169, 174
 coccolithophores, 168, 181
 coesite, 289
 collisionless gas, 282
 comet, 265
 compatibility, 33
 compatible element, 17
 in magmatic differentiation, 39, 229
 in partial melting, 34
 compensation law, 104
 complex, 139
 complexation, 176
 component
 definition, 26
 concentration
 measure of, 316
 Concordia, 84
 slope in concordia plot, 85
 condensation
 and H–O isotopic fractionation, 152
 condensation of atmospheric vapor, 37
 condensation sequence, 258
 conservation
 of mass, 25, 26
 conservative
 mixing, 27
 property, 101
 consortia, 180
 constants, 322
 continents, 220
 continents and life, 200
 continents and nutrients, 199
 contraction
 lanthanides, 10
 convection, 237
 and mixing, 131
 conveyor belt, 161
 cooling
 secular cooling of deep seawater, 187
 cooling age, 106
 cooling rate, 106
 coordination number, 11
 core, 264
 age of planetary, 270
 composition, 261, 264
 segregation, 258
 cosmic rays, 78, 79
 cosmogenic nuclides, 75
 counting statistics, 321
 Cr, 14, 17, 20, 34, 123
 Cr³⁺, 12
 Craig, 61
 critical phenomena, 206
 cross-section, 252
 crust composition, 244
 crust formation ages, 242
 crustal growth, 241
 crystal field, 12, 13
 Cu isotopes, 68
 cumulate, 37, 229, 236, 273, 275, 277, 296
 cyanobacteria, 177
 cycle
 geochemical, 129
 cyclical ions, 154
 cytoplasm, 174
 daughter nuclide, 72
 dead carbon, 79
 Debye length, 146
 Debye solid, 51
 decay (radioactive), 71
 decay constant, 71
 various systems, 78
 decay constants, 268
 deep-water upwelling, 161
 degree of melting, 35, 39, 87, 222, 229, 231
 dehydration, 211, 212, 230, 233, 291, 312
 delamination, 240
 δ notation
 definition, 56
 delta notation, 56
 $\delta^{11}\text{B}$, 150
 $\delta^{13}\text{C}$, 156
 K/T boundary, 191
 Neoproterozoic ice ages, 197
 Paleocene–Eocene boundary, 191

- δD , 152
 - hydrous minerals, 60
 - ice, 60
- $\delta^{15}N$, 156
- $\Delta^{17}O$, 256
- $\delta^{18}O$
 - definition, 56
 - in basalts, 235
 - in foraminifera, 186, 187
 - in orogenic magmas, 233
 - Sun, 60
- $\delta^{34}S$, 66
 - barites, 193
 - in seawater, 185
 - marine sulfate, 192
 - pyrite, 195
- $\Delta^{33}S$, 195
- denitrification, 68, 178, 179
- densities, 322
- depleted
 - definition, 232
- depletion
 - MORB source, 230
- depth, 322
- diagenesis, 110, 178
- diagenesis
 - early, 204
- diamictites, 197
- diatom, 289
- diatoms, 168
- dielectric constant, 146
- differentiation, 225, 290
- differentiation
 - vs. mixing, 2
- diffusion, 101, 103, 204
 - and heterogeneities, 133
 - as random walk, 103
 - boundary layer, 110
 - coefficient, 104
 - length, 105
- diffusivity, 104
- diopside, 16
- dipole, 47
- discontinuities
 - seismological discontinuities in the Earth, 218
- disequilibrium decay series, 81
- dissimilatory reduction, 178
- dissipative process, 308
- dissociation
 - acid and base, 138
 - water, 139
- dissociation constant, 139
- dissolution, 154, 316
- distillation, 38
- distillation processes, 37
- DM component, 234
- DMS, 299
- Dodson, 106
- Dole effect, 61
- dolomite, 293
- dominance diagrams, 141
- Doushantuo, 197
- downwelling, 161
- dust, 297
- Early Solar System
 - chronology, 271
- Earth's age, 265
- Earth–Moon
 - common oxygen isotopic source, 257
- eclogite, 29, 87
- E_h , 139
- E_h –pH diagrams, 141
- ϵ_{HF} , 75, 245
- Einstein, 50
- Einstein solid, 51
- elastic energy, 31
- electrical neutrality, 140, 143
- electrolytes, 146
- electromagnetic force, 5, 21
- electromagnetic radiation
 - energy, 50
- electron, 5
- electron acceptor, 139
- electron balance in mineral reactions, 203
- electron capture
 - decay by, 22
- electron donor, 139
- electron shell, 5
- electronic energy, 47
- element
 - inert, 123
 - major, 18, 112, 123, 154, 158, 221, 222, 225, 241, 244, 312
 - reactive, 123
 - trace, 17, 31, 33, 34, 147, 212, 222, 224, 230, 231, 233, 235, 238, 241, 244, 312
 - transport, 101
- elements
 - formation, 249
 - properties, 5
- EM component, 234
- enantiomer, 172
- ϵ_{Nd} , 75, 245
- energy
 - electronic, 47
 - gravitational, 258
 - ionization, 20
 - mineral reaction, 20
 - nuclear vs. chemical, 20
 - of chemical bond, 47
 - rotational, 46
 - thermal, 47

- translational, 46
- vibrational, 47
- energy-level splitting, 13
- enrichment
 - definition, 233
- enstatite, 16
- enstatite chondrite, 262
- enthalpy, 207
- enthalpy of reaction, 203
- entropy, 308
 - of mixing, 53
- episodic crustal growth, 242
- ϵ notation, 75
- equilibrium
 - secular, 81
- equiline, 89
- erosion, 152
- erosion rate, 155
- erosion rate and pH, 154
- escape velocity, 279
- estuary, 156, 297, 300
- Eu, 34, 229, 274
- eutectic, 222, 313
- evaporation
 - and H–O isotopic fractionation, 152
- evaporite, 155
- evolution curve
 - radiogenic isotopes, 91
- excess
 - ^{230}Th excess method, 81
- excess argon, 83
- external isochron, 88
- extinct radioactivities, 267, 278
- extinctions
 - mass, 191
- facies
 - metamorphic, 211
- Faraday cage, 321
- fayalite, 210
- Fe, 13, 15, 19, 20, 156, 203, 218, 222, 225, 226, 230, 263, 264, 294, 295
 - maximum binding energy, 250
- Fe as a nutrient, 177
- Fe isotopes, 68
- Fe^{2+} , 13, 14
- ^{60}Fe , 270
- feldspar, 16, 18, 26, 34, 107, 144, 154, 202, 208, 211, 215, 222, 224, 273, 289, 291
 - oxygen isotope fractionation, 62
- felsic, 19
- Fenner, 297
- $\text{Fe}(\text{OH})_3$ solubility, 144, 297
- fermentation, 171
- ferric Fe, 203, 296
- Fick's law, 104
- film
 - intergranular, 36
- fission, 250
 - decay by, 22
- fixation, nitrogen, 68
- flintstone, 289
- fluctuations
 - and residence time, 122
- fluid inclusion, 206
- flux, 101
- fluxes (geochemical), 322
- foraminifera, 151, 156, 168, 186, 187
 - oxygen isotopes, 62
- force
 - electromagnetic, 5, 21
 - strong, 5, 21
 - weak, 5, 22
- force constant, 49
- forcing, 121, 129, 323
- forsterite, 15, 29, 210, 259
- fossil fuel, 189
- fourfold coordination, 11
- FOZO component, 234
- fractional crystallization, 37
- fractional melting, 37
- fractionation, 2, 27
 - elemental, 31, 56
 - isotopic, 45
- fractionation coefficient
 - isotopic, 46
- frequency, 50
- fulvic acids, 181
- fusible element, 20
- fusion, 250, 316
- Ga, 78
- gabbro, 229, 236, 272, 277
- gardening, 273
- garnet, 2, 15, 19, 29, 34, 87, 219, 222, 290, 296
- gas source, 319
- Gaskiers, 197
- gass loss
 - auroral zone, 283
- Genesis, 256
- geochemical systems, 120
- geochron, 267
- geochronology, 71
- geological time scale, 315
- geotherm, 213
- geothermal system, 209
- GERM, 303
- giant planets, 271
- Gibbs' free energy, 309
- glacial, 185
- Global Meteoric Water Line, 61
- GMWL, 61
- gneiss, 211

- goethite, 297
 Goldschmidt, 17
 classification, 7
 granite, 19, 25, 34, 62, 88, 209, 211, 221, 222, 224,
 230, 233, 241, 296, 298
 I- and S-types, 224
 radioactivity, 72
 granulite facies, 202, 211, 300
 and CO₂, 212
 gravitational energy, 258, 265
 greenhouse effect, 145, 185–187, 197,
 279, 297
 greenschist facies, 211
 groundwater, 111
 growth curve
 ⁴He/³He, 93
 slope of, 91
 Gy, 78
 gypsum, 295, 298

 H, 249
 half-life, 71
 halite, 292
 hardness, 49
 harmonic oscillator, 48
 frequency, 50
 Hawaii, 220, 222, 235, 236, 243, 291
³He/⁴He ratio, 236
³He/⁴He ratio in basalts, 236
⁴He/³He evolution, 93
 heat production
 radioactive, in granulite facies, 212
 hemoglobin, 174
 Hesperian, 276
 heterogeneities
 and mixing, 131
 heterogeneities and mixing, 133
 heterotroph, 171
¹⁷⁶Hf/¹⁷⁷Hf
 in OIB source, 234
¹⁸²Hf, 267, 270
 HFSE, 18
 high-field-strength elements, 18
 high-spin Fe²⁺, 14
 highlands (Moon), 272
 Himalaya
 and climate, 190
 HIMU component, 234
 histogram of crustal ages, 242
 homochirality, 172
 homogenization
 of isotopic compositions, 72
 homonuclear diatomic molecules, 50
 and greenhouse, 186
 Hooke's law, 31
 hopanes, 174
 hornblende, 16

 hot spot, 220, 230, 237, 243, 246
 human body
 radioactivity, 71
 humic acids, 181
 humic substances, 169
 hydrocarbons, 169
 hydrodynamic escape, 283
 hydrogen isotopes, 59
 Earth, 60
 Martian atmosphere, 60
 solar nebula, 60
 hydrostatic pressure, 211
 hydrothermal
 submarine, and seawater δ¹⁸O, 63
 hydrothermal reactions, 205
 hydrothermal solutions
 boiling, 206
 hyperbola (mixing), 30, 306

¹²⁹I, 267, 270
 ice, 187
 ice ages, 185
 Neoproterozoic, 197
 ice volume, 184
 ICP-MS, 317, 320
 igneous rock, 19
 illite, 292
 ilmenite, 16, 275, 296
 Imbrium, 272
 incompatibility, 33
 incompatible element, 292
 definition, 17
 in magmatic differentiation, 229
 in MORB, 230
 in partial melting, 34, 222
 incompatible elements, 37
 incremental fractionation, 37
 inert element, 123
 initial isotope ratio, 76
 instrumental mass bias, 59
 interfaces, 36
 internal isochron, 88
 internal standardization, 73
 ion exchange, 321
 ion probe, 320
 ionic bond, 12
 ionic compounds, 12
 ionic radius, 16, 18
 ionic strength, 147
 ionization potential, 20
 ionosphere, 282
 ions
 hard/borderline, 15
 Ir anomalies, 185
 Irving–Williams stability order, 176
 isochron
 and model age, 92

- equation, 76
 extinct radioactivities, 267
 method, 86
 minerals, 88
 whole rocks, 88
 isotherm
 BET, 116
 Langmuir, 115
 isotope, 45
 definition, 5
 isotope dilution, 317
 equation, 318
 isotope fractionation, 45
 kinetic effect, 59
 quantum mechanical, 59
 isotope fractionation line
 slope, 58, 59
 isotopic composition
 measure of compositions, 319
 isotopic fractionation, 45
 effect of mean mass, 55
 biological effects, 64
 effect of T , 55
 in diagenesis, 205
 kinetic, 64, 66
 liquid–vapor, 51, 152
 isotopic homogenization, 72, 87
 isotopic tracers, 71
 isotopomer, 46
 Isua, 267

 Jeans escape, 279
 Joly, 265
 Jupiter, 255

 K, 20, 158, 263, 291
 solubility in the core, 265
 K-feldspar, 16, 18, 209, 292
 K/Na fractionation
 as a thermometer, 208
 K/T boundary, 191
 K/U ratio, 259, 292
 ^{40}K – ^{40}Ar method, 83
 ka, 78
 kaolinite, 144, 291
 Kelvin, 265
 and the age of the Earth, 266
 kerogen, 169
 kinetic isotope effect, 64, 66, 114
 kinetics, 113
 komatiite, 223
 KREEP basalts, 272
 ky, 78

 Lagrangian representation,
 102, 124
 lake, 120

 laminite, 178
 laminites, 192
 lanthanides, 7
 contraction, 10
 large-ion lithophile elements, 18
 late veneer, 264
 latent heat, 312
 layered mantle convection, 237
 lead–lead method, 89
 length scale
 of heterogeneities, 131
 Lewis acid, 15
 LGM, 187
 Li isotopes, 68
 Li, Be, B abundances in stars, 251
 Libby, 78
 life and redox, 170
 lignin, 174, 181
 LILE, 18
 limonite, 297
 LIP, 243
 lipids, 174
 liquidus, 314
 lithophile, 17
 lithophile element, 259, 264
 lithosphere, 218
 lithospheric plate, 220, 239
 lithostatic pressure, 211
 log–log plot
 and distillation processes, 39
 low-spin Fe^{2+} , 14
 ^{176}Lu – ^{176}Hf ages, 214
 ^{176}Lu – ^{176}Hf isochron, 86
 Lunar Prospector, 273
 lysocline, 161

 Ma, 78
 mafic, 19
 magic numbers, 250, 254
 magma, 221
 residence time in reservoir, 126
 magma chamber, 225
 magma ocean, 270, 272, 273
 magmatic differentiation, 225, 294
 magnetic field, 265
 magnetic reversals, 83
 magnetite, 16
 magnetotactic bacteria, 177
 major element, 18, 112, 123, 154, 158, 221, 222, 225,
 241, 244, 312
 major elements, 158
 in seawater, 158
 majorite, 289, 290
 mantle, 25
 Earth's mantle oxidation state, 210
 mantle components, 234
 mantle convection, 220, 237, 266

- mantle geotherm, 213
 marine chemistry, 156
 marine sulfate
 sulfur isotopes, 66
 Marinoan, 197
 Mars, 255, 276
 Mars atmosphere, 278
 mass
 mean mass effect on isotopic fractionation, 55
 mass action law, 139, 311
 mass bias, 59
 mass conservation, 25, 26
 mass difference
 and isotopic fractionation, 57
 mass discrimination, 57
 mass effect on partitioning, 51
 mass fractionation, 57
 and radiogenic isotopes, 73
 mass fractionation line, 58
 terrestrial, 58
 mass number, 5
 mass spectrometer, 319
 mass-independent fractionation, 58
 sulfur isotopes, 67, 195
 masses, 322
 Maxwell–Boltzmann velocity distribution, 280
 MC-ICP-MS, 320
 mean free path, 281
 melt fraction, 33, 35, 39, 87, 222, 229, 231
 melting
 crust, 212, 221, 224
 mantle, 221
 membrane, 174, 176
 Mendeleev, 7
 metalloproteins, 182
 metals
 biochemistry, 182
 metamorphic rock, 19
 metamorphism, 211
 metasomatic fronts, 111
 metasomatism, 233
 metastability, 313
 Metazoans, 196
 meteoric water, 152
 meteorite, 1, 19, 257
 methane, 169, 210
 and the origin of life, 198
 Mid-Atlantic Ridge, 199
 methane hydrates, 170
 methanogens, 179
 methanotroph/methanogen consortia, 181
 MeV, 20
 Mg, 15, 17, 19, 20, 34, 123, 158, 222, 230, 244, 251, 259, 293
 Mg isotopes, 68
 mg#, 31, 294
 mica, 16, 19, 290
 micronutrients, 177
 mid-ocean ridge, 220
 Milankovic, 187
 Miller and Urey's experiment, 198
 mineral
 reaction, 29, 184, 202
 mineral assemblage
 cooling, 108
 equilibrium, 108
 mineral isochron, 88
 Mississippi Valley-type ore deposits, 207
 mixing, 27
 and heterogeneities, 131
 hyperbola, 30
 in Concordia plot, 85
 line, 27
 population, reservoir, 123
 vs. differentiation, 2
 mixing hyperbola, 306
 mixing time of the ocean, 127, 161
 MMS, 298
 Mn²⁺, 14
 Mn, Fe hydroxides, 177
 Mo isotopes, 68
 model age, 76, 92
 Moho, 218
 MOLA, 276
 molecular orbitals, 12
 Moon, 257, 272
 Moon–Earth
 common oxygen isotopic source, 257
 MORB, 33, 92, 209, 227, 230, 233, 236, 238, 239, 300
 multiple collection, 321
 multiple reservoir
 dynamics, 127
 muscovite, 16, 88, 202
 My, 78

 N, 123, 156, 158, 251
 Na, 15, 20, 123, 158, 225, 263, 292
 NaCl, 207
 NADW, 161, 162
 Nb, 233
 Nd isotopes
 in seawater, 185
 ¹⁴²Nd anomalies, 246, 270, 272
 ¹⁴³Nd/¹⁴⁴Nd
 and crustal growth, 242
 in lunar rocks, 274
 in MORB source, 232
 in OIB source, 234
 neon, 237
 Neoproterozoic glaciations, 197
 nephelinite, 224
 Nernst
 law, 31
 neutrality, 140

- neutrino, 22
 neutron, 5
 absorption, 251
 flux, 252
 Ni, 34, 39, 123, 218, 229, 263, 264
 Ni²⁺, 14
 Nicolaysen, 76
 nitrification, 68
 nitrogen isotopes, 67
 atmosphere, 67
 Precambrian, 196
 Noachian, 276
 nodule (Fe-Mn), 79, 110, 296, 298
 non-linear transport, 111
 normal modes, 50, 64
 normalization
 to a reference composition, 33
 normalization (internal)
 isotope, 74
 nuclear reactions, 249
 nuclear wastes, 111
 nucleon, 5, 250
 nucleosynthesis, 249
 up to Fe, 250
 nucleosynthetic anomalies, 45
 nucleus, 5, 20
 liquid drop model, 6
 nuclide, 5
 chart of the nuclides, 5
 nutrient, 156, 300
- O, 251
 OAE, 192
 ocean
 differentiation and mixing by, 26
 mixing time, 127
 thermohaline circulation, 161
 oceanic anoxic events, 192
 oceanic plateau, 243
 oceanic sulfide, 195
 octahedral site, 11, 14
 OIB, 34, 227, 230, 233, 234, 236, 238, 239, 300
 oil seeps, 177
 olivine, 2, 14, 15, 17, 27, 29, 34, 39, 105, 110, 210,
 218, 222, 224, 225, 229, 259, 272, 295, 296, 300,
 314
 Ontong–Java, 243
 Onuma, 31
 open system, 87
 ophiolites
 water–rock interaction, 63
 orbital, 8, 11, 12
 e_g , 12
 t_{2g} , 12
 molecular, 12
 organic carbon
 oxidation, 139, 177, 189
 organic matter
 maturation, 181
 origin of life, 198
 orogenic magmas, 189, 226, 230, 233, 296
 orthopyroxene, 16
 Os, 34
¹⁸⁷Os/¹⁸⁸Os
 in MORB source, 232
 oscillator
 harmonic, 48
 overgrowth, 85
 O₂ in mineral reactions, 203
 oxygen atmospheric pressure
 the 2.1 Ga crisis, 193
 oxygen fugacity
 basalts, 226
 oxygen isotope composition
 Solar System, 256
 oxygen isotope fractionation
 carbonates, 62
 magmatic differentiation, 62
 melting, 62
 recycling, 62
 oxygen isotopes, 60
 atmosphere, 61
 in seawater, 63
 mantle, 61, 62
 meteoric water, 63
 Sun, 60
 oxygen minimum, 159
 ozone isotope composition, 58
 ozone layer, 195
- P, 156, 158, 205, 299
 pK , 139
 p process, 251
²³¹Pa, 82
 Pacific vs. Atlantic seawater, 161
 paleosols, 194
 paleothermometry, 62
 parent nuclide, 72
 parent/daughter ratio, 76, 91
 partial melting, 25, 33
 bulk, eqns for trace elements, 33
 partition coefficient, 31, 312
 bulk solid/liquid, 32
 dependence on T and P , 31
 dependence on composition, 31
 dependence on ionic radius, 31
 in distillation processes, 37
 in dynamic systems, 121, 128
 passive tracers, 102
 Patterson, 266
 Pauli principle, 9
²¹⁰Pb, 82
 Pb–Pb method, 89
²⁰⁴Pb, 85, 89

- ^{206}Pb , 85, 89
 $^{206}\text{Pb}/^{204}\text{Pb}$
 in OIB source, 234
 ^{207}Pb , 85, 89
 $^{207}\text{Pb}/^{206}\text{Pb}$ ratio, 126
 ^{208}Pb , 89
 PCA, 28
 P_{CO_2} , 185
 P_{CO_2} , 140, 186
 P_{CO_2} , 148
 PDB, 60, 64
 pe, 139
 pe–pH diagrams, 141
 Peclet number, 106
 Pee Dee Bee, 60, 64
 pegmatite, 209
 peridotite, 20, 224, 230, 262, 277, 295
 periodic table, 7, 9
 peritectic, 314
 perovskite, 218, 289, 295, 296
 petroleum, 169
 pH, 138, 148, 289, 299, 300
 and $\delta^{11}\text{B}$, 150
 in seawater, 161
 of the ocean, 185
 P_{H_2} in the solar nebula, 259
 phase
 mineral, 3
 phase diagram, 313
 phenocryst, 221
 phlogopite, 291
 phonons, 51
 phosphoglycerides, 174
 phosphorites, 168
 P cycle, 130
 photic zone, 156
 photodissociation
 isotopic effects, 58
 photoelectric effect, 50
 photolysis
 SO_2 , 195
 photon, 50
 photosynthesis, 64, 156, 171
 physical constants, 322
 phytoplankton
 carbon isotopes in, 66
 picrite, 222
 plagioclase, 19, 211, 225, 229, 272, 275, 290, 292,
 293, 295, 296
 Planck, 50
 planetary atmospheres, 279
 planetesimal, 1, 255, 265
 plankton composition, 175
 plants, 79
 plate, 218
 plate tectonics, 218
 plume, 220, 243
 plumes, 220
 plutonic rock, 221
 P_{O_2} , 203
 Poisson process, 71, 125, 134, 321
 polar ice, 187
 poloidal movement, 132
 porphyrin, 296
 potassium–argon method, 83
 pressure
 effect on coordination, 15
 effect on reactions, 202
 primitive mantle, 236, 262
 probability
 and radioactivity, 71
 and residence time, 123, 127
 production
 primary, 161
 productivity
 biological, 66, 185
 primary, 156
 progress of a reaction, 310
 proteins, 173
 protolith, 243
 proton, 5, 138
 proton exchange, 144
 proxy, 184
 PTt path, 108
 ^{234}Pu , 22
 pyrite, 110, 113, 179, 193, 195
 pyroxene, 2, 14, 16, 29, 34, 87, 145, 210, 219, 222,
 224, 225, 229, 231, 272, 290, 292, 295, 296, 300,
 312
 quantum, 47, 50
 quantum number, 8
 quartz, 16, 29, 80, 105, 144, 147, 202, 206, 211, 224,
 289, 312, 313
 quartz vein, 209

 r process, 251, 254
 radioactive decay, 45
 α process, 21
 β^- process, 21
 branched process, 22
 electron capture, 22
 spontaneous fission, 22
 radioactive heating, 258, 265
 radioactivity, 6, 20, 71
 as a removal process, 123
 radiogenic ingrowth, 45
 radiogenic nuclide, 72
 radiogenic tracers, 90
 rain, 152
 rare-earth elements, 7, 10, 17, 34, 229–231, 297
 ratio
 elemental or isotopic and mixing, 29, 306
 Rayleigh distillation, 37, 38, 59, 229

- Rayleigh's law, 37
 ^{87}Rb – ^{87}Sr isochron, 86
 ^{187}Re – ^{187}Os in basalts, 235
 ^{187}Re – ^{187}Os isochron, 86
 reaction
 mineral, 29, 184, 202
 reaction rate, 113
 reactive element, 123
 reactivity, 121
 recycling
 in mantle, 242
 through the thermocline, 159
 recycling
 in mantle, 235
 Redfield ratio, 156, 175
 redox reaction, 139, 203, 210
 reduced carbon, 147
 reduced mass, 50
 reference material
 isotopic, 56
 refractory element, 20, 222
 regolith, 273
 relaxation, 121, 323
 relaxation time, 128
 and mantle convection, 239
 reservoir, 19, 20, 33, 89, 120, 127, 160, 225, 237, 239,
 257, 263, 288
 composition of terrestrial reservoirs, 19
 resetting vs. closure, 213
 residence time, 121, 128, 323
 and probability, 123, 127
 in the mantle, 237
 magma in reservoir, 126
 respiration, 147, 159, 171
 retentivity, 108
 rhyolite, 221
 river-water composition, 152
 RKR reaction, 158
 rock
 definition, 28
 rotational energy, 46
 rubisco, 65
 run-off, 152

 S, 123, 203, 263, 264, 298
s process, 251
 Saanich River, 204
 Sc, 34, 229
 scavenging, 112
 schist, 88, 211
 ΣCO_2 , 148
 sea-level, 185
 sea-level variations, 170
 sea-surface temperature (SST), 184
 seawater
 origin, 264
 origin of, 261

 pH, 150, 161
 radioactivity, 71
 temperature, 184
 secular equilibrium, 81, 89
 sedimentary rock, 19
 sedimentation rate, 82, 120
 measurement of, 79
 seismic tomography, 239
 self-shielding, 256
 serpentinization, 210
 and the origin of life, 198
 shergottite, 277
 shergottite age, 278
 shielding, 10
 SHRIMP, 320
 Si, 20, 158, 222, 230, 233, 244, 251, 262,
 263, 288
 Si burning, 251
 Si isotopes, 68
 siderophile, 17
 siderophile element, 264
 siderophile elements, 264
 silica, 26, 147, 155, 205, 208, 210, 221, 289, 293,
 295, 312
 silicates
 classification, 15
 SIMS, 320
 single reservoir
 dynamics, 120
 sink, 101
 sixfold coordination, 11
 ^{146}Sm , 270, 272
 ^{147}Sm – ^{143}Nd isochron, 86
 smectite, 293
 SMOW, 60
 SNC, 257
 SNC meteorites, 276, 277
 snow (heavy isotope), 51
 Snowball Earth, 196
 solar activity, 79
 solar nebula, 255, 258
 Solar System, 248
 age, 265
 solid solution, 17, 296, 311
 solubility
 of gases, 140
 of minerals in melts, 225
 of solids, 140
 temperature dependence, 312
 and complexes, 144
 solubility product, 140
 soluble element, 20
 solution (solid), 17
 source, 101
 spallation, 45
 speciation, 143
 carbonates, 148

- species
 - definition, 26
- SPECMAP, 187
- sphalerite, 210
- spidergram, 33
- spin, 8
 - low/high, 14
- spinel, 19, 222
- splitting
 - energy level, 13
- Sr, 34, 229
 - residence time in the ocean, 122
- Sr isotopes
 - internal normalization, 74
- $^{87}\text{Sr}/^{86}\text{Sr}$
 - in marine carbonates and climates, 190
 - in MORB source, 232
 - in OIB source, 234
 - in orogenic magmas, 233
- stability
 - valley of, 6
- stable isotopes
 - precipitation, 61
- stable isotope fractionation, 45
- standard
 - isotopic, 56
- standardization
 - internal for radiogenic isotopes, 73, 74
- steady state, 121, 127, 129
- sterols, 174
- stirring vs. mixing, 131
- stishovite, 289
- stretching, 132
- stromatolites, 177, 194
- strong force, 5, 21
- Sturtian, 197
- subduction, 220, 230
- substitution, 16, 294, 296, 311
- sulfate, 114, 155, 178
- sulfide oceanic, 195
- sulfides
 - sulfur isotopes, 67
- sulfur
 - isotope fractionation, 66
 - mass-independent fractionation, 195
 - sulfur anomalous fractionation, 58
 - sulfur isotope reference material, 66
 - sulfur isotopes
 - igneous, 67
 - marine sulfate, 66
 - sulfides, 67
- Sun composition, 249
- Superior, 243
- supernova, 254
- surface water
 - C and N, 156
- suspension, 297
- sylvite, 292
- symmetry, 55
 - molecules, 64
- T-Tauri phase, 256, 271
- Ta, 233
- tectonic site
 - magma diversity, 229
- temperature
 - effect on isotopic fractionation, 55
 - effect on reactions, 202
- ternary diagrams, 31
- terpenes, 174
- tetrahedral site, 11
- tetrahedron, 15
- Th, 297
- ^{230}Th excess
 - isochron representation, 89
 - method, 81
- ^{232}Th , 81
- thermal ionization, 320
- thermal spring, 205
- thermobarometry, 106
- thermocline, 159
- thermodynamics, 308
- thermometry, 294
 - oxygen isotopes, 55
 - thermal spring, 207
- thermonuclear reactions, 249
- tholeiitic basalt, 222
- Ti, 17, 225, 226
- time scale, 130, 315
- time vs. age, 78
- time-integrated parent/daughter ratio, 91
- TIMS, 320
- tomography, 239
- toroidal movement, 132
- trace element, 17, 31, 33, 34, 147, 212, 222, 224, 230, 231, 233, 235, 238, 241, 244, 312
- tracer
 - isotopic, 71
 - passive, 102
- transition elements, 9, 12, 13
- translational energy, 46
- transport, 101
- traveling waves, 51
- tree rings (^{14}C), 79
- tremolite, 16
- troilite, 266
- twelffold coordination, 11
- two-phase flow, 111
- U, 297
- U, Th, K
 - as heat sources, 212, 220, 266, 274
- U–Pb dating of zircons, 84
- ^{234}U , 82

- ^{235}U , 81
- ^{238}U , 22, 81
- ultramafic, 25
- ultramafic inclusions, *PT* estimates, 213
- uncertainty principle, 8, 50
- upper mantle, 233
- upwelling, 161, 289
- uraninite, 194
- uranium disequilibrium series, 81
- Urey, 55
- Urey ratio, 239

- valence, 12
- valley of stability, 6
- van Krevelen diagram, 169
- variability
 - geochemical variability of magmas, 221
 - of incompatible elements in basalts, 34
- vector
 - use of vectors for mass balance, 28
- velocity gradient, 132
- Venus, 278
- Vesta, 257
- vibration modes, 51
- vibrational energy, 47
- Viking, 277
- volatile element, 259, 263

- volcanic CO_2 , 189
- Vostok, 187

- water
 - in magmas, 223
 - liquid and heavy isotopes, 51
- water cycle, 152
- water mass, 161
- water–solid reaction, 144
- water/rock ratio, 214
- weak force, 5, 22
- weathering, 152, 190, 292, 294
 - and climate, 190
- whole-mantle convection, 237
- whole-rock isochron, 88
- Witwatersrand, 194

- XRF, 317

- zero-point energy, 50
- zircon, 34, 84
 - high-closure temperature, 109
 - overgrowth, 85
- zircon age
 - river bedload, 242
- Zn isotopes, 68
- Zn^{2+} , 14