

Index

- α -Process in stars 11
- Absolute configuration, determination of 1125, 1126
- Abundance of elements, Tables of 1294
- Acetylides *see* Carbides
- Acidity function H_0 (Hammett) 51, 52
- Acid strength of binary hydrides 49, 51
of oxoacids (Pauling's rules) 50
of HF 815
- Actinide contraction 1264
- Actinide elements
abundance 1253
alkyls and aryls 1278
atomic and physical properties 1263
carbonyls 1278
chalcogenides 1471
complexes
+7 oxidation state 1273
+6 oxidation state 1273
+5 oxidation state 1274
+4 oxidation state 1275
+3 oxidation state 1277
+2 oxidation state 1278
+1 oxidation state 1278
coordination numbers and stereochemistries 1267
cyclopentadienyls 1278
discovery 1252
group trends 1264–1267
halides 1269–1272
hydrides 64, 1267
lanthanide-like behaviour 1251, 1264, 1266
magnetic properties 1272, 1273
mixed metal oxides 1269
organometallic compounds 1278–1280
oxidation states 1268,
oxides 1268–1269
preparation of artificial elements 1252–1262
problems of isolation and characterization 1251, 1260,
1262, 1264
redox behaviour 1265–1266
separation from used nuclear fuels 1260–1262
spectroscopic properties 1272–1273
- Actinium
abundance 945
discovery 944
radioactive decay series 1254
see also Actinide elements, Group 2 elements
- Actinoid *see* Actinide elements
- Actinon *see* Actinide elements
- Actinyl ions 1273, 1274
- Activated carbon 274
see also Carbon
- Adenine 61, 62
- Adenosine triphosphate (ATP)
discovery in muscle fibre 474
in life processes 528, 1101
in nitrogen fixation 1035, 1036
in phosphorus cycle 476
in photosynthesis 125
- Agate 342
- Air 411, 604, 889, 890
- Alane 227
- Albite 357
- Alkali metals (Li, Na, K, Rb, Cs, Fr)
abundance 69
alkoxides 87
atomic properties 75
biological systems containing 70, 71, 73, 97
carbonates 59–90
chelated complexes of
chemical reactivity of 76
complexes of 90
crown-ether complexes of 90
cryptates of 90
cyanates 324
cyanides 321
discovery of 68, 69
flame colours of 75
halides
imides, amides 99–102
bonding in 80
properties of 82–83
hydrides
reactions of 84
hydroxides 86, 87
hydrogen carbonates (bicarbonates) 88
intercalation compounds with graphite 293, 294
intermetallic compounds with As, Sb, Bi 554, 555
isolation of 68, 69
nitrates 89
nitrites 90
organometallic compounds 106
oxoacid salts 87–90
oxides 84
ozonides 85

- Alkali metals — *contd*
 peroxides 84, 85
 physical properties 74, 75
 polysulfides 677–679, 679, 681
 reactions in liquid ammonia 78–79
 sesquioxides 85
 solubilities in liquid ammonia 78
 solutions in amines 79
 solutions in liquid ammonia 77–79
 solutions in polyethers 79
 suboxides 84, 85, 86
 sulfides 679, 681, 682
 superoxides 84, 85
see also individual metals; Li, Na, K, Rb, Cs, Fr
- Alkaline earth metals (Be, Mg, Ca, Sr, Ba, Ra)
 abundance 108–110
 atomic properties 111
 chemical reactivity of 112
 complexes of 122–127
 halides
 crystal structures of 117–118
 uses 118
 hydride halides, MHX 119
 hydrides 64, 115
 hydroxides 119–122
 intermetallic compounds with As, Sb, Bi 554, 555
 organometallic compounds 127–138
 oxides 119, 121
 oxoacid salts 122
 ozonides 119
 peroxides 119
 physical properties 112
 stereochemistry of 114
 sulfides 679
 superoxides 121
 thermal stability of oxoacid salts 113
 univalent compounds of 113
see also individual metals: Be, Mg, Ca, Sr, Ba, Ra
- Alkene insertion reactions (Ziegler) 259, 260
 Alkene metathesis 1038
 polymerization (Ziegler-Natta) 240, 241, 972
 Allotelluric acid 782
 Allotropy *see* individual elements: B, C, P, S etc.
 Alnico steel 1114, 1146
 Aluminium
 abundance 217
 alloys 220
 borohydride 169, 228
 chalcogenides 252
 III-V compounds 255, 258
 halide complexes 233–237
 heterocyclic organo-AlN oligomers 265, 266
 history of 216
 hydrides 227
 hydrido complexes 228–231
 lower halides AlX, AlX₂ 233
 organometallic compounds 257–266
 orthophosphate AlPO₄ 526
 production 216, 218–226
 ternary oxide phases 247–252
 trialkyls and triarylals 257, 258–260
 dimeric structure of 253
 preparation 259
 in Ziegler-Natta catalysis 259–263, 972
 trichloride 233
 Friedel-Crafts activity of 234, 236
 structure 234
 trichloride adducts, structure of 234, 235, 672
 trihalide complexes 233–237
 uses 220
see also Group 13 elements
- Aluminium hydroxide
 bayerite and gibbsite 243, 245
- Aluminium ion
 hydration number of 604
- Aluminium oxide hydroxide
 diaspore and boehmite 243
- Aluminium oxides
 catalytic activity 244
 corundum 242, 243
 “Saffil” fibres 244,
 structural classification 242, 243
see also Portland cement, High-alumina cement
- Aluminium trimethyl, Al₂Me₆ 291, 258, 259
 reactions with MgMe₂ 131
- Alumino-silicates *see* Silicate minerals
- Alumino-thermic process 1003
- Alums 216
 chrome 1027
 iron 1088
 rhodium 1129
 titanium 970
 vanadium 993
- Amalgamation process 1175, 1201, 1203
 Americium 1252, 1262
see also Actinide elements
- Amethyst 342
- Amidopolyphosphates 506
- Aminoboranes 209
- Ammonia
 adduct with Ni₃ 441
 chemical reactions 423, 424, 486
 fertilizer applications 422
 hydrazine, production from (Raschig synthesis) 427,
 428
 industrial production 408, 419
 inversion frequency 423
 inversion of, discovery 403
 nitric acid production from 466, 467
 odour 420
 physical properties 422, 423
 production statistics 420
 synthesis of (Haber-Bosch) 408, 420
 uses of 422
- Ammonia, liquid
 acid-base reactions in 425
 alkali metal solutions in 77–79, 392
 ammonolysis of PCl₅ 535
 amphoteric behaviour in 425
 discovery of coloured metal solutions 408
 H bonding in 52–55, 422
 metathesis reactions in 425
 redox reactions in 425
 solubility of compounds in 424, 425
 solvate formation in 425

- solvent properties of 77–79, 422, 424–426
 syntheses in 426 and *passim*
 synthesis of metal cluster ions in 392, 393
 Ammonium nitrate
 explosive decomposition of 466, 469
 thermolysis of 443, 469
 Ammonium nitrite, decomposition to N₂ 409
 Ammonium phosphates 524
 Ammonium salts 422
 Amosites 351
 Amphiboles 351
 Amphoteric behaviour
 definition 225
 of Al and Ga 225
 of SbCl₅ 697
 of SF₄ (Lewis acid-base) 811
 of V₂O₅ 981
 of ZnO 1209
 Amphoteric cations 52
 Anderson structure 1011
 Andrieux's phosphide synthesis 489
 Angeli's salt 459, 460
 Angular functions 1285, 1288, 1289
 Andrussow process for HCN 321
 Anorthite 357, 358
 Antiferroelectrics 58
 Anti-knock additives 371, 799
 Antimonates 577
 Antimonides 554
 Antimonious acid, H₃SbO₃ 575, 578
 Antimonite esters 561
 Antimony
 abundance and distribution 548–549
 alloys 549, 554
 allotropes 551–552
 amino derivatives 561
 atomic properties 550
 catenation 583
 chalcogenides 581, 582
 chemical reactivity 552, 553, 577
 cluster anions 553, 588
 coordination geometries 554
 encapsulated 554
 extraction and production 548, 549
 halide complexes 564–570
 halides 558–566
 see also trihalides, pentahalides, oxide-halides, mixed halides, halide complexes
 halogeno-organic compounds 596, 598
 history 547
 hydride 551–558
 intermetallic compounds *see* Antimonides
 metal-metal bonded clusters 583, 588, 589
 mixed halides 563, 562
 organometallic compounds 592, 596–598
 organometallic halides 596, 597
 oxoacid salts of 591
 oxidation state diagram 578
 oxide Sb₂O₃ 572–574
 oxide halides 570–572
 oxides and oxocompounds 572–578
 pentahalides 561–562, 568–570, 785
 pentaphenyl 545
 physical properties 551, 552
 selenium complex anions 581
 sulfide, Sb₂S₃ 547, 549, 580–581, 648
 trichloride solvent system 560
 trifluoride as fluorinating agent 560
 trihalides 558–561, 564–566, 569
 uses 549
 volt-equivalent diagram 578
 Anti-tumour activity of Pt^{II} complexes 1163
 Apatites 109, 475, 480, 525
 reduction to phosphides 489
 Aqua regia 790, 792, 1179
 Aragonite 109
 Arenes as η⁶ ligands 940
 Argentite (silver glance) 1174
 Argon
 atomic and physical properties 891
 clathrates 893
 discovery 889
 production and uses 889
 see also Noble gases
 Arsenates 577
 Arsenic
 abundance and distribution 548, 549
 allotropes 551
 alloys 549, 554
 amino derivatives 561
 atomic properties 550
 catenation 583–590
 chalcogenide cluster cations 579
 chalcogenides 578–583
 chemical reactivity 552–554, 577
 cluster anions 553, 588–591
 coordination geometries 553
 diiodide 564
 encapsulated 554
 extraction and production 548, 549
 halide complexes 564–569
 halides 558–566
 see also trihalides, pentahalides, diiodide, oxide halides, mixed halides, halide complexes
 halogenoorganoarsenic compounds 593–596
 history 547
 hydrides 557, 558, 583, 679
 intermetallic compounds *see* Arsenides
 metal-metal bonded species 583–590
 mixed halides 563
 organoarsenic(I) compounds 597
 organoarsenic(III) compounds 583–587, 592–594, 596
 arsabenzene 593
 arsanaphthalene, 593
 physiological activity 596
 preparation of 593, 595
 reactions of 593, 595
 organoarsenic(V) compounds 594, 596
 organic compounds 553
 oxoacid salts of 591
 oxidation state diagram 578
 oxide As₂O₃ 549, 572–575
 reactions 574
 structure and polymorphism 573
 uses 549, 574
 oxide halides 570–572

- Arsenic — *contd*
 oxides and oxocompounds 570–578
 pentahalides 561, 664
 physical properties 551, 552
 selenides 581
 sulfide, As_2S_3 547, 548, 578, 579, 648
 chemical reactions 580, 581
 structure 578, 579
 sulfide, As_4S_4 548, 578–581, 649
 sulfides, As_4S_n 578–580
 triangular species 583, 586–589
 trichloride solvent system 560
 trihalides 558–561, 564, 566
 uses 549
 volt-equivalent diagram 578
 Arsenicals, therapeutic uses 593
 see also Organoarsenic(III) and Organoarsenic(V)
 compounds
 Arsenides 554–558
 stoichiometries 554
 structures 554–557
 Arsenious acid $As(OH)_3$ 574
 Arsenite 575, 575, 577
 Arsenite esters 561
 Arsenopyrite 649
 Arsenidine complexes 597
 Arsine 558
 Arsinic acids $R_2AsO(OH)$ 594
 Arsinous acids R_2AsOH 594
 Arsonic acids $RAsO(OH)$ 596
 Arsonous acids $RAs(OH)_2$ 594
 Asbestos 109, 351
 Asbestos minerals 349, 351
 Astatate ion, AtO_3^- 886
 Astatide ion At^- 886
 Astatine
 abundance 796
 atomic properties 800
 chemistry 885, 886
 nuclear synthesis 791, 795
 radioactivity of isotopes 795, 885
 redox systematics 885
 trihalide ions 886
 see also Halogens
 Atactic polymer 972
 Atmosphile elements 648
 Atmosphere
 composition 409, 603
 industrial production of gases from 409, 604
 origin of O_2 in 602
 Atom-at-a-time chemistry 1282
 Atomic energy 1256
 Atomic orbitals 1285–1289
 Atomic piles 1256
 see also Nuclear reactors
 Atomic properties, periodic trends in 23–27
 Atomic volume curve, periodicity of 23, 24
 Atomic weight, definition 15
 Atomic weights
 history of 15, 601
 precision of 15–19
 relative uncertainty of
 Table of *see* front end paper
 variability of 17–19, 368
 ATP *see* Adenosine triphosphate
 Austenite
 Autoprotolysis constants of anhydrous acids 710
 Azides 433
 Azoferredoxin 1036, 1098
 Azotobacter 999, 1036
 Azotobacter *vinelandii* 1036

 β -alumina *see* Sodium β -alumina,
 β -elimination reactions 926
 Back (π) bonding 923, 926, 927, 931, 1166
 Baddeleyite 955
 structure of 955
 Baking powders 524, 525
 Barium
 history of 108
 organometallic compounds 136
 polysulfides 681
 see also Alkaline earth metals
 Bart reaction 596
 Basic oxygen steel process 120, 1072
 Bastnaesite 945, 1229, 1232
 Batteries
 dry 1204
 lead 371, 549
 sodium-sulfur 678
 Bauxite 243
 production statistics 218
 in Al production 219
 Bayer process 167
 Bayerite 243, 245
 Belousov-Zhabotinskii oscillating reactions 865
 Bentonite *see* Montmorillonite
 Benzene as η^6 ligand 940–941
 Berkelium 1252, 1262
 see also Actinide elements
 Berry pseudorotation 474, 499, 914
 see also Stereochemical non-rigidity
 Beryl 107, 108, 349
 Beryllia *see* Beryllium oxide
 Beryllium
 alkoxides etc 122, 129
 alkyls 126–130
 ‘anomalous’ properties of 114, 122
 ‘basic acetate’ 122, 123
 ‘basic nitrate’ 122
 borohydride 115, 116
 chloride 116, 117
 complexes of 122–125
 cyclopentadienyl complexes 130,
 discovery 107, 108
 fluoride 116
 hydride 115, 115, 128
 oxide 107, 119–120
 salts, hydrolysis of 121
 uses of metal and alloys 110
 see also Alkaline earth metals
 Beryllium compounds, toxicity of 107
 Beryllium ion, hydration number of 605
 Bessemer process 1072

- BHB bridge bond, comparison with H bond 64, 70
see also Three-centre bonds
- “Big-bang” 1, 5, 10
- Biotite *see* Micas
- Bismuth
 abundance and distribution 548, 549, 550
 allotropes 551, 551
 alloys 549, 554
 atomic properties 550
 Bi⁺ cation 564, 591
 catenation 582
 chalcogenides 581, 582
 chemical reactivity 552, 553, 577
 cluster cations 564, 565, 583, 588–591
 extraction and production 549, 550
 halide complexes 564–567
 halides 558–564
see also trihalides, pentahalides, oxide halides, lower halides, mixed halides, halide complexes
 history 547
 hydride 557, 558
 hydroxide, Bi(OH)₃ 575
 hydroxo cluster cation, [Bi₆(OH)₁₂]⁶⁺ 575, 591, 592
 intermetallic compounds *see* Bismuthides
 lower halides 564
 metal-metal bonded clusters 583, 583–591
 mixed halides 564
 nitrate and related complexes 591, 592
 organometallic compounds 592, 596, 599
 oxidation state diagram 578
 oxide, Bi₂O₃ 573, 574
 oxide halides 572, 572
 oxides and oxo compounds 573–575
 oxoacid salts of 591
 pentafluoride 561
 physical properties 550, 552
 trihalides 558–561, 564, 566
 uses 549
 volt-equivalent diagram 578
- Bismuthates 577
- Bismuthides 554
- Bismuthine 557
- Biuret 305, 1191
- “Black oxide” of mercury 1213
- Blast furnace 1073
- Bleaching powder 790, 860
- “Blister” copper 1175
- “Blue proteins” 1198–1199
- Blue vitriol 1190
- Boehmite 243
- Bohrium 1281, 1283
- Boiling points, influence of H bonding 54
- Borane adducts, LBH₃ 165
 amine-boranes 208–209
- Borane anions 151, 166, 178, 181, 590
see also Boranes
- Boranes
arachno-structures 152, 154, 159
 bonding 157–162, 590
 classification 151
closo-structures 152, 153, 161
conjuncto-structures 152, 155–157
hypho-structures 152, 153, 172
 as ligands 177
nido-structures 152, 154, 161
 nomenclature 157
 optical resolution of *i*-B₁₈H₂₂ 670
 physical properties 162, 163
 preparation 162
 topology 158–160, 175
see also Diborane, Petaborane, Decaborane, Metalloboranes, Carboranes, etc.
- Borate minerals
 occurrence 140
 production and uses 140
see also Borates
- Borates 205–207
 B–O distances in 206
 industrial uses 207
 structural principles 205
- Borax 139
see also Borate minerals
- Borazanes 209
- Borazine 210, 408
- Bordeaux mixture (fungicide) 1190
- Boric acids
 B(OH)₃ 203
 HBO₂ 204
- Borides
 bonding 151
 catenation in 148
 preparation 146
 properties and uses 146
 stoichiometry 145, 147
 structure 147–151
- Born-Haber cycle 94–96, 79, 82–83
- Borohydrides *see* Borane anions, Tetrahydro-borates, etc.
- Boron 167
 abundance 139
 allotropes 141–144
 atomic properties 144, 222
 chemical properties 144, 145
 crystal structures of allotropes 141
 hydrides *see* Boranes
 isolation 139–140, 144
 neutron capture therapy using ¹⁰B 179
 nitride 208, 208
 nuclear properties 144
 oxide 203
 physical properties 144, 222
 sulfides 213–214
 variables atomic weight of 17
see also Group 13 elements
- Boron carbide
 B₄C 149
 B₁₃C₂ 149
 B₅₀C₂ 143
- Boron halides 195–202
 B₂X₄ 200
 B_{*n*}X_{*n*} 200, 202
 lower halides 199–202
see also Boron trihalides
- Boron nitride, B₅₀N₂ 143
- Boron-nitrogen compounds 207–211
- Boron-oxygen compounds 203–207
 organic derivatives 207

- Boron trifluoride *see* Boron trihalides
- Boron trihalides
 adducts 198–199
 bonding 196
 physical properties 196
 preparation 196
 scrambling reactions 197, 198
- Brass 1175, 1178, 1178, 1201, 1203, 1397
- Brimstone 645, 646
- Brønsted's acid-base theory 32, 48ff
 in non-aqueous solutions 51
 in aqueous solutions 628
- Bromates, BrO_3^- 862–864
 reaction scheme 866
 redox systematics 853–856
- Bromic acid, HBrO_3 863
- Bromides, synthesis of 821, 822
see also individual elements
- Bromine
 abundance and distribution 795
 atomic and physical properties 800–804
 cations Br_n^+ 842–844
 history 790, 790, 792, 794, 925
 monochloride 824–825, 833
 monofluoride 825, 833
 oxide fluorides 880–881
 oxides 850, 851
 nomenclature 853
 redox properties 853–855
see also individual compounds, bromic acid, bromates, perbromates, etc.
 pentafluoride 832–834
 production and uses 798, 800
 radioactive isotopes 801, 802
 reactivity 805
 standard reduction potentials 854
 stereochemistry 806
 trifluoride 827–831, 832
 volt-equivalent diagram 855
see also Halogens
- Bronze 1173, 1175
- Bronzes
 molybdenum 1016
 titanium 964
 tungsten 1016
 vanadium 987
- “Brown-ring” complex 447, 1094
- Brucite 121, 352, 385
- Buffer solutions 48, 49, 521, 524
- Bulky tertiary phosphine ligands, special properties of 494
- Butadiene as a η^4 ligand 935–936
- Cadmium
 abundance 1204
 chalcogenides 1208, 1210
 coordination chemistry 1215–1217
 discovery 1201
 halides 1211–1212
 organometallic compounds 1221
 oxides 1211, 1212
 production and uses 1202–120
- toxicity 1224
see also Group 12 elements
- Cadmium chloride structure 1211
- Cadmium iodide structure type 556, 680, 680, 1211
 relation to NiAs 556, 680, 680
 nonstoichiometry in 679
- Caesium
 abundance 70
 compounds with oxygen 83–86
 discovery 69
- Calamine (smithsonite) 1202
- Calcite 109
- Calcium
 in biochemical processes 125
 carbide 297, 298, 320
 carbonate *see* limestone
 cyclopentadienyl 136, 137
 history of 108
 organometallic compounds 136, 137
 phosphates 524–526
see also Alkaline earth metals, Lime, etc.
- Caliche (Chilean nitre) 796
- Californium 1252, 1262
see also Actinide elements
- Calomel 1213
- Capped octahedral complexes 916
- Capped trigonal prismatic complex 916
- Caprolactam, for nylon-6 422
- Carat 272, 1176
- Carbaboranes *see* Carboranes
- Carbene ligands 929
- Carbides 297–301
 silicon (SiC) 334
- Carbido complexes 927, 1107–1108
- Carbohydrates, photosyntheses of 125
- Carbon
 abundance 270
 allotropes 274–278, *see also* Fullerenes
 atomic properties 276, 372–372
 bond lengths (interatomic distances) 290, 292
 chalcogenides 314–319
 chemical properties 289
 coordination numbers 290, 291, 292
 cycle (global) 273
 disulfide 313–318, 653
 halides 301, 304
 history of 268–270
 hydrides of 301
 interatomic distances in compounds 290–292
 occurrence and distribution 270–274
 oxides 305
see also Carbon monoxide, Carbon dioxide
 “monofluoride” 289
 radioactive ^{14}C 276
 suboxides 305
- Carbon dioxide 305, 314
 aqueous solutions (acidity of) 309, 310
 atmospheric 273–274
 coordination chemistry 312
 industrial importance 307, 308
 insertion into M–C bonds 134, 312
 as a ligand 312, 313
 in photosynthesis 125

- physical properties 305
 production and uses of 311
 use in ^{14}C syntheses 310
- Carbon monoxide 305–310
 bonding in 926, 927
 chemical reactions 306, 308
 industrial importance 307
 as a ligand 926–929
 physical properties 306
 poisoning effect of 306, 1101
 preparation of pure 306
 similarity to PF_3 as a ligand 496
- Carbonates, terrestrial distribution 274, 273
- Carbonic acid 310
- Carbonic anhydrase 1225
- Carbonyl fluoride, reaction with OF_2 640
- Carbonyl halides *see* Carbon oxohalides
- Carbonyls *see* Carbon monoxide as a ligand
see also individual elements
- Carboplatin 1165
- Carboranes 161, 181ff
 bonding 181
 chemical reactions 186, 189
 isomerization 185–187
 preparation 181–185
 structures 181, 185
- Carborundum *see* Silicon carbide
- Carbosilanes 362
- Carboxypeptidase A 1224
- Carbyne ligands 928–930
- Carnotite 977
- Caro's acid *see* Peroxomonosulfuric acid
- Cast-iron 1071
- Cassiterite *see* Tin dioxide
- Castner-Kellner process (chlor-alkali) 790, 1203
- Catalysis
 ammonia, oxidation to NO , NO_2 423, 465, 466
 synthesis (Haber–Bosch) 43, 421–422
 ammonia(l)/metal solutions, effects of impurities 78
conjuncto boranes, preparation of 162
 C_{60} , hydroxylation by base 284
 carbonylation of $\text{B}_{12}\text{H}_{12}^{2-}$ 180
 C–H bonds, homogeneous catalytic activity of 494
 chlorination of organic compounds by CuCl 798
 S_2Cl_2 to SCl_2 by FeCl_3 689
 SiC to SiCl_4 by NiCl_2 811
 SO_2 to O_2SCl_2 by C or FeCl_3 694
 Claus process for recovery of S from H_2S 651, 699
 “clock” reactions, autocatalysis 864
 C–N–O cycle in stars 9
 contact process for H_2SO_4 646, 700, 708, 981
 CO, organic reactions of 309
 CS_2 , chlorination by Fe/FeCl_3 and by I_2 317
 synthesis by SiO_2 or Al_2O_3 317
 Fischer–Tropsch process 309, 1106
 fluorination of ammonia by Cu 439
 graphite by acid 289
 SOF_2 by CsF 685
 SO_3 by AgF 640
 graphite \rightarrow diamond transition by molten metals 278
 H_2 , *ortho-para* conversion by paramagnetic species 35
 HCN, production of 321
 hydrazine, decomposition by heavy metals 428
 hydrodesulfurization (HDS) by Mo compounds 1005
 hydroformylation of alkenes 309, 593, 1135, 1140
 hydrogen peroxide, decomposition of 635
 production of 634
 hydrogenation by metal hydrides 47
 hydrogenation of alkenes 1134–1135
 NO by $\text{Pt}/\text{charcoal}$ 431
 unsaturated organic compounds 38, 43, 1146
 hypohalous acids, decomposition of 858
 hyponitrous acid (HONNOH), base decomposition of 460
 nitramide (H_2NNO_2), base decomposition of 459
 O_2 , preparation from H_2O_2 603
 organotin compounds, synthesis of 399
 oxidation of SF_4 by O_2/NO_2 687
 SO_2 700, 708
 phase transfer catalysis by Br-containing compounds 794
 cryptands 97
 Reppe synthesis by Ni^{II} complexes 309, 1167, 1172
 propene, dimerization by AlPr_3^t 260
 S_4N_4 , depolymerization to $2\text{S}_2\text{N}_2$ by Ag_2S 725
 silanes, formation by Cu 338, 363
 hydrolysis by base 339
 silicone polymers, cross linking of 365
 steam-hydrocarbon reforming process 39, 421
 Wacker process by $\text{PdCl}_2/\text{CuCl}_2$ 1172
 water-gas shift reaction 38–39, 311, 421, 1106
see also Catalysts
- Catalysts
 alumina (activated) 243, 245
 BF_3 199, 200, 686
 carbon (activated) 274, 305, 321, 694
 carbonyl complexes of metals 309, 593, 1106, 1135, 1142
 crown ethers in synthesis of organoantimony compounds 596
 dithiolato complexes in polymerizations and oxidations 674
 Friedel Crafts 171, 176, 186, 199, 235–6, 338, 385
 HBr 812
 HCl in hydrolysis of glucose 812
 heteropolymetalates in petrochemical industry 1014
 HF 200, 810
 I_2 317, 508, 800
 Ir 321, 1115
 lanthanide oxides 1232
 “magic acid” in organic catalytic processes 570
 metalloenzymes in biological systems 1138
 MoS_2 in hydrogenations 1018
 NEt_3 in malathion production 509
 Ni, Pd, Pt 43, 321, 421, 431, 603, 634, 646, 810, 1148
 NO complexes in homogeneous catalysis 450, 452
 N_2O_5 in decomposition of ozone 458
 nonstoichiometric oxides in heterogeneous catalysis 644
 organotin compounds for polyurethanes 400
 Ph_3PO as an O atom transfer catalyst 504
 polymerization catalysts 105, 200, 229
 polyphosphoric acid in petrochemical processes 520
 Pt/Re for lead-free petroleum products 1043
 Rh 321, 1115
 SbFCl_4 in fluorinations 304

- Catalysts — *contd*
 tin oxide systems 385
 Vaska's compound 615, 1135–1136
 V_2O_5 708, 981
 Wilkinson's catalyst 43, 1134–1135
 zeolites 309, 359
 Ziegler–Natta catalysts 260–261, 972
see also Catalysis
- Catenation in Group 14 elements 374, 402
Catena-polyarsanes 584–587
Catena- S_8 diradical 660, 662
Catena- S_x 656, 659
 formation at λ point 660
- Caustic soda *see* Sodium hydroxide
- Cellophane 317
- Cement 251, 252
- Cementite 1075
- Cerium 1229
 diiodide 1240
 +4 oxidation state 1236, 1239, 1244
 production 1230
see also Lanthanide elements
- Chabazite *see* Zeolites
- Chain polyphosphates 526–529
 diphosphates 526
 tripolyphosphates 528, 528
see also Adenosine triphosphate, Sodium
 tripolyphosphate, Graham's salt, Kurrol's salt,
 Maddrell's salt
- Chain reactions, nuclear 1256, 1261
- Chalcocite (copper glance) 1174
- Chalcogens, group trends 754–759
see also S, Se, Te, Po
- Chalcophile elements 646, 648
- Chalcopyrite (copper pyrite) $CuFeS_2$ 649, 1174, 1365
- Chaoite 275, 276
- Chelate effect 910–911
- Chelation 906, 910
- Chemical periodicity 20ff
- Chemical properties of the elements, periodic trends in 23
- Chemical shear structures 644
see also oxides of Ti, Mo, W, Re, etc.
- Chemiluminescence of phosphorus 483
- Chernobyl, nuclear reactor disaster 146
- Chevreton phases 1018, 1031
- Chile saltpetre 407
see also Sodium nitrate
- Chlorates, ClO_3^- 862–865
 redox properties 1001, 1002
- Chloric acid, $HClO_3$ 863
- Chlorides, synthesis of 821, 822
see also individual elements
- Chlorin 126
- Chlorine
 abundance and distribution 795
 atomic and physical properties 800–804
 bleaching power 790, 793
 cations Cl_2^+ , Cl_3^+ 842, 843
 dioxide, ClO_2 844, 845, 846–848
 history 790–793
 hydrate 790
 monofluorides 824–827, 832
 oxide fluorides 875–880
 oxides 844–850
 oxoacids and oxoacid salts 853ff
 nomenclature 853
 redox properties 853–855
see individual compounds, Hypochlorous acid,
 Hypochlorites, Chlorous acid, etc.
 pentafluoride 832–834
 production and uses 797–798
 radioactive isotopes 801, 802
 reactivity 805
 standard reduction potentials 850
 stereochemistry 806
 toxicity 793
 trifluoride 827–830, 852
 volt equivalent diagram 855
see also Halogens
- Chlorite 355, 357, 413
- Chlorites, ClO_2^- 854, 855, 859–862, 1002, 1007–1009
- Chlorofluorocarbons 608, 793, 848
- Chlorophylls 109, 125–127
- Chloroplatinic acid 1154
- Chlorosulfanes *see* Sulfur chlorides
- Chlorous acid, $HClO_2$ 854, 855, 859, 861
- Chromate ion 1009, 1024, 1193
- Chromate alum 1028
- Chrome ochre 1003
- Chromic acid 1007
- Chromite 1003
- Chromium
 abundance 1003
 bis(cyclopentadienyl) 939, 1038
 borazine complex 210
 carbonyls 928–929, 1037
 carbyne complexes 929
 chalcogenides 680, 1017, 1018
 complexes
 +6 oxidation state 1023–1024
 +5 oxidation state 1024–1025
 +4 oxidation state 1025–1027
 +3 oxidation state 1027–1031
 +2 oxidation state 1031–1035
 with S 666
 compounds with quadruple metal-metal bonds
 1032–1034
 cyclooctatetraene complex 943
 cyclopentadienyls 939, 1037
 dibenzene “sandwich” compound 940, 1039
 discovery 1002
 dithiolene complex redox series 675
 halides and oxohalides 1019–1023
 hexacarbonyl 928, 1037
 importance of Cr^{III} in early coordination
 chemistry 914, 1027
 organometallic compounds 371, 373–375, 1207–1210
 oxides 1007–1009
 peroxo complexes 636, 637
 polynuclear complexes in dyeing and tanning 1030
 “polyphenyl” compounds 940
 production and uses 1003
 sulfides, nonstoichiometry in 679
see also Group 6 elements
- Chromocene 1038
- Chrysotile 351, 352, 357

- Cinnabar (vermillion), HgS 649, 1202, 1210
- Circular dichroism (CD) 1125
- Cisplatin 1164
- Class-a and class-b metal ions 909
see also Ligands
- Clathrate compounds 893, 1161
- Claus process (S from H₂S) 651, 652, 699
uses of 356
- Clock reaction (H. Landolt) 864
- Cluster compounds
boranes incorporating P, As or Sb 212
boron carbide 149
boron hydrides 151–180
carbido metal carbonyls 1107–1108
carboranes 181–189
cobalt, rhodium and iridium carbonyls 928ff,
1140–1143
cobalt–sulfur complexes 1119
of germanium, tin and lead 383, 392–396, 455–458
of indium 256–7
gold phosphines 1197
iron, ruthenium and osmium carbonyls 928ff,
1104–1108
lanthanide halides 1242
lithium alkyls 103–105
lithium imides 100
mercury-containing 1120
metal borides 148, 149–151
metalloboranes 171–173, 178
metallocarboranes 189–195
molybdenum and tungsten dihalides 1022
nickel, palladium and platinum carbonyls 1168–71
niobium and tantalum halides 991
of phosphorus, arsenic, antimony and bismuth 563,
588–591
rhenium alkyls 1068, 1069
rhenium carbidocarbonyls 1065
scandium halides 950
stabilization by encapsulated heteroatoms 950, 966,
992, 1065, 1107, 1141, 1169, 1242
of tellurium 761, 764
Te₆⁴⁺ 161, 761
technetium and rhenium chalcogenides 1049
tungsten and molybdenum halides 1021–1022
zirconium halides 965
- Cluster and cage structure 918
see also Cluster compounds
- Cobalt
abundance 1113
allyl complexes 933
arsenide 555, 556
atomic and physical properties 1115–1116
biochemistry of 1138, 1139, 1322
carbido carbonyls 1141–1142
carbonyls 928, 929, 1140–1143
complexes
+5 oxidation state 1121
+4 oxidation state 1121
+3 oxidation state 1122–1129
+2 oxidation state 1129–1133
+1 oxidation state 1133
lower oxidation states 1137
with S 666–669
with SO₂ 701
coordination numbers and stereochemistries 1117
cyclobutadiene complex 936
cyclooctatetraene complexes 942
cyclopentadienyls 1143
dithiolene complexes, redox series 676
halides 1119–1121
importance of Co^{III} in early coordination chemistry
914, 1122, 1123, 1302
nitrate (anhydrous) 469
nitrate complexes 469, 470, 543
optical resolution of [Co{(μ-OH)₂Co(NH₃)₄]₃ 670, 915
organometallic compounds 1139–1143
oxidation states 1117
oxides 1117–1119
oxoanions 1120, 1121
production and uses 1114, 1115
reactivity of element 1116
relationship with other transition elements 1116–1117
standard reduction potentials 1122
sulfides 1118
- Cobaltite (cobalt glance) 1114
- Cobaltocene 939, 1143
- Coesite 342, 343
- Coinage metals (Cu, Ag, Au) 1173
see also Group 11 elements and individual element
- Coke 274
historical importance is steel making 1070, 1072
see also Carbon
- “Cold fusion” 1151
- Cold fusion (nuclear) 1280, 1283–4
- Columbite 977
- Columbium 976
see also Niobium
- Combustion 600–602, 612
- Complexometric titration of Bi^{III} with EDTA 577
- Contact process *see* Sulfuric acid manufacture
- Cooperativity 1100, 1199
- Cooper pairs 1183
- Coordinate bond 198, 921
see also Donor-acceptor complexes
- Coordination number 912
two 945
three 913
four 913
five 914
six 916
seven 916
eight 916
nine 917
above nine 917
- Copper
abundance 1174
acetylide 1180
alkenes and alkynes 1199
alkyls and aryls 1200
biochemistry of 1197
carboxylates 1192–1193
chalcogenides 1181–1182
complexes
+3 oxidation state 1187
+2 oxidation state 1189–1194

- Copper — *contd*
 +1 oxidation state 1194–1197
 Cu–S–O system 677
 halides 1183–1185
 history 1173
 nitrate, structure of 471, 1190
 nitrate complexes 469, 470, 471, 544
 organometallic compounds 925, 1199, 1200
 oxides 1181
 production and uses 1174, 1175
see also Group 11 elements
- Copper oxide Cu_{2-x}O , nonstoichiometry in 642
 “Corrosive sublimate” 1212
- Corundum *see* Aluminium oxides
- Cosmic black-body radiation 2
- Cossee mechanism 261
- Cotton effect 1125
- Creutz-Taube anion 1097
- Cristobalite 343, 344
- Critical mass 1256, 1257, 1261
- Crocidolite 351
- Crocoite 1003
- Crown ethers 96, 97
 complexes with alkali metals 95, 97
 complexes with alkaline earth metals 124
 “hole sizes” of 96
 “triple-decker” complex
- Cryolite 219
- Crypt, molecular structure of 98
 complexes with alkali metals 97, 393, 394
 complexes with alkaline earth metals 125
- Crystal field
 octahedral 922
 strong 923
 weak 922
- Crystal field splittings 922–923
- Crystal field stabilization energy 1131
- Crystal field theory 922
- Cubic, eight coordination 916, 1275, 1480
- Cupellation 1173
- Cuprite 1174
- Curium 1252, 1262
see also Actinide elements
- Cyanamide 319
 industrial production 324
- Cyanates 320, 324
 as ligands 325
- Cyanide ion as ligand 322, 926
- Cyanide process 1175, 1196
- Cyanogen 319–321
 halides 320, 323, 340
- Cyanuric acid 305
- Cyanuric compounds 320, 323
- Cyclobutadiene as η^4 ligand 935–938
- Cycloheptatrienyl as η^7 ligand 941
- Cyclometaphosphoric acids 541, 542
- Cyclometaphosphoric acids $(\text{HPO}_3)_n$ 512
see also *Cyclo*-polyphosphoric acid, *Cyclo*-poly-phosphates
- Cycloocta-1,5-diene (cod) as ligand 932
- Cyclooctatetraene as η^8 ligand 942
 as η^2 , η^4 , η^6 , etc., ligand 943
- Cyclopentadienyl
 as η^5 ligand 937–940
 as η^1 ligand 940
see also Ferrocene, individual metals
- Cyclo*-polyarsanes 584–586
- Cyclo*-polyphosphates 529–531
- Cyclophosphazanes 533, 534
- Cyclo* polyphosphoric acids 529
see also *Cyclo*-metaphosphoric acids
- Cyclo*- S_6 (ϵ -sulfur) 656
- Cyclo*- S_7 656–657
- Cyclo*- S_8 (α)
 crystal and molecular structure 654
 physical properties 654–656
 polymerization at λ point 660
 solubility 654
 transition α - $\text{S}_8 \rightleftharpoons \beta$ - S_8 654
 vapour pressure 660
- Cyclo*- S_9 657
- Cyclo*- S_{10} 656–657
- Cyclo*- S_{11} 657
- Cyclo*- S_{12} 656–658
- Cyclo*- S_{18} 656, 658, 778
- Cyclo*- S_{20} 656, 659
- Cyclo*-silicates 347, 349
- Cytochromes 1095, 1101, 1198, 1279
- Cytosine 61, 62
- d-block contraction 27, 222, 251, 561, 655, 1234
- d orbitals 922–923, 1285–1289
 splitting by crystal fields 922–923
- Dalton’s atomic theory 509
- Dalton’s law of multiple proportions 509
- Dawson structure 1015
- Decaborane, $\text{B}_{10}\text{H}_{14}$ 159, 163
 adduct formation 176
 Brønsted acidity 175
 chemical reactions 175–177
 preparations 187
 structure 175
- Degussa process for HCN 321
- Density of the elements
 periodic trends in 24
- Denticity 906
- Deoxyribonucleic acids 476
- Detergents
 polyphosphates in 474, 477
 sodium tripolyphosphate in 528
- Deuterium
 atomic properties 34
 discovery 32
ortho- and *para*- 36
 physical properties 35
 preparation 39
- Dewar-Chatte-Duncanson theory 931
- Diagonal relationship 27
 B and Si 202, 347
 Be and Al 107
 Li and Mg 76, 102, 1113
 N and S 722
- Diamond
 chemical properties 278
 occurrence and distribution 271, 272

- physical properties 278
 production and uses 272
 Diarsane, As₂H₄ 583
see also Arsenic hydrides
 Diaspore 243
 Diatomaceous earth 342
 Diatomic molecules (homonuclear), bond dissociation energies of 584
 Diazotization of aromatic amines 463
 Dibenzenechromium 940, 1039
see also Benzene as η⁶ ligand
 Diborane, B₂H₆ 154, 159
 chemical reactions 163–170
 cleavage reactions 165
 hydroboration reactions 166, 183
 preparation 164
 pyrolysis 164
 Dibromonium cation Br₂⁺, compound with Sb₃F₁₆[−] 569
 Dicacodyl, As₂Me₄ 583–585
 Dichlorine hexoxide, Cl₂O₆ 844, 845, 849, 850
 Dichlorine monoxide, Cl₂O 844–847
 Dichromate ion, Cr₂O₇^{2−} 1009
 Dicyandiamide 320, 324
 Dielectric constant, influence of H bonding 55
 Dihydrogen 34
 coordination chemistry of 44–7
 Dimethylaminophosphorus dihalides 533
 Dimethyl sulfoxide as ionizing solvent 694
 Dinitrogen
 complexes, synthesis of 413, 414
 coordination modes 415
 discovery of donor properties 414, 1097
 isoelectronic with CO, C₂H₄ 416
 as ligand 408, 413–416
 Dinitrogen monoxide *see* Nitrous oxide
 Dinitrogen pentoxide N₂O₅ 444, 458
 Dinitrogen tetroxide 444, 454–458
 chemical reactions 456–458
 nonaqueous solvent properties 456–458
 physical properties 456, 457
 preparation 456
 structure 455
see also Nitrogen dioxide
 Dinitrogen trioxide, N₂O₃ 444
 Diopside 349
 Dioxygen
 bonding in metal complexes 619–620
 chemical properties 612, 613
 coordination chemistry of 615
 difluoride 639
 molecular-orbital diagram 606
 paramagnetic behaviour 601
 reactions of coordinated O₂ 619–620
 reaction with haemoglobin 614, 1099–1101
 singlet state 607, 614, 716
 singlet-triplet transitions 606
 superoxo and peroxo complexes 615, 616
 Vaska's discovery of reversible coordination 615, 1135
see also Oxygen, Oxygen carriers, Singlet
 Diphosphazenes 535
 Diphosphonic acid *see* Diphosphorous acid
 Diphosphoric acid, H₄P₂O₇ 510, 516, 518
 Diphosphorous acid, H₄P₂O₅ 512
 Diphosphorus tetrahalides 497
 Disilenes 362
 Disulfates, S₂O₇^{2−} 705, 712
 imido derivatives 743
 preparation in liquid SO₂ 700
 Disulfites, S₂O₅[−] 705, 720
 Disulfuric acid, H₂S₂O₇ 705, 711
 Disulfurous acid, H₂S₂O₅ 853, 705, 720
 Dithiocarbamates 317
 as ligands 665, 673, 674, 796
 Dithiolenes as ligands 665, 674–676
 Dithionates, S₂O₆^{2−} 705, 715
 Dithionic acid, H₂S₂O₆ 705, 715
 Dithionites, S₂O₄^{2−} 705, 720
 Dithionous acid, H₂S₂O₄ 705, 720
 DNA *see* Deoxyribonucleic acids
 Döbereiner's triads 21
 Dodecahedral complexes 916
 Dolomite 109, 272
 Donor-acceptor complexes
 of AlX₃ 235–237
 of AsX₃ 552, 564
 of CN[−] 321, 322
 of CO *see* Carbonyls
 of *cyclo*-polyarsanes 584–586
 of *cyclo*-polyphosphazenes 540
 of dithiocarbamates and xanthates 673, 674, 1080
 of dithiolenes 674
 first (H₃NBF₃) 408
 of GaH₃ 232
 of Group 13 halides 237–239
 of H₂S 673, 673, 714
 of N₂ 414–416, 1097
 of NO *see* Nitrosyls
 of O₂ 615–620
 of PH₃ and tertiary phosphines 493–495
 of PX₃ 495, 497
 of S_n 665–672
 of SbF₅ 561, 569, 570, 702
 of SCN[−] 324–327, 345
 of SF₄ 686
 of S₄N₄ 723
 of SO, S₂O₂, SO₂ 700–703
 of SO₃ 703, 704
 stability of 198
see also Class-a and class-b metal ions, Coordinate bond, Ligands, individual elements
 Double-helix structure of nucleic acids 474
 Downs cell 72, 73
 Dry batteries 1204
 Dubnium 1281–2
 Dysprosium 1229
 +4 oxidation state 1244
see also Lanthanide elements
 e-Process in stars 8
 Effective atomic number (EAN) rule 921
see also Eighteen electron rule
 Effective ionic radii, Table of 1295
 Eighteen electron rule 1037, 1104, 1109, 1112, 1134
 Einsteinium 1252, 1262
see also Actinide elements

- Eka-silicon, Mendeleev's predictions 29
- Electrical properties, influence of H bonding 53
- Electric arc process of steelmaking 1072
- Electrofluorination 821
- Electron affinity 75, 82, 800
- Electron-counting rules
for boranes 161
for carbonyl clusters 1107, 1142, 1169
for carboranes 181
for gold-phosphine clusters 1197
for metal-halide clusters 966, 1018, 1022
for metallocarboranes 194
- Electron transfer reactions, mechanisms of 1124
- Electronegativity
definition of 26
periodic trends in 26
- Electronic structure and chemical periodicity 21–23
- Electronic structure of atoms 21–23
- Elements
abundance in crustal rocks 1294
bond dissociation energies of gaseous diatomic 584
cosmic abundance 3ff, 12ff
isotopic composition of 47
table of atomic weights *see* inside back cover
origin of 1, 5, 9ff, 12ff
periodic table of *see* inside front cover
periodicity in properties 20–31
 $Z = 104$ –112, *see* Transactinide
- Ellingham diagram 308, 307, 369
- Emerald 107, 1003
- Enstatite 349
- Entropy and the chelate effect 910
- Equilibrium process in stars (e-process) 8
- Erbium 1229
see also Lanthanide elements
- Ethene (ethylene) as a ligand 930, 931
- Eutrophication 478, 528
- Europium 1229
+2 oxidation state 1239, 1240, 1241, 1248
magnetic properties of 1243
see also Lanthanide elements
- Exclusion principle (Pauli) 22
- Extended X-ray absorption fine structure (EXAFS) 1036
- f-block contraction 562, 1234
- Faraday's phosphide synthesis 489
- Faujasite 358
- Fehling's test 1181
- Feldspars 354, 358, 414
- Fenton's reagent 636
- Fermium 1252, 1262
see also Actinide elements
- Fermi level, definition of 332
- Ferredoxins 1035, 1036, 1098, 1101–1103
- Ferricinium ion 1109
- Ferrites 1081, 1209
- Ferritin 1098, 1104
- Ferrocene
bonding 938–939
historical importance of 924, 1070, 1109
physical properties 937
reactions 1109–1112
structure 937
synthesis 938, 1109
- Ferrochrome 1003
- Ferroelectricity 57–58, 386, 571
- Ferromanganese 1041
- Ferromolybdenum 1003
- Ferrophosphorus 480, 492, 525
- Ferrosilicon alloys 330
- "Ferrous oxide", Fe_{1-x}O , nonstoichiometry in 643, 644
- Ferrovandium 977
- First short period, "anomalous" properties of 27
- Fischer (Karl) reagent 628
- Fischer-Tropsch process 309, 1106
- Fish population, relation to phosphate-rich waters 479
- Flint 328, 342
- Fluorapatite *see* Apatites
- Fluoridation and dental caries 447, 525, 791, 792
- Fluorides 820–821
solubility in HF 817
synthesis 820–821
- Fluorinated peroxo compounds 639, 640
- Fluorinating agents 820–821
 AsF_3 , SbF_3 560
 AsF_5 , BiF_5 , SbF_5 562, 563
- Fluorine
abundance and distribution 795
atomic and physical properties 800–804
chemical synthesis of 821
history 789–792
isolation 789, 791
oxides *see* Oxygen fluorides
oxoacid, HOF 789, 853, 856
preparation of fluorides using 820
production and uses 796–798
radioactive isotopes 801, 802, 936
reactivity 804–806
stereochemistry 806
toxicity 792, 810
see also Halogens
- Fluorite, CaF_2 109
crystal structure of 117
- Fluorspar 789, 790
fluorescence 789, 790
see also Fluorite
- Fluorosulfuric acid 689
- Fluxional behaviour *see* Stereochemical non-rigidity
- Francium
abundance 68
discovery 68
see also Alkali metals
- Frasch process for sulfur 646
- Freons (eg CCl_2F_2) 304, 791
- Friedel-Crafts catalysis
 AlX_3 complexes 171, 176, 186, 235, 236, 338
 BF_3 complexes 199
 SnCl_4 385
- Fullerenes
chemical properties 282–7
discovery 279
incorporation of heteroatoms 287–9
structure 280
- Fullerides 285
- Fullerols 284

- Fuller's earth *see* Montmorillonite
 "Fulminating" silver and gold 1180
 Fulminate ion 319, 433
 Fundamental physical constants, Table of values back end paper
 "Fusible white precipitate" 1219
- g (gerade), definition 938
 Gabbro rock 358
 Gadolinium 1229
 diiodide 1242
 see also Lanthanide elements
 Galena (Pb glance) 649
 roasting reactions 677
 see also Lead sulfide
 Gallane 231
 Gallium
 abundance 218
 arsenide, semiconductor 221
 chalcogenides 252, 253
 III-V compounds 256
 discovery 216
 as eka-aluminium 216
 hydride 231
 hydride halides 232
 lower halides 240
 organometallic compounds 262-266
 oxides 246
 production and uses 219
 sulfides 285, 286
 trihalides 237
 see also Group 13 elements
 Gallium, ion, hydration number of 605
 Garnets 348
 magnetic properties of 946, 1081
 Garnierite 1145
 Germanes *see* Germanium hydrides
 Germanium
 abundance 368
 atomic properties 371, 372
 chalcogenides 389, 390
 chemical reactivity and group trends 373, 375
 cluster anions 393
 dihalides 376
 dihydroxide 382
 dioxide 383
 discovery 367
 halogeno complexes 376
 hydrides 374, 373
 hydrohalides 375
 isolation from flue dust 369
 monomeric Ge(OAr)₂ 390
 monoxide 376, 382
 organo compounds 376, 396, 404
 physical properties 371, 372
 silicate analogues 383
 sulfate 387
 tetraacetate 387
 tetrahalides 375, 377
 uses 369
 Germanocene 398
 German silver 1146
 Germenes 397
 Germylenes 397
 Gibbs' phase rule 676
 Gibbsite 243, 245, 352
 Girbotol process 311
 Glassmaker's soap 1048
 Gold
 abundance 1174
 alkyls 1180, 1200
 chalcogenides 1181-1182
 cluster compounds 1197, 1198
 complexes
 +3 oxidation state 1188-1189
 +2 oxidation state 1189
 +1 oxidation state 1196
 lower oxidation states 1197
 with S 666
 halides 1183-1184
 history 1173
 nitrate complexes 469, 471
 organometallic compounds 925, 1199-1200
 oxide 1181
 production and uses 1367, 1174,
 see also Group 11 elements
 Goldschmidt's geochemical classification
 Graham's salt 528-531
 Graphite
 alkali metal intercalates 293
 chemical properties 289-292
 halide intercalates 295, 295
 intercalation compounds 293-294
 monofluoride 289
 occurrence and distribution 270
 oxide 289, 290
 oxide intercalates 296
 physical properties 278
 production and uses 271
 structure 275
 subfluoride 289-290
 Greek alphabet *see* back end paper
 Greenhouse effect 273, 687
 Grignard reagents 131-136
 allyl 933
 constitution of 131, 132
 crystalline adducts of 133
 preparation of 132
 Schlenk equilibrium 131, 132
 synthetic uses of 134, 135, 151
 Group 0 elements *see* Noble gases
 Group 1 elements *see* Alkali metals
 Group 2 elements *see* Alkaline earth metals
 Group 3 elements (Sc, Y, La; Ac)
 atomic and physical properties 946, 947
 chemical reactivity 948-949
 group trends 948-949
 high coordination, numbers 952
 oxidation states lower than +3 949, 950
 see also individual elements and Lanthanide elements
 Group 4 elements (Ti, Zr, Hf)
 atomic and physical properties 957-958
 coordination numbers and stereochemistries 960
 group trends 957-960

- Group 4 elements (Ti, Zr, Hf) — *contd*
 oxidation states 960
see also Titanium, Zirconium, Hafnium, Rutherfordium
- Group 5 elements (V, Nb, Ta)
 atomic and physical properties 978
 coordination numbers and stereochemistries 980
 group trends 979, 980
 oxidation states 980
see also Vanadium Niobium, Tantalum, Dubnium
- Group 6 elements (Cr, Mo, W)
 atomic and physical properties 1004, 1008
 coordination numbers and stereochemistries 1006
 group trends 1005
 oxidation states 1006
see also Chromium, Molybdenum, Tungsten
- Group 7 elements (Mn, Tc, Re)
 atomic and physical properties 1043
 coordination numbers and stereochemistries 1046
 group trends 1044, 1045
 oxidation states 1046
 oxoanions 1049, 1050
 redox properties 1044, 1045
see also Manganese, Technetium, Rhenium
- Group 8 elements *see* Iron, Ruthenium, Osmium
- Group 9 elements *see* Cobalt, Rhodium, Iridium
- Group 10 elements *see* Nickel, Palladium, Platinum
- Group 11 elements (Cu, Ag, Au)
 atomic and physical properties 1176, 1177
 coordination numbers and stereochemistries 1179, 1180
 group trends 1177–1180
 oxidation states 1179
see also Copper, Silver, Gold
- Group 12 elements (Zn, Cd, Hg)
 atomic and physical properties 1203, 1205
 coordination numbers and stereochemistries 1207
 group trends 1205–1208
see also Zinc, Cadmium, Mercury, Element 112
- Group 13 elements (B, Al, Ga, In, Tl)
 amphoteric behaviour of Al, Ga 225
 atomic properties 222
 chemical reactivity 224–227
 group trends 223–227, 237
 +1 oxidation state 224, 227
 physical properties 222, 224
 trihalide complexes, stability of 237–239
 unusual stereochemistries 256
see also individual elements
- Group 14 elements *see* Carbon, Silicon, Germanium, Tin, Lead
- Group 15 elements
see Nitrogen, Phosphorus, Arsenic, Antimony, Bismuth
- Group 16 elements *see* Oxygen, Sulfur, Selenium, Tellurium, Polonium
- Group 17 elements *see* Halogens
- Guanidine 305
- Guanine 61, 62
- Guano 408
- Gunpowder 645, 646
- Gypsum 109, 122
 diluent in superphosphate fertilizer 525
 occurrence in evaporites 647
 process for H₃PO₄ manufacture 521, 522
 S recovery from 651, 652
- H bridge-bond in boranes and carboranes 154
- Haber–Bosch ammonia synthesis 408, 409,
 historical development 421
 production statistics 421
 technical details 421
- Haem 126, 1099
- Haematin 1099
- Haematite 1071
- Haemocyanin 1199
- Haemoglobin 1098–1101
- Hafnates 964
- Hafnium
 abundance 955
 alkyls and aryls 973
 carbonyls 973
 complexes
 +4 oxidation state 967–969
 +3 oxidation state 969
 lower oxidation states 971
 compounds with oxoanions 966, 967
 cyclopentadienyls 973–975
 dioxide 962
 discovery 954
 halides 964–966
 neutron absorber 965, 1258
 organometallic compounds 973–975
 production and uses 956
 sulfides 962
see also Group 4 elements
- Hahnium, *see* Dubnium
- Halates, XO₃[−] 862–866
 astatate 885
 disproportionation 855
- Halic acids, HOXO₂ 862–863
- Halides 819–824
 astatide 886
 intercalation into graphite 294, 295
 synthesis of 819–823
 trends in properties 823
see also individual elements: Al, As, Be, B, etc. *and*
 individual halides: Br[−], Cl[−], etc.
- Halites, XO₂[−] 859–862
- Hall effect 258, 549, 552, 1017
- Halogen cations, X_n⁺ 842–844
see also Polyhalonium cations
- Halogen(I) fluorosulfates, XO₂F 883–885
- Halogen(I) nitrates XONO 883, 884
- Halogen(I) perchlorates, XOClO₃ 883, 884
- Halogens (F, Cl, Br, I, At) 784–887
 abundance and distribution 795, 796
 atomic and physical properties 800–804
 charge-transfer complexes 806–809
 history (time charts) 790, 791
 origin of name 789, 790
 production and uses 796, 800
 reactivity towards graphite 296
 stereochemistry 806
see also individual elements, Interhalogen compounds
- Halous acids, HOXO 859, 861
- Hammett acidity function *H*₀ 51, 52
- Hapticity
 classification of organometallic compounds 925
 distinction from connectivity 925, 928

- Hassium 1281, 1283
Hausmannite 1041, 1049
Heat of vaporization, influence of H bonding 54
Heavy water 39
Helium
 abundance in universe 3
 atomic and physical properties 891, 890
 discovery 888
 production and uses 889, 890
 thermonuclear reactions in stars 10
 see also Noble gases
Hemimorphite 348
Hertzprung–Russell diagrams 6
Heteropoly blues 1015
Heteropolymolybdates 1013, 1015
Heteropolytungstates 1013, 1015
Heteropolyvanadates
Hexamethylphosphoramide 532
Hexathionates, $S_6O_6^{2-}$, preparation and structure 717, 718, 851
High temperature superconductivity 945, 1183–3, 1232
High–alumina cement 251
High-spin complexes 923
Hittorf's allotrope of phosphorus 482
Holmium 1229
 see also Lanthanide elements
"Horn silver" 1174
Hume–Rothery rules 1178
Hydrargillite 243, 245
Hydrazido complexes with metals 430
 see also Dinitrogen as a ligand
Hydrazine 408, 422, 427–431
 acid-base properties 428
 as a bridging ligand 431
 hydrate 429, 430
 industrial production 429
 methyl derivatives as fuels 429
 molecular structure and conformation 427, 428
 oxidation of 434
 preparation 427
 properties of 427
 reaction with nitrous acid 432
 reducing properties 430
 uses 429
 water treatment using 429
Hydrides, binary 64–67
 acid strength of 48
 bonding in 64
 of boron *see* Boranes
 classification of 64
 complex 67
 covalent 64, 67
 interstitial 67
 ionic 64, 65
 nonstoichiometric 66, 67
 and periodic table 65
 of sulfur *see* Sulfanes
 see also individual elements
Hydroboration *see* Diborane
Hydrochloric acid, HCl(aq) 790, 792, 809, 812
 azeotrope 815
Hydrofluoric acid, HF(aq) 790
 acid strength of 814
 azeotrope 815
 preparation of fluorides using 820–821
Hydroformylation of alkenes 309, 1135, 1140
Hydrogen
 abundance (terrestrial) 32
 abundance in universe 2
 atomic properties 34
 chemical properties 43
 cyanide, H bonding in 55
 as the essential element in acids 32
 history of 32, 33
 industrial production 38
 ionized forms of 36
 isotopes of 34
 see also Deuterium, Tritium
 ortho- and *para*- 32, 35
 physical properties of 34
 portable generator for 39
 preparation 38
 stereochemistry of 44
 see also Dihydrogen
 thermonuclear reactions in stars 9
 variable atomic weight of 17
Hydrogen azide, HN₃ 432, 433
Hydrogen bond 33, 52–64
 in ammonia 423
 in aquo complexes 625
 bond lengths (table) 60
 comparison with BHB bonds 64
 in DNA 61, 62
 and ferroelectricity 57
 in HF 812, 813
 influence on properties 53
 influence on structure 59
 in proteins and nucleic acids 61, 62
 and proton nmr 56
 strength of X-ray and neutron diffraction 56
 theory of 63
 and vibrational spectroscopy 56
 in water 623
Hydrogen bromide, HBr
 azeotrope 815
 hydrates 815
 physical properties 813
 production and uses 811, 812
Hydrogen chloride, HCl
 hydrates 813, 814
 nonaqueous solvent properties 813
 physical properties 813
 production and uses 811–812
 see also Hydrochloric acid
Hydrogen dinitrate ion, $[H(NO_3)_2]^-$ 468
"Hydrogen economy" 39, 39
Hydrogen fluoride, HF 809–810
 H bonding in 52–53, 812
 hydrates 814
 nonaqueous solvent properties 816–818
 physical properties 812, 813
 preparation of fluorides using 820
 production and uses 809–811
 skin burns, treatment of 810
 see also Hydrofluoric acid

- Hydrogen halides, HX 809–819
 chemical reactivity 813–816
 nonaqueous solvent properties 816–819
 physical properties 812, 813
 preparation and uses 809–812
- Hydrogen iodide, HI
 azeotrope 815
 hydrates 815
 physical properties 812
 production and uses 811, 812
- Hydrogen-ion concentration *see* pH scale
- Hydrogen peroxide 633
 acid-base properties 636–638
 chemical properties 634, 638
 physical properties 633, 634, 635
 preparation 633
 production statistics 634
 redox properties 634–637
 structure 635
 uses of 633–634
- Hydrogen sulfate ion, HSO_4^- 705, 706, 711–713
- Hydrogen sulfide, H_2S
 chemistry 682
 as ligand 665, 673
 molecular properties 682, 767
 occurrence in nature 646–648, 651, 771
 physical properties 682, 767
 preparation (laboratory) 682
 protonated $[\text{SH}_3]^+$ 683
see also Sulfanes, Wackenroder's solution
- Hydrogen sulfite ion, HSO_3^- 705, 719
- Hydrometalation 926
- Hydronitrous acid *see* Nitroxyl acid
- Hydroperoxides 636
- Hydroxonium ion, H_3O^+ 628–631, 814, 815
- Hydroxyl ion, hydration of 630, 632
- Hydroxylamine 422, 431–432
 configurational isomers 432, 432
 hydroxylamides of sulfuric acid 744–746
 preparation 495, 431, 432
 properties 495, 431, 432
- Hypersensitive bands in spectra of lanthanides 1244
- Hypobromous acid, HOBr 853, 855, 857, 858
- Hypochlorite, OCl^- 854, 855, 857–859
 molecular hypochlorites 859
- Hypochlorous acid, HOCl 853–859
 preparation 857
 reactions 858–859
 uses 860
- Hypofluorites (covalent) 639, 688
- Hypofluorous acid, HOF 638, 639
 preparation 791, 853, 856
- Hypohalates, OX^- 853–859
- Hypohalous acids, HOX 853–859
- Hypoiodous acid, HOI 853–859
- Hyponitric acid, $\text{H}_2\text{N}_2\text{O}_3$ 530, 459
- Hyponitrites 459–461
- Hyponitrous acid, $\text{H}_2\text{N}_2\text{O}_2$ 459–459
- Hypophosphoric acid (diphosphoric(IV) acid), $\text{H}_4\text{P}_2\text{O}_6$
 512, 515–516
 isomerism to isohypophosphoric acid 515
- Hypophosphorous acid, H_3PO_2 512, 513
- Hypophosphites 513, 516
 “Hyposulphite” used in photography 1186, 1196
- Icosagens 227
- Icosahedron, symmetry elements of 141
- Ilmenite 955, 960, 963
- Inclusion compounds 985
see also Clathrate compounds
- Indium
 abundance 218
 chalcogenides 252–254
 III–V compounds 255–258
 discovery 216
 lower halides 240
 organometallic compounds 262,
 oxide 247
 production and uses 219
 trihalides 237, 238
see also Group 13 elements
- Industrial chemicals, production statistics 407
see also individual elements
- Industrial Revolution 1070, 1072
- Inert-pair effect 27
 in Al, Ga, In, Tl 226
 in Ge, Sn, Pb 374
 in P, As, Sb, Bi 553, 566, 568
- “Infusible white precipitate” 1219
- Inner-sphere reactions 1124
- Ino-silicates 347, 349–351
- Interelectronic repulsion parameter
 for hexaquo chromium(III) 1029
 for hexaquo vanadium(III) 996
 for high-spin complexes of cobalt(III) 1127
 for high-spin complexes of cobalt(II) 1132
- Interhalogen compounds 824–828
 diatomic, XY 824–828, 833
 first preparation 790, 791
 hexa-atomic, XF_5 832–835
 octa-atomic, IF_7 832–835
 tetra-atomic, XY_3 828–831, 833
see also Polyhalide anions, Polyhalonium cations
- Invar 1146
- Iodates, IO_3^- 862, 863
 reaction scheme 866
 redox systematics 854–856
- Iodic acid, HIO_3 863, 864, 866
- Iodides, synthesis of 822
see also individual elements
- Iodine
 abundance and distribution 795
 atomic and physical properties 800–804
 cations I_n^+ 842–844
 charge-transfer complexes 806–809
 colour of solutions 806–809
 crystal structure 803
 goitre treatment 790, 794
 heptafluoride 832–835
 history 790, 791, 793
 Karl Fischer reagent for H_2O 627
 monohalides 824–828, 833
 oxoacids and oxoacid salts 853
 nomenclature 853

- redox properties 854–856
see also individual compounds, Iodic acid, Iodates,
 Periodic acids, Periodates, etc.
- oxide fluorides 881–883
 oxides 851–853
 pentafluoride 832–834
 “pentoxide”, I_2O_5 851–853
 production and uses 799, 800
 radioactive isotopes 801, 802
 reactivity 805
 standard reduction potentials 854
 stereochemistry 806
 trichloride 828–829, 831, 833
 trifluoride 828, 830, 831, 833
 volt equivalent diagram 855
see also Halogens
- Iodine trichloride, complex and $SbCl_5$ 568
 Iodyl fluorosulfate, IO_2SO_2F 882
 Ionic-bond model 79–81, 963
 deviations from 81
 Ionic radii 80, 81
 table of 1295
 Ionization energy, periodicity of 24
- Iridium**
 abundance 1113
 atomic and physical properties 1115–1116
 carbonyls 928, 1140–1143
 complexes
 +5 oxidation state 1121
 +4 oxidation state 1121–1122
 +3 oxidation state 1121, 1127, 1129
 +2 oxidation state 1129–1130
 +1 oxidation state 1133–1137
 lower oxidation states 1137
 with SO_2 702
 coordination numbers and stereochemistries 1117
 cyclopentadienyls 1143
 discovery 1113
 halides 1119–1121
 organometallic compounds 1139–1143
 oxidation states 1117
 oxides 1117, 1118
 production and uses 1114
 reactivity of element 1116
 relationship with other transition elements 1116–1117
 sulfides 1117
- Iron**
 abundance 1071
 allyls 933
 alums 1088
 atomic and physical properties 1074
 biochemistry of 1098
 bis (cyclopentadienyl) *see* Ferrocene
 carbidocarbonyls 1107–1108
 carbonyl halides 1108
 carbonyl hydrides and carbonylate 1107
 carbonyls 928, 1071, 1104
 chalcogenides 1080, 1081
 complexes
 +3 oxidation state 1088–1091
 +2 oxidation state 1091–1095
 lower oxidation states 1098
 with S 666, 671
 with SO 696
 with SO_2 702
 coordination numbers and stereochemistries
 cyclooctatetraene complexes 945
 cyclopentadienyls 1109–1112
 see also Ferrocene
 dithiocarbamate complexes 673, 1090
 electronic spin states 1079
 halides 1083–1085
 history 1070, 1072
 mixed metal oxides (ferrites) 1081
 organometallic compounds 937, 1104–1112
 oxidation states 1077, 1078
 oxides 1079, 1080
 oxoanions 1081, 1121
 production and uses 1071–1072
 proteins 1098–1104
 reactivity of element 1075
 relationship with other transition elements 1077
 standard reduction potentials 1077, 1093, 1101
 Iron age 1070
 Iron pyrites
 reserves of 651
 source of S 759–649
 structure 555, 557, 680
 Iron-sulfur proteins 1102–1104
 Irving-Williams order 909,
 Isocyanates 319, 322
 as polyurethane intermediates 305
 Isohyphosphoric acid [diphosphoric (III, $H_4P_2O_6$)] 512,
 515, 516
 Isomerism 918
 cis-trans 919, 1128
 ‘classical-nonclassical’ in organoboron structures 186
 conformational 918
 coordination 920
 fac-mer 919
 geometrical 919
 ionization 920
 ligand 921
 linkage 920
 optical 919
 polymerization 921
 polytopal 918
 syn-anti 935
 Isopolymolybdates 1175–1183
 Isopolyniobates 987
 Isopolytantalates 987
 Isopolytungstates 1175–1183
 Isopolyvanadates 1146–1150
 Isotopes, definition of 22
- Jahn-Teller effect 1021
 in Cu^{II} 1190
 in high-spin Cr^{II} 1021, 1032
 in high-spin Mn^{II} 1049, 1057
 in low-spin Co^{II} 1133
 in Ti^{III} 970
 Jasper 342
 Joliotium, *see* Dubnium

- Kaolinite 349, 352–354, 357
 Karl Fischer reagent 627
 Keatite 342, 343
 Keggin structure 1014, 1015
 Keiselguhr 342
 Kinetic inertness
 of chromium(III) complexes 1027
 of cobalt(III) complexes 1123
 Kirsanov reactions 535
 Kraft cheese process 524
 Kraft paper process 89
 Kroll process 955, 956
 Krypton
 atomic and physical properties 801, 890
 clathrates 893
 compounds of 903
 discovery 889
 see also Noble gases
 Kupfernickel 1144, 1145
 Kurchatovium *see* Rutherfordium
 Kurrol's salt 528–531

 Landolt's chemical clock 864
 Lanthanide contraction 27, 1232, 1234
 Lanthanide elements
 abundance 1229
 alkyls and aryls 249
 aquo ions 1245
 arsenides 555
 atomic and physical properties 1232–1235
 carbonyls 1238
 chalcogenides 679, 1238, 1239
 complexes 1244–1248
 coordination numbers and stereochemistries 1236, 1237
 cyclopentadienides 1238
 group trends 1232–1237
 halides 1240–1242
 history 1228, 1228
 magnetic properties 1242–1244
 organometallic compounds 1248, 1249
 +2 oxidation state 1240, 1248
 +4 oxidation state 1240, 1244
 oxides 1238, 1239
 production and uses 1230–1232
 as products of nuclear fission 1228, 1251, 1260
 separation of individual elements 1424, 1426–1428
 spectroscopic properties 1242–1244
 see also individual elements and Group 3 elements
 Lanthanoid *see* Lanthanide elements
 Lanthanon *see* Lanthanide elements
 Lanthanum
 abundance 945
 complexes 950–953
 discovery 944, 1228
 halides 949–950
 organometallic compounds 953
 oxide 949
 production and uses 945–946
 salts with oxoanions 949
 see also Group 3 elements, Lanthanide elements
 Lapis lazuli 359
 Laser, ruby 1029

 Lattice defects, nonstoichiometry 643
 see also Spinel (inverse) and individual elements
 Lattice energy
 calculation of 82
 of hypothetical compounds 83
 Lawrencium 1252, 1262
 see also Actinide elements
 Lead
 abundance 368
 alloys 371
 in antiquity 367
 atomic properties 371
 atomic weight variability 368
 benzene complex with Pb^{II} 405
 bis(cyclopentadienyl) 395, 404
 chalcogenides 389
 chemical reactivity and group trends 435, 373,
 cluster anions 374, 393
 cluster complexes 387, 395
 dihalides 375, 381, 382
 dinitrate 388
 halogeno complexes 382
 hydride 375
 hydroxo cluster cation 395
 isolation and purification 369–371
 metal–metal bonded compounds 392
 mixed dihalides 382
 monomeric Pb(OAr)₂ 390
 monoxide 383, 384, 386, 395
 nitrate, thermolysis of 456, 469
 nonstoichiometric oxides 385–387
 organohydrides 375
 organometallic compounds 402–405
 oxides, nonstoichiometric 384–387
 oxides, uses of 386
 oxoacid salts 388
 Pb–S–O system 677
 physical properties 371, 372
 pigments 386, 388
 production statistics 369, 370, 371
 pseudohalogen derivatives 389
 radiogenic origin 368
 sulfate 388
 tetraacetate 388
 tetrafluoride 388
 tetrahalides 375, 381
 toxicity 367, 368
 uses 371, 386
 Lead chamber process for H₂SO₄ 646
 Leblanc process for NaOH 71, 790
 Lewis acid (acceptor) 905
 see also Donor-acceptor complexes, Class-a and class-b
 metals
 Lewis base (donor) 198, 905
 see also Donor-acceptor complexes, Ligands
 Lifschitz salts 1156, 1160
 Ligand field theory 922
 Ligands
 ambidentate 907, 920
 chelating 906
 classification as “hard” and “soft” 326, 909
 classification by number of donor atoms 906–907
 macrocylic 907

- non-innocent 1055
 "octopus" 99
 tripod 907
see also Class-a and class-b metals, Hapticity, Linkage isomerism, Synergic bonding
- Ligand polyhedral model 1105, 1140–1
 Lime, production and uses of 119–121
 Limestone, occurrence and uses 109, 120–121, 274
 Limonite 1071, 1146
 Linde synthetic zeolites 358, 359
 Linkage isomerism
 of nitrite ion 463, 464, 920
 of SO₂ 702
 of thiocyanate ion 326, 920
- Litharge *see* Lead monoxide
- Lithium
 abundance 69
 acetylide, synthetic use of 103
 alkyls and aryls 102–106
 aluminium hydride 228–9
 "anomalous" properties of 75–76
 compounds with oxygen 84, 85
 coordination chemistry of 90–4
 diagonal relationship with Mg 76, 102
 discovery of 68
 methyl, bonding in 103
 methyl, structure of tetrameric cluster 103, 104, 113
 organometallic compounds 102–106
 production of metal 71, 73
 reduction potential of 75, 76
 stereochemistry of 91
 terrestrial distribution of 69
 variable atomic weight of 18
see also Alkali metals
- Lithium compounds
 industrial uses of 70
 organometallics, synthesis of 102, 103
 organometallics, synthetic uses of 105–106
- Lithium tetrahydroaluminate
 synthetic reactions of 229
- Lithophile elements 648
- Lodestone 1080
- Loellingite structure 557
- Lone pair, stereochemical influence 377, 772, 775–777
- Lonsdaleite 274, 276
- Low-spin complexes
 of cobalt(III), electronic spectra
 of octahedral, d⁴ ions, 1087
- Lutetium 1228
see also Lanthanide elements
- Macrocyclic effect 911
 Macrocyclic polyethers *see* Crown ethers
- Maddrell's salt 528–531
- Madelung constant 83
- "Magic acid" 570
- "Magic numbers" in nuclear structure 3, 13
- Magma, crystallization of silicates from 329
- Magnéli-type phases
 of molybdenum and tungsten oxides
 of titanium oxides 959
 of vanadium oxides 952
- Magnesium
 alkyl alkoxides 133, 136
 in biochemical processes 125
 complexes of 123–126
 cyclopentadienyl 136
 diagonal relationship with Li 76, 102
 dialkyls and diaryls 131–133
 history of 108
 organometallic compounds 131
 see also Grignard reagents
 porphyrin complexes of *see* Chlorophyll
 production and uses of 110, 111
see also Alkaline earth metals
- Magnetic moment
 of low-spin, octahedral, d⁴ ions 1087
 orbital contribution to 1132, 1158
see also individual transition elements, Spin equilibria
- Magnetic quantum number *m* 22
- Magnetite, Fe₃O₄ 1071
 inverse spinel structure 249, 1080
- Magnus's salt 1163
- Malachite 1174
- Malathion 509
- Manganates 1050, 1051, 1222
- Manganese
 abundance 1040
 allyl complexes 934
 biochemistry of 1061–2
 carbonyls 928, 1062–1064
 chalcocogenides 1049
 complexes
 +4 oxidation state 1056
 +3 oxidation state 1057–1058
 +2 oxidation state 1058–1061
 lower oxidation states 1061
 with S 667–669
 with SO₂ 702
 cyclooctatetraene complex 943
 cyclopentadienyls 1065–1067
 dioxides 1045–1048
 uses of 1048
 halides and oxohalides 1051
 nodules 1041
 organometallic compounds 935, 943, 1062–1069
 oxides 1045
 production and uses 1041–1043
see also Group 7 elements
- Manganin 1042
- Manganocene
- Marcasite structure 555–557, 680
 mineral FeS₂ 648
- Marine acid 793
- Marsh's test for As 558
- Martensite 1075
- Masurium 1040
see also Technetium
- Mass number of atom 22
- Matches 474, 509
- Meitnerium 1281, 1283
- Melamine 323
- Mellitic acid 289
- Melting points, influence of H bonding 54
- Mendeleev's periodic table 20

- Mendelev, prediction of new elements 29, 217
- Mendelevium 1252, 1262
see also Actinide elements
- Mercaptans, origin of name 1220
- Mercuration 1222
- Mercury
 abundance 1202
 alkyls and aryls 1222
 chalcogenides 1208, 1211
 cyclopentadienyls 1223
 halides 1211–1213
 history 1173
 organometallic compounds 926, 1222–1224
 +1 oxidation state 1213–1215
 +2 oxidation state 1413–1416
 oxide 1208–1209
 polycations 1214, 1215
 production and uses 1203
 sulfide, solubility of 638, 679
 toxicity 1225
- Mesoperiodic acid *see* Periodic acids
- Metal cations
 amphoteric 52
 hydrolysis of 51
- Metallocarbohedrenes (met-cars) 300
- Metalloboranes 172–174, 178
- Metallocarboranes 189–195
 bonding 188, 190, 194
 chemical reactions 195
 structures 188
 synthesis 189–191
- Metallocenes *see* Ferrocene, individual metals
- Metalloregulatory proteins 1226
- Metaperiodic acid *see* Periodic acids
- Metaphosphates *see* Chain polyphosphates,
 Cyclo-polyphosphates
- Metaphosphimic acid tautomers 541
see also Tetrametaphosphimates
- Metatelluric acid (H_2TeO_4)_n 781
- Methane 300
 as greenhouse gas 274, 302
 in Haber-Bosch NH_3 synthesis 420
- Methanides *see* Carbides
- Methyl bridges
 in Al_2Me_6 258, 259
 in $BeMe_2$ 127
 in $MgMe_2$ and $Mg(AlMe_3)_2$ 131
- Methyl methacrylate 321
- Methylene complexes *see* Carbene ligands
- Methylparathion 509
- Meyer's periodic table 21, 23
- Meyer reaction 596
- Mica 109, 349, 356–413
- Millon's base 1218, 1220
- Mischmetall 946, 1228
- Mohorovicic discontinuity 358
- Mohr's salt 1092
- Molecular orbital theory of coordination compounds
 922–924
- Molecular sieves *see* Zeolites
- Molybdates 1008–1016
- Molybdenite, MoS_2 649, 1003
- Molybdenum
 abundance 1002
 benzene tricarbonyl 941
 biological activity 1035–7
 blues 1008
 bronzes 1016
 carbonyls 928, 1037, 1038
 carbyne complexes 929
 chalcogenides 1017–1018
 complexes
 +6 oxidation state 1023–1024
 +5 oxidation state 1024–1025
 +4 oxidation state 1025–1027
 +3 oxidation state 1027–1031
 +2 oxidation state 1031–1035
 with S 666–669, 672
 with SO_2 702
 compounds with quadruple metal–metal bonds
 1032–1034
 cyclopentadienyl compounds 933, 1038
 discovery 1002
 halides and oxohalides 1019
 heteropolyacids and salts 1014–1016
 isopolyacids and salts 1009–1014
 nitrogen fixation, role in 1035–1037
 nonstoichiometric oxides 1008
 organometallic compounds 1037–1039
 oxides 1007–1009
 production and uses 1003, 1004
see also Group 6 elements
- Molybdic acid 1010
- Molybdocene 1038
- Molybdoferredoxin 1035, 1098
- Monactin 96
- Monazite 945, 1230, 1232, 1254
- Mond process 1146,
- Monel 1146
- γ -Monoclinic sulfur 655
- Montmorillonite 349, 353, 356
- Mössbauer spectroscopy
 with ^{57}Fe 1094, 1095, 1096, 1101
 with ^{127}I , ^{129}I 802, 838, 841
 of nonstoichiometric oxides 642
 with ^{99}Ru 1062
 with ^{119}Sn 371
 with ^{125}Te 753
 with ^{129}Xe 898
- Mother-of-pearl 122
- Muriatic acid 792
- Muscovite *see* Mica
- Myoglobin 1098–1101
- n–p–n junction *see* Transistor
- n-type semiconductor *see* Semiconductor, Transistor
- Nacreous sulfur 655
- NADP 125
- Names of elements having $Z > 100$ 30, 1252, 1280–1283
- NbS_2Cl_2 structure 671
- NbS_2X_2 667
- Neodymium 1228
 +2 oxidation state 1237, 1239, 1241

- +4 oxidation state 1244
see also Lanthanide elements
- Neon
 atomic and physical properties 891, 892
 discovery 889
see also Noble gases
- Neptunium 1252, 1262
 bis(cyclooctatetraene) 942
 radioactive decay series 1254
see also Actinide elements
- Nernst equation (for electrode potentials) 435
- Neso-silicates 347, 348
- Nessler's reagent 1218
- Neutrons
 fast 1256
 slow, thermal 1256
- Newnham process for roasting PbS 677
- Nicolite (Kupfernickel) 1145
- Nichrome 1146
- Nickel
 abundance 1145
 alkene and alkyl complexes 1170–1172
 π -allylic complexes 933, 1172
 "anomalous" behaviour of Ni^{II} 1160, 1159
 aryls 1168
 atomic and physical properties 1148–1150
 biochemistry of 1167
 carbonyls 928, 929, 1168–1170
 chalcogenides 1152
 complexes
 +4 oxidation state 1154
 +3 oxidation state 1155
 +2 oxidation state 1156–1162
 +1 oxidation state 1166
 zero oxidation state 1166, 1167
 with SO₂ 702
 coordination numbers and stereochemistries 1150
 cyclobutadiene complexes 936
 cyclopentadienyls 1170
 dithiolene complexes, redox series 675
 halides 1152, 1153
 organometallic compounds 1167–1172
 oxidation states 1150
 oxides 1151, 1152
 phosphides 489
 production and uses 1145–1148
 reactivity of elements 1149
 tetracarbonyl 928, 929, 1168
- Nickel arsenide 555, 556, 649
 relation to CdI₂ 556, 697
 structure type 555, 556,
- Nickelocene 939, 1170,
- Nickel silver 1146
- Nielsbohrium, *see* Bohrium
- Niobates 987
- Niobium
 abundance 977
 alkyls and aryls 999
 bronzes 987
 carbonylate anions 980, 1000
 chalcogenides 988
 complexes
 +5 oxidation state 994
 +4 oxidation state 994–995
 compounds with oxoanions 993
 cyclopentadienyls 940, 1000–1001
 discovery 976
 halides and oxohalides 988
 nonstoichiometric oxides 982
 organometallic compounds 999–1001
 oxides 982, 983
 production and uses 977
 see also Group 5 elements
- Nitramide, H₂NNO₂ 459
- Nitrates 465, 467–472, 539–545
 coordination modes 469–471
 thermal stability 469
see also individual elements
- Nitric acid 422, 456, 457, 459, 465–468
 anhydrous 465, 467
 hydrates 469, 468
 industrial production 466, 467
 industrial uses 467
 ionization in H₂SO₄ 711
 self-ionic dissociation
- Nitric oxide, NO 422, 442
 bonding in paramagnetic molecule 446
 catalytic production from NH₃ 466
 chemical reactions 446
 colourless, not blue 446
 complexes with transition metals *see* Nitrosyl complexes
 crystal structure 446
 dimeric 446
 physical properties 446
 preparation 445
 reaction with atomic N 413
- Nitride ion, N³⁻ 417
 as ligand 418–419
- Nitrides 417–419
- Nitrido complexes *see* Nitride ion as ligand, also individual elements
- Nitriles *see* Cyanides
- Nitrite ion, NO₂⁻
 coordination modes 463
 nitro-nitrito isomerism 463, 464, 920
- Nitrites 422, 461–465
see also Nitro-nitrito isomerism
- Nitrogen
 abundance in atmosphere 406, 407–409
 abundance in crustal rocks 407
 active *see* atomic
 atomic, production and reactivity of 412, 413
 atomic properties 411, 412, 550
 atypical group properties 416, 550
 chemical reactivity 412–416
 comparison with C and O 416
 comparison with heavier Group 15 elements 416, 551, 577
 cycle in nature 406, 408, 410
 dinitrogen tetrafluoride 439, 440
 dioxide 444, 455, 612
see also Dinitrogen tetroxide
 discovery 406

- Nitrogen — *contd*
 fixation, industrial 466
 see also Haber-Bosch ammonia synthesis
 fixation, natural 999, 1035–1037, 1098, 1102
 halides 438–441
 history 407, 408
 hydrides of 426–433
 see also Ammonia, Hydrazine, Hydroxylamine
 industrial uses 409
 isotopes, discovery of 408
 isotopes, separation of 142
 ligand 408
 monoxide *see* Nitric oxide
 multiple bond formation 416, 417
 oxidation states 434, 437
 oxides 443–458
 see also individual oxides
 oxoacids 459–466
 see also individual oxoanions
 oxoanion salts *see* Nitrosyl halides, Nitryl halides
 physical properties 412
 production 411
 standard reduction potential for N species 434
 stereochemistry 413
 synthesis of pure 409
 tribromide 441
 trichloride 441
 trifluoride 438–439
 triiodide, ammonia adduct 441
 trioxide 444, 458
 see also Dinitrogen
 Nitrogenase 1035, 1098
 Nitro-nitrito isomerism 463, 464, 920
 Nitronium ion 458, 712
 Nitroprusside ion 1094, 1095
 Nitrosyl azide 433, 443
 Nitrosyl trifluoride, ONF₃ 438, 439
 Nitrosyl halides 441, 442
 Nitrosyl complexes 447–453
 coordination modes 450, 450–452
 electronic structure of 450, 451
 preparation 448, 449
 see also individual elements
 Nitrous acid 459, 461–462
 reaction with hydrazine 432
 Nitrous oxide, N₂O 443–445
 chemical reactions 443, 445
 isotopically labelled 443
 physical properties 442, 445
 preparation 443
 use in “whipped” ice cream 445
 Nitroxyl 459, 461
 Nitroxyl acid 459
 Nitryl halides, XNO₂ 441
 Nmr spectroscopy with:
 ¹⁰B 144
 ¹¹B 144, 197
 ^{79,81}Br 802, 803
 ¹³C 276, 326, 914, 995, 1104, 1105
 ^{35,37}Cl 791, 802, 803
 ¹⁹F 197, 499, 562, 563, 684, 739, 791, 802–803, 817,
 841, 904, 1022
 ¹H 34, 56, 230, 532, 933, 935, 940, 973, 1111, 1129,
 1135, 1165, 1223
 ^{2,3}H 34
 ¹²⁷I 802, 803
 ⁹⁵Mo 1025
 ¹⁴N 326, 408, 411, 1025
 ¹⁵N 408, 411
 ¹⁷O 601, 604, 605, 630, 984, 1012
 ³¹P 474, 482, 516, 1165
 ¹⁹⁵Pt 1165
 ³³S 662
 ⁷⁷Se 762, 769
 ²⁹Si 330
 ¹¹⁹Sn 371
 ¹²⁵Te 762
 ⁵¹V 985
 ¹⁸³W 1012
 NO *see* Nitric oxide
 Nobel prize for Chemistry, list of laureates 1296–1299
 Nobel prize for Physics, list of laureates 1300–1304
 Nobelium 1252, 1463
 see also Actinide elements
 Noble gases (He, Ne, Ar, Kr, Xe, Rn) 888–904
 atomic and physical properties 890–891
 bonding in compounds of 897
 chemical properties 892–904
 clathrates 893
 discovery 888, 889
 production and uses 889, 890, 1044
 see also individual elements
 Nomenclature of elements having Z > 100 30, 1252,
 1280–1283
 Nonactin 96
 Nonaqueous solvent systems
 AsCl₃ 561
 BrF₃ 820, 821
 ClF₃ 829
 HCl 819
 HF 570, 816–819
 H₂SO₄ 710–712, 759
 ICl 827
 IF₅ 834
 NH₃ 77–79, 424–426
 SbCl₃ 561, 655
 SO₂ 664, 700, 759
 superacids 570
 Non-haem iron proteins (NHIP) 1102, 1103
 Nonstoichiometry
 in chalcogenides 765, 766
 in oxides 642–644
 in sulfides 679
 see also individual compounds
 Nuclear fission 1256
 products 1257, 1260
 spontaneous 1253, 1262
 Nuclear fuels 1257–1262
 breeding 1259
 enrichment 1259
 reprocessing 1097, 1260–1262
 Nuclear reactions in stars 7–13
 Nuclear reactors 1256–1260
 different types 1258
 natural 1257

- Nuclear structure of atoms 22
 Nuclear waste, storage 1257, 1261
 Nucleic acid
 definition
 double helix structure of 474
 and H bonding 60, 62
 Nucleogenesis 2ff
 Nylon-6 and -66, 422
- Obsidian 342
 Octahedral complexes 914–916, 922–923
 distortions in 915–916 *see also* Jahn–Teller effect
 “Octopus” ligands 99
 Oddo’s rule 3
 Oklo phenomenon 1257
 Oligomerization of acetylene 1172
 Olivine 109, 347
 One-dimensional conductors 1156, 1165
 Onyx 342
 Opal 342
 Open-hearth process 1072
 Optical activity 919, 1125
 Optical isomers 915, 919, 1125
 Optically active metal cluster compound 667
 Optical rotatory dispersion (ORD) 1125
 Orbital contribution to magnetic moment
 of high-spin complexes of Co^{II} 1132
 of octahedral d^2 ions 996
 of octahedral d^4 ions 1089
 of tetrahedral complexes of Ni^{II} 1158
 Orbital degeneracy 1244
 Orbital quantum number, l 26,
 Orford process 1146
 Organometallic compounds 924–943
 classification 924–925
 definition 924
 dihapto ligands 930–933
 heptahapto ligands 941
 hexahapto ligands 940–941
 monohapto ligands 925–930
 octahapto ligands 941–943
 pentahapto ligands 937–940
 tetrahapto ligands 935–937
 trihapto ligands 933–935
 see also individual elements and ligands
 Orpiment *see* Arsenic sulfide, As_2S_3
 Orthonitrate ion, NO_4^{3-} 472
 Orthoperiodic acid *see* Periodic acids
 Orthophosphates 523–526
 AlPO_4 , structural analogy with SiO_2 526
 uses of 524–525
 see also individual metals
 Orthophosphoric acid *see* Phosphoric acid
 Osmates 1082
 Osmiamates 1085
 Osmium
 abundance 1071
 anomalous atomic weight of in Re ores 19
 atomic and physical properties 1074–1075
 carbido-carbonyls 1107–1108
 carbonyl halides 1108
 carbonyl hydrides and carbonylate anions 1105–1108
 carbonyls 928, 929, 1104–1105
 chalcogenides 1081
 complexes
 +8 oxidation state 1085
 +7 oxidation state 1085
 +6 oxidation state 1085–1086
 +5 oxidation state 1086
 +4 oxidation state 1086–1088
 +3 oxidation state 1088–1089
 +2 oxidation state 1091–1098
 with SO_2 702
 coordination numbers and stereochemistries 1078
 cyclooctatetraene complex 943
 discovery 1070
 halides and oxohalides 1082–1083
 organometallic compounds 1104–1112
 oxidation states 1077, 1079
 oxides 1079, 1081
 oxoanions 1082
 production and uses 1072–1074
 reactivity of element 1075
 relationship with other transition elements 1075–1079
 standard reduction potentials 1077
 Osmocene 937, 1111
 Osmyl complexes 1085, 1086
 Outer-sphere reactions 1124
 Oxidation state
 periodic trends in 27–28
 variability of 27, 905
 Oxides 640–644
 acid-base properties 628, 640, 641
 classification 640–642
 nonstoichiometry in 642–644
 structure types 641, 753
 see also individual elements
 Oxonium ion 48
 OXO process (hydroformylation) 309, 1135, 1140
 Oxovanadium (vanadyl) ion 982, 995
 Oxygen
 abundance 600, 602
 allotropes 607
 atomic 611, 612
 atomic properties 604, 605
 chemical properties 612–615
 coordination geometries 613–615
 crown ether compounds 95–97, 124, 601
 difluoride 638
 fluoride 638–640
 history 600, 601, 604
 industrial production 604
 industrial uses 604
 isotopes, separation of 604
 liquefaction 601, 604
 liquid 601, 603–604, 606
 occurrence in atmosphere, hydrosphere and lithosphere
 600, 602, 605
 origin of, in atmosphere 602
 origin of blue colour in liquid 607
 oxidation states 613
 physical properties 605
 preparation 603, 604
 radioactive isotopes 605
 reduction potential, pH dependence 628–629

- Oxygen — *contd*
 roasting of metal sulfides 676–678
 standard reduction potentials 628, 629, 737
see also Dioxygen, Ozone
- Oxygen carriers
 complexes of cobalt 1132
 haemocyanin 1199
 haemoglobin and synthetic models 1098–1101
 Vaska's compound 615, 617, 1136, 1137
see also Dioxygen
- Oxyhyponitrous acid *see* Hyponitric acid
- Ozone, O₃
 bonding 607, 608
 chemical reactions 609–611, 848, 849
 discovery 607
 environmental implications 608, 848
 hole 608
see also Chlorofluorocarbons
 molecular structure 607, 608, 708
 physical properties 607, 608
 preparation 609, 611
- Ozonide ion, O₃[−] 610
- Ozonides (organic) 610, 611
- Ozonolysis 610, 611, 849
- p-Process in stars 13
- p-type semiconductors *see* Semiconductor, Transistor
- Palladium
 absorption of hydrogen 1150, 1151
 abundance 1145
 alkene and alkyne complexes 1170–1172
 alkyls and aryls 1167, 1168
 π-allylic complexes 953, 1172, 1172
 atomic and physical properties 1148–1149
 carbonyl chloride 1168
 chalcogenides 1152
 complexes
 +4 oxidation state 1154
 +3 oxidation state 1154, 1156
 +2 oxidation state 1156–1166
 zero oxidation state 1166–1167
 coordination numbers and stereochemistries 1150
 discovery 1144
 halides 1152–1154
 organometallic compounds 1167–1172
 oxidation states 1150
 oxides 1151, 1152
 production and uses 1146, 1147
 reactivity of element 1149
- Paraperiodic acid *see* Periodic acids
- Parathion 509
- Patronite 977
- Pauli exclusion principle 22
- Pearlite 1075
- Pentaborane, B₅H₉ 154, 159, 163
 Brønsted acidity 171, 172
 chemical reactivity 171
 metalloborane derivatives 171–173
 preparation 165
 properties 170
 structure 171
- Pentagonal bipyramidal complexes 916
- Pentathionates, S₅O₆^{2−}, preparation and structure 717, 718, 851
- Pentlandite 1145
- Perbromates, BrO₄[−] 871–872
 discovery 789, 871
 radiochemical synthesis 871
 redox systematics 854, 855, 872
 structure 871
- Perbromic acid, HBrO₄ 871
- Perbromyl fluoride, FBrO₃ 881
- Perchlorates, ClO₄[−] 865–871
 bridging ligand 791, 868–871
 chelating ligand 868–871
 coordinating ability 791, 868–871, 1020
 monodentate ligand 791, 868–871
 production and uses 865, 867
 redox systematics 854, 855
 structure 868
- Perchloric acid, HClO₄ 865–868
 chemical reactions 867, 868
 hydrates 867
 physical properties 865, 866
 preparation 865, 866
 structure 868
- Perchloryl fluoride, FClO₃ 876, 879, 880
- Perhalates, XO₄[−] 854, 855, 865–875
- Perhalic acids, HOXO₃ 865–875
- Periodates 872–875
 redox systematics 854, 855
 reaction schemes 874
 structural relations 873
 synthesis 872, 873
 transition metal complexes 875
- Periodic acids 872–875
 acid-base systematics 874
 nomenclature 872
 preparation 873
 redox systematics 854, 855
 structural relations 873
- Periodic reactions
 Belousov-Zhabotinskii reactions 865, 865
 Bray's reaction 865
- Periodic table *see* inside front cover
 and atomic structure 20–23
 history of 20, 21
 and predictions of new elements 29–31
- Permanganates 1050, 1051
- Perosmate 1082, 1085
- Perovskite structure 963
 in ternary sulfides 681
- Peroxo anions 638
- Peroxodisulfates, S₂O₈^{2−} 713
- Peroxodisulfuric acid, H₂S₂O₈ 713
- Peroxo complexes of O₂ 616
- Peroxo compounds, fluorinated 639, 640
- Peroxo chromium complexes 637, 1024
- Peroxodiphosphoric acid, H₄P₂O₈ 512
- Peroxomonophosphoric acid, H₃PO₅ 512
- Peroxomonosulfuric acid, H₂SO₅ 705, 712
- Peroxonitric acid, HOONO₂ 458
- Peroxonitrous acid, HOONO 459
- Peroxoselenous acid 783
- Peroxtellurates 783

- Perrhenates 1050
 Perruthenates 1082
 Pertechnetate ion 1050
 Perxenates, XeO_6^{4-} 901
 pH scale 32, 49
 "Pharaoh's serpents" 1218
 Phase rule 676
 Phase-transfer catalysis 97
 Phenacite 347
 Phlogiston theory 30, 600, 601, 793
 Phlogopite *see* Micas
 Phosgene 305
 Phospha-alkenes 545
 Phospha-alkynes 545
 Phosphate cycles in nature 475–479
 Phosphate rock
 occurrence and reserves 476
 phosphorus production from 480, 520, 525
 statistics of uses 525
 Phosphates *see* Chain phosphates, Cyclophosphates,
 Orthophosphates, Superphosphates, Tripolyphosphates
 Phosphatic fertilizers 474, 477–479, 520, 524–526
 Phosphazenes 534–536
 Phosphides 489–492
 Phosphine, PH_3
 chemical reactions 492, 493
 comparison with NH_3 , AsH_3 , SbH_3 , BiH_3 557
 inversion frequency 493
 Lewis base activity 493–495
 molecular structure 492, 493
 preparation 492
 tertiary phosphine ligands 494
 Phosphinic acid *see* Hypophosphorous acid
 Phosphinoboranes 211
 Phosphites 513, 514
 Phosphonic acid *see* Phosphorous acid
 Phosphonitrilic chloride (NPCl_2)_x 408
 see also Polyphosphazenes
 Phosphoramidic acid 532
 Phosphorescence
 of arsenic 550
 of phosphorus 474, 485
 Phosphoric acid, H_3PO_4 516, 517, 518–522
 autoprotolysis 518
 in colas and soft drinks 520
 hemihydrate 518–521
 industrial production 521–522
 industrial uses 520
 polyphosphoric acids in 522
 proton-switch conduction in 518, 598
 self-dehydration to diphosphoric acid 518
 self-ionization 518
 structure 518
 successive replacement of H in 519, 521
 "thermal" process 521, 522
 trideutero 518
 "wet" process 520, 521
 Phosphoric triamide 532
 Phosphorus acid, H_3PO_3 512, 514
 Phosphorus
 abundance and distribution 475
 allotropes 473, 474, 479–483
 alloys 492
 atomic properties 482–483
 black allotropes 481–483, 551
 bond energies 483
 catenation 473, 483, 485
 chemical reactivity 483, 578
 cluster anions 491, 588
 coordination geometries 483
 disproportionation in aqueous solutions 511–513
 encapsulated 554
 fertilizers 474, 477–479, 520, 604
 halides 495
 see also individual triahalides and pentahalides
 history 473, 474
 Hittorf's violet allotrope 481
 hydrides 492–495
 see also Phosphine
 mixed halides 495
 multiple bond formation 473
 organic compounds 542–546
 oxides 503–506
 see also "Phosphorus trioxide", "Phosphorus
 pentoxide"
 oxohalides 501, 502
 oxosulfides 507, 510
 pentaphenyl 545
 peroxide, P_2O_6 506
 production and uses 479, 480, 520, 525
 pseudohalides 495, 501
 radioactive ^{32}P 482
 red, amorphous 481, 482, 483
 stereochemistry 485–486
 sulfides 506–509
 industrial uses of 509
 organic derivatives 509
 physical properties 507
 stoichiometry 506
 structures 507
 synthesis 506, 508
 thiohalides 498, 501–503, 508
 triangulo- μ_3 - P_3 species 587, 588
 white, α - P_4 480–481, 483, 551
 ylides 545
 Phosphorus oxoacids 510–531
 lower oxoacids 516–517
 nomenclature 511–512, 517
 standard reduction potentials 513
 structural principles 510–512, 517
 volt-equivalent diagram 513
 see also individual acids and their salts, e.g. Phosphoric
 acid, Phosphates, etc.
 Phosphorus pentahalides 495, 498–501
 ammonolysis of PCl_5 with liquid NH_3 535
 fluxionality of PF_5 498
 industrial production of PCl_5 500
 ionic and covalent forms 498–501, 537
 mixed pentahalides 499
 organo derivatives 499–501
 reactions of PCl_5 with NH_4Cl -diphosphazenes 535
 structural isomerism 499, 500
 "Phosphorus pentoxide", P_4O_{10} 504–506
 chemical reactions 505
 cyclo-phosphates, relation to 530
 hydrolysis 505, 520

- "Phosphorus pentoxide", P_4O_{10} — *contd*
 polymorphism 504, 505
 preparation 504
 structure 504
 Phosphorus tribromide 496, 497, 500
 Phosphorus trichloride
 chemical reactions 497
 hydrolysis to phosphates 514
 industrial production 496
 organophosphorus derivatives 496, 497, 514
 Phosphorus trifluoride 495, 496
 as a poison 1101
 similarity to CO as ligand 496
 Phosphorus triiodide 495, 497
 "Phosphorus trioxide", P_4O_6
 disproportionation to P_4O_n 504
 hydrolysis 504
 preparation 503, 504
 structure 504
 Phosphoryl
 halides, POX_3 502
 pseudohalides 501
 Photographic image intensification with ^{35}S 662
 Photographic process 790, 794, 1185–1187
 Photosynthesis
 manganese in 1061
 NADP in 125
 ^{18}O tracer experiments 601, 602
 as origin of atmospheric O_2 602
 see also Chlorophylls
 Photosystem II 1056, 1061
 Phyllo-silicates 347, 349–354
 Physical constants, table of consistent values: end paper
 Physical properties, periodic trends in 23
 see also individual elements
 Piezoelectricity 58, 345
 Pig-iron 1072
 Pitchblende 1250, 1255
 Plagioclase *see* Feldspars
 Plaster of Paris 122
 Platinum
 abundance 1145
 alkene and alkyne complexes 1170–1172
 alkyls and aryls 1167–1168
 π -allylic complexes 934, 1172
 anti-tumour compounds 1163
 atomic and physical properties 1148–1149
 blues 1165
 β -elimination in alkyls and aryls 926
 black 1148
 carbonylate anions 1169
 catalytic uses 466, 467, 1145
 chalcogenides 1152
 complexes
 +6 and +5 oxidation states 1154
 +4 oxidation state 1154–1155
 +3 oxidation state 1155–1156
 +2 oxidation state 1156–1166
 zero oxidation state 1166–1167
 with S 666
 with SO_2 702
 coordination numbers and stereochemistries 1150
 halides 1152–1154
 optical resolution of $[Pt(S_5)_3]^{2-}$ 670
 organometallic compounds 931, 932, 1167–1172
 see also Zeise's salt
 oxidation states 1150
 oxides 1151, 1152
 production and uses 1146, 1147
 reactivity of element 1149
 sulfide, structure 679
 Platinum metals, definition 1070
 Plutonium
 "breeding" 1259
 bis(cyclooctatetraene) 942
 critical mass 1261
 discovery 1252
 extraction from irradiated nuclear fuel 1260, 1261
 natural abundance 1253
 redox behaviour 1265–1267
 self-heating 1264
 see also Actinide elements
 Plutonium economy 1259
 P–N compounds 531–542
 Point groups 1290–1292
 Pollution, atmospheric by SO_2 646, 698–699, 710
 see also Eutrophication, Water
 Polonium
 abundance 747
 allotropy 751
 atomic and physical properties 753, 754, 890
 chemical reactivity 754–759
 coordination geometries 756
 dioxide 780
 discovery 747
 halides 767, 768, 769, 770
 hydride, H_2Po 766, 767
 hydroxide 781
 nitrate 786
 oxides 779–780
 polonides 765, 766
 production and uses 750
 radioactivity 748, 750
 redox properties 755
 selenate 786
 sulfate 786
 toxicity 757–759
 Polyethene (polythene) 261, 262, 972
 Polyhalide anions 827, 829–831, 834–839
 bonding 838, 839
 containing astatine 887
 structural data 836–839
 Polyhalonium cations 827, 829–831, 833–835
 stoichiometries 839
 structures 840
 Polyiodides 806, 835–839
 Polypeptide chains 61, 62
 Polymetaphosphoric acid 512
 Polyphosphates, factors affecting rate of degradation 523
 see also Chain polyphosphates, *Cyclo*-polyphosphates
 Polyphosphazenes 536
 analogy with silicones 536
 applications 542–543
 basicities 540
 bonding in 537–540
 hydrolysis 541

- melting points of $(\text{NPX}_2)_n$ 538
 pentameric $(\text{NPCl}_2)_5$ 538
 preparation 536, 537
 reactions 540–542
 structure 536–538
 tetrameric $(\text{NPCl}_2)_4$ 537, 538
 trimeric $(\text{NPX}_2)_3$ 537
 Polyphosphoric acid 511
 catalyst for petrochemical processes 52
 Polysulfanes *see* Sulfanes
 Polysulfates, $\text{S}_n\text{O}_{3n+1}^{2-}$ 712
 Polysulfides
 of chlorine *see* Sulfur chlorides
 of hydrogen *see* Sulfanes
 use in Na/S batteries 678
 Polythiazyl *see* $(\text{SN})_x$
 Polythionates, $\text{S}_n\text{O}_6^{2-}$ 705, 714, 716–718
 seleno- and telluro- derivatives 717, 782
 Polythionic acids, $\text{H}_2\text{S}_n\text{O}_6$ 705, 716
 Polyurethane 305, 422
 Polywater 632, 633
 Porphin 126
 Porphyrin complexes of Mg *see* Chlorophylls
 Portland cement
 constitution of 252
 manufacture of 252
 see also High-alumina cement
 Potassium
 abundance 69
 compounds with oxygen 84–85
 discovery 68
 graphite intercalates 293–295
 nitrate, thermolysis of 468, 469, 541
 orthonitrate 474
 phosphates 524
 polysulfides 681, 682
 polythionates, preparation and structure 717
 production of metal 73, 74
 silyl 339, 340
 terrestrial distribution of 70
 see also Alkali metals
 Potassium chlorate, thermal decomposition to give O_2 603
 Potassium compounds
 as fertilizers 73
 production and uses of 73, 74
 Potassium permanganate, thermal decomposition to give O_2 603
 Powder metallurgy 1005, 1144
 Praseodymium 1229
 diiodide 1441
 +4 oxidation state 1237, 1239, 1244
 see also Lanthanide elements
 Praseodymium-oxygen system
 ordered defects and nonstoichiometry in 643–644
 Principal quantum number n 22
 Promethium 1228
 see also Lanthanide elements
 Protactinium
 abundance 1253
 bis(cyclooctatetraene) 942
 discovery 1250
 redox behaviour 1265–67
 see also Actinide elements 628–631, 814, 815
 Proton, hydration of 951, 952
 see also Hydrogen, ionized forms, and pH
 Proton-switch conduction
 in H_2O 623
 in H_3PO_4 518
 in H_2SO_4 843
 Protoporphyrin IX (PIX) 1099
 Prout's hypothesis 888
 Prussian blue 1094
 Pseudohalogen concept 319, 324
 see also individual elements for pseudohalo derivatives
 PTFE *see* Teflon
 Purex process 1261
 Purple of Cassius 1177
 PVC plastics, organotin stabilizers for 409
 Pyrite structure 555, 557, 680
 see also Iron pyrites
 Pyrochlore 977
 Pyrophosphoric acid *see* Diphosphoric acid
 Pyrophosphoryl halides 502, 503, 506
 Pyrophyllite 352–355, 413
 Pyrrhotite Fe_{1-x}S 649

 Quadruple metal-metal bonds 1031–1035
 Quantum numbers 22
 Quartz 342–344
 enantiomorphism 342
 uses 346
 Quaternary arsonium compounds 594
 Quaternary bismuth cations, BiR_4^+ 599
 Quaternary phosphonium cations 485, 495, 498–501, 545, 546

 r-Process in stars 12
 Racah parameter *see* Interelectronic repulsion parameter
 Radial functions 1285–1287
 Radioactive decay series 1254
 Radioactive elements
 discovery 21
 varying atomic weights of 18
 Radiocarbon dating 277
 Radium, history of 108
 see also Alkaline earth elements
 Radius ratio rules 80
 Radon
 atomic and physical properties 890, 891
 difluoride 903
 discovery 889
 fluoro complexes 903
 see also Noble gases
 Rare earths *see* Lanthanide elements
 Raschig synthesis of hydrazine 427, 428
 Rayon 317, 422, 653
 Realgar *see* Arsenic sulfide, As_4S_4
 Red cake 977
 Red lead, Pb_3O_4 385, 388
 Reduction potentials *see* Standard reduction potentials
 Reinecke's salt 1028
 Relativistic effects 599, 1180
 Reppe synthesis 309, 1167, 1172
 Rhenates 1051

- Rhenium
 abundance 1041
 alkyls 1062, 1068–1069
 carbidocarbonyls 1065–1066
 carbonyls 928, 1062–1064
 chalcogenides 1049
 complexes
 +7 oxidation state 1054
 +6 oxidation state 1055
 +5 oxidation state 1055
 +4 oxidation state 1056
 +3 oxidation state 1057–1058
 +2 oxidation state 1058
 lower oxidation states 1061
 compounds with metal-metal multiple bonds 1057, 1058, 1230
 cyclopentadienyls 1067–1068
 discovery 1040
 halides and oxohalides 1051–1054
 nine-coordinate hydrido complex 1046, 1054
 organometallic compounds 1062–1068
 oxides 1045–1049
 production and uses 1041
 trioxide 1047
 structure of 1047
- Rhodium
 abundance 1113
 atomic and physical properties 1114–1115
 carbidocarbonyls 1141–1142
 carbonyls 928, 1140–1143
 complexes
 +4 oxidation state 1121
 +3 oxidation state 1122–1129
 +2 oxidation state 1129
 +1 oxidation states 1133–1136
 lower oxidation states 1137
 with SO₂ 702
 coordination numbers and stereochemistries 1117
 cyclopentadienyls 1143
 discovery 1113
 halides 1119–1121
 optical resolution of
 cis-[Rh{η²-(NH)₂SO₂}₂(OH)₂]₂⁻ 670
 organometallic compounds 1139–1143
 oxidation states 1117
 oxides 1117, 1118
 production and uses 1114
 reactivity of element 1116
 relationship with other transition elements 1119, 1295
 sulfides 1118
- Rhodocene 1143
- Ribonucleic acids 476
- Ring-laddering 99
- Ring-stacking 99
- “Ring whizzing” 1112, 1223
- RNA 476
- Rochelle salt, discovery of ferroelectricity in 57, 963
- Roussin’s salts 447, 1094
- Rubidium
 abundance 70
 compounds with oxygen 70–71
 discovery 69
see also Alkali metals
- Rubridoxins 1098, 1101, 1102
- Ruby 242, 1003
 laser 1029
- Russell-Saunders coupling 1242
- Rusting of iron 1076, 1076
- Ruthenates 1082
- Ruthenium
 abundance 1071
 atomic and physical properties 1074–1076
 bipyridyl complexes and solar energy conversion 1096
 blue 1097
 carbidocarbonyls 1107–1108
 carbonyl halides 1108
 carbonyl hydrides and carbonylate anions 1105–1108
 carbonyl 928, 1104–1105
 chalcogenides 1081
 complexes
 +8 oxidation state 1085
 +7 oxidation state 1085
 +6 oxidation state 1085
 +5 oxidation state 1086
 +4 oxidation state 1086–1088
 +3 oxidation state 1088, 1091
 +2 oxidation state 1091–1097
 with S 668–670
 with SO₂ 702
 coordination numbers and stereochemistries 1078
 discovery 1070
 halides 1082–1084
 mixed valence compounds of 1097
 nitrosyl complexes 1097
 organometallic compounds 1104–1287
 oxidation states 1077, 1078
 oxides 1079, 1080, 1255
 oxoanions 1081
 production and uses 1073
 reactivity of element 1075
 relationship to other transition elements 1075–1079
 standard reduction potentials 1077
- Ruthenium red 1091
- Ruthenocene 937, 1111
- Rutherfordium 1281–2
- Rutile 955, 961, 1119
 structure type 962
- s-Process in stars 12
- “Saffil” fibres 244
- Salt (NaCl)
 history 790, 792
 location of deposits 793, 795
 uses in chemical industry 71, 72
 world production statistics
- “Salt cake” 89, 810
- Saltpetre 407
 see also Potassium nitrate
- Samarium 1228
 magnetic properties 1243
 +2 oxidation state 1239, 1240, 1241, 1248
see also Lanthanide elements
- “Sandwich” molecules 189, 264, 924, 1109
see also Ferrocene, cyclopentadienyls of individual elements, Dibenzenechromium, Uranocene

- Scandium
 abundance 945
 complexes 950–953
 discovery 944, 1228
 as eka-boron 944
 halides 949, 950
 organometallic compounds 953
 oxide 949
 production 945
 salts with oxoanions 949
see also Group 3 elements
- Scheelite 1003, 1004, 1169
 Schönites 1190
 SCOPE 273
 Scotch hearth process for roasting PbS 677
 Seaborgium 1281–3
 Se₂ as ligand 758, 759
 Secondary valency 912
 Selenates 781
 Selenic acid, H₂SeO₄ 782
 Selenides 765, 766
 Selenites and diselenites 781
 Selenium
 abundance 748
 allotropy 761–753
 atomic and physical properties 753, 754
 chemical reactivity 754–759
 coordination geometries 756–757
 dioxide 779, 780
 discovery 747
 halide complexes 776
 halides 767, 768, 772
 hydride, H₂Se 759, 766–767
 nitride, Se₄N₄ 783
 organocompounds 759, 786, 787
 oxides 779–780
 oxoacids 781–783
 oxohalides 777, 910
 polyatomic anions 762–5
 polyatomic cations, Se_n²⁺, [Te_nSe_{4–n}]²⁺ 759–761
 production and uses 748, 749
 pseudohalides 778, 779, 911
 redox properties 755
 sulfate 786
 sulfides 783
 toxicity 759
 trioxide 780
- Selenocyanate ion 329, 324–325
 ambidentate properties 757, 778
 Selenopolythionates 783
 Selenosulfates 783
 Selenous acid, H₂SeO₃ 781
 Semiconductors
 II–VI 255
 III–V 221, 255, 258, 549
 As, Sb and Bi chalcogenides 581, 679
 nonstoichiometric oxides 644
- Shear plane
 SHIP technique 1283
 SI prefixes, origin of inside back cover
 SI units inside back cover
 conversion to non SI units 1293
 Siderite 1071
 Siderophile elements 648
 Silaethenes 362
 Silaneimines 361
 Silanethiones 360
 Silanes
 chemical reaction 338–339
 homocyclic polysilanes 763
 physical properties 337
 silyl halides 339, 340
 silyl potassium 339, 340
 synthesis 337
 Silenes 362
 Silica
 fumed 345
 gel 345
 historical importance 328
 hydrated 346
 phase diagram 344
 polymorphism 342–346
 in transistor technology 383
 uses 345, 346
 vitreous 344
see also Quartz, Tridymite, Cristobalite, Coesite, Stishovite
- Silicate minerals 347–359
 comparison with silicones 364
 Silicates 328–330, 347–359
 with chain structures (metasilicates) 349, 350
 with discrete units 347–348
 disilicates 348
 with framework structures 354–359
 with layer structures 349–357
 metasilicates 348, 350
 orthosilicates 347, 348
 soluble (Na, K) 344, 346
 Silicides 336–337
 preparation 336
 structural units in 337
 Silicomanganese 1041
 Silicon
 abundance and distribution 329
 atomic properties 330, 371
 carbide 334
 chemical properties of 328, 331, 372
 coordination numbers 335
 dioxide *see* Silica
 double bonds to 362
 halides 340–342
 history 328
 hydrides *see* Silanes
 isolation 329, 330
 nitride 360
 organic compounds 361–366
 physical properties 330, 371, 372
 purification 330
 sulfide 359
 Silicones 364–366
 comparison with mineral silicates 364
 elastomers 365
 oils 365
 organotin, curing agents for 400
 resins 365

- Silicones — *contd*
 synthesis 364, 365
 uses 365
- Siloxanes 364, 366
- Silylamides 360, 361
- Silver
 abundance 1174
 acetylide 1180
 alkenes and alkynes 1199
 chalcogenides 1181–1182
 complexes
 +3 oxidation state 1187, 1188
 +2 oxidation state 1189
 +1 oxidation state 1195, 1196
 halides 1183–1185
 history 1173
 nitrate, thermolysis of 469
 organometallic compounds 1199–1200
 oxides 1181
 production and uses 1174
- Silver halides in photographic emulsions 1186
- Singlet oxygen 607
 generation of 614
 reactions of 615
- Skutterudite *see* Cobalt arsenide
- Smalt 1113
- Smaltite 1114, 1145
- S–N heterocycles incorporating a third element 736, 737
- (SN)_x polymer
 partially halogenated derivatives 728
 structure 727, 728
 superconducting properties of 408, 646, 722, 727, 728
 synthesis 726, 728
- S₂N₂ 725, 726
 polymerization to (SN)_x *qv* 726–727
 preparation 727
 structure and bonding 726
- S₄N₂ 727, 728
- S₄N₄ 408, 646, 722–725
 preparation 722
 reactions 725, 730, 734, 736
 structure and bonding 856, 857
- S₅N₆ 729
- S₁₁N₂ 728–729
- S_{14+x}N₂ 728–729
- Soapstone *see* Talc
- Sodalite *see* Ultramarines
- Sodanitre *see* Chile saltpetre
- Sodide anion, Na[−] 99
- Sodium
 abundance 69
 β-alumina
 structure and properties 249, 250
 use in Na/S batteries 678
 arsenide 554
 azide 409, 453, 440
 bismuthate 554
 carbonate
 hydrates of 88, 89, 104
 production and uses of 89
 chlorate 862
 compounds with oxygen 84–86
 diphosphates 526, 527
 discovery 68
 distribution 69, 70
 dithionite 721, 722
 hydroxide, production and uses of 72, 89
 hypophosphite 513
 nitrate, thermolysis of 468, 469
 nitroprusside 447
 nitroxylate 459
 orthonirate 471
 phosphates 512, 521, 523, 524–525
 polysulfides 677–679, 681, 688
 polythionates, preparation and structure 717–718
 production of metal 71
 silicates, soluble 343, 346
 solutions in liquid ammonia 77–79, 393
 sulfate, production and uses of 89
 sulfide batteries 678, 679
 thiosulfate, in photography 714, 1186, 1187
 tripolyphosphate 527, 528
see also Alkali metals
- Sodium chloride structure 80, 242, 983
see also Salt
- Sodium hypochlorite
 industrial uses 860
 Raschig synthesis of hydrazine using 427, 428
- Solar energy conversion 1096
- Solvo-acids and bases
 in anhydrous H₂SO₄ 711
 in liquid AsCl₃, SbCl₃ 560
 in liquid BrF₃ 831
 in liquid NH₃ 425
 in liquid N₂O₄ 457
 in water 628
- Soro-silicates 347–349
- Solvay process 71
 byproduct Ca from 112
- Spallation 14
- Spectral sensitization of photographic emulsions 1186
- Spectroscopic terms 1242
- Sphalerite (Zinc blende) 649, 1202
 structure of 679, 1209
- Spiegeleisen 1041
- Spin crossover *see* Spin equilibria
- Spin equilibria
 in Cr^{II} and Mo^{II} compounds 1034
 in Fe^{II} compounds 1095
 in Fe^{III} compounds 1096
 in Mn^{II} compounds 1066–1067
 in niobium halides 992
- Spinel 109
- Spinel structure
 in Co₃O₄ 1118
 defect structure of γ-Al₂O₃ 243
 in Fe₃O₄ (inverse) 1079
 in ferrites and garnets 1081
 in Mn₃O₄ 1048
 normal and inverse 247–249, 1080
 in ternary sulfides 681
 valence disordered types 249
- Spin-forbidden bands
 in compounds of Fe^{III} 1089

- in compounds of Mn^{II} 1060
- in compounds of Ni^{II} 1158
- Spin-orbit coupling
 - in actinide ions 1271
 - in d^4 ions 1087
 - in octahedral Ni^{II} 1158
 - in lanthanide ions 1242
 - in tetrahedral Co^{II} 1132
- Spin quantum number m_s 22
- Spodumene 69, 349
- Square antiprismatic complexes 916
- Square planar complexes 913
- Square pyramidal complexes 914
- Stability constants of coordination compound
 - factors affecting 908–911
 - overall 908
 - stepwise 908
- Staging *see* Graphite intercalation compound
- Standard reduction potentials 434
 - IUPAC sign convention 436
 - see also* individual elements
- Stannates 354
- Stannocene 402
- Starch/iodine reaction 790, 864
- Stars
 - spectral classification of 5
 - temperatures of 5
- Steel 1072–1075
- Stellar evolution 5
- Stereochemical non-rigidity (fluxional behaviour)
 - $\text{Al}(\text{BH}_4)_3$, $\{\text{Al}(\text{BH}_4)_2\text{H}_\mu\}_2$ 230
 - allyl complexes 934
 - Berry pseudorotation mechanism 474, 499
 - 5-coordinate compounds 914
 - 8-coordinate compounds 995
 - $\text{Fe}(\text{CO})_5$ 914, 1104
 - iron cyclopentadienyl complexes 1111
 - PF_5 498
 - SF_4 684
 - titanium cyclopentadienyl 974
- Stibine
- Stibinidene complexes 597
- Stibnite *see* Antimony sulfide, Sb_2S_3
- Stishovite 342
- Strength of oxoacids, Pauling's rules 50
- Strontium
 - history 108
 - organometallic compounds 136
 - polysulfides 681
 - see also* Alkaline earth metals
- stylx numbers *see* Boranes, topology
- Sulfamic acid, $\text{H}[\text{H}_2\text{NSO}_3]$ 408, 741, 742
- Sulfamide $(\text{H}_2\text{N})_2\text{SO}_2$ 742, 743
- Sulfanes 682–683
 - nonexistence of SH_4 and SH_6 685
 - physical properties 683
 - preparation 682
 - synthesis of polythionic acids from 716
 - see also* Hydrogen sulfide
- Sulfate ion as ligand (η^1 , η^2 , μ) 712
- Sulfates 711, 712
 - see also* individual elements
- Sulfide minerals
 - geochemical classification 648
 - names and formulae 649
- Sulfides
 - anionic polysulfides 678, 681, 682
 - applications and uses 677–679
 - electrical properties 681
 - hydrolysis 678, 679, 682
 - industrial production 678
 - magnetic properties 681
 - preparation (laboratory) 677
 - roasting in air 676–678
 - solubility in water 678, 679
 - S_n^{2-} structures 631, 681
 - structural chemistry 679–681
 - see also* individual elements
- Sulfates 703
- Sulfites, SO_3^{2-} 705, 719
 - in paper manufacture 652
 - protonation to HSO_3^- 719
- Sulfoxylates, $\text{MS}(\text{O})\text{OR}$ 703
- Sulfur
 - abundance 647
 - allotropes 646, 652–661
 - see also* individual allotropes, e.g. *Cyclo-S_n*, *Catena-S_n* etc.
 - atomic properties 661
 - atomic S 664
 - atomic weight, variability of 18, 661, 662
 - in biological complexes 667
 - bromides S_nBr_2 691
 - catenation 652, 656ff, 681–683, 689, 690, 716–718
 - chemical reactivity 662–664
 - chiral helices 660
 - chlorides 689–692, 716
 - industrial applications of SCl_2 and S_2Cl_2 690
 - preparation 690, 691
 - properties of S_nCl_2 690, 691
 - $[\text{SCl}_3]^+$ 691, 693
 - SCl_7I 693
 - chlorofluorides 640, 686–689
 - conformations (c, dt, lt) 656, 659, 665
 - conversion to SO_2/SO_3 for H_2SO_4 *see* Sulfuric acid
 - coordination geometries 663
 - Crystex 659
 - dihedral angles in S_n 654, 655
 - fibrous (ψ , ϕ) 659–660
 - fluorides 683–689
 - chemical reactions 685–689
 - fluxionality of SF_4 685
 - isomeric S_2F_2 684
 - physical properties 685, 687
 - stoichiometries 684
 - structures 684–685
 - synthesis 685–688
 - gaseous species 661
 - halides 683–693
 - see also* individual halides
 - hexafluoride 685, 687
 - applications as a dielectric gas 687
 - reaction with SO_3 695
 - history 645, 646
 - iodides 691–693

- Sulfur — *contd*
- bond energy relations in 691
 - SCl_7I 693
 - $[\text{S}_2\text{I}_4]^{2+}$ 692, 693
 - $[\text{S}_7\text{I}]^+$ 692
 - $[\text{S}_{14}\text{I}_3]^{3+}$ 692
 - λ point 660
 - as ligands 701–703
 - ligand properties of chelating $-\text{S}_n-$ 665, 670, 672
 - ligand properties of S atom 665–666
 - ligand properties of S_2^{2-} 665–669, 668, 671
 - liquid 654, 660
 - monoxide 698
 - nitrides 722–729
 - organic thio ligands 673
 - origin in caprock of salt domes 647
 - oxidation states 664
 - oxidation state diagram of species 706
 - oxides 695–704
 - higher, SO_{3+x} , SO_4 704,
 - lower dioxides 695–698
 - lower oxides S_nO 695–698
 - see also* Sulfur dioxide, Sulfur trioxide
 - oxoacids 706–721
 - schematic classification 707
 - table of 705
 - thermodynamic interrelations 706
 - see also* individual oxoacids and oxoacid anion
 - oxofluorides 688
 - see also* Thionyl fluorides, Sulfuryl fluorides
 - peroxofluorides 689
 - plastic (χ) 659
 - polyatomic cations 664, 665
 - polymeric (μ) 659
 - production 649–652
 - Frasch process 649–650
 - from pyrite 651
 - from sour gas and crude oil 651
 - statistics 762, 768
 - radioactive isotopes 661
 - reserves 651
 - rhombohedral *see* *Cyclo- α -S₈*
 - rubbery S 659
 - S–S bonds 652, 654, 662, 667, 681–683, 716–718
 - S_2 656, 661
 - S_3 656, 661
 - S_4 661
 - S_4^{2+} *see* polyatomic cations
 - S_8 *see* *Cyclo-S₈*
 - S_8^{2+} *see* polyatomic cations
 - S_n *see* *Cyclo-S_n*
 - S_{19}^{2+} *see* polyatomic cations
 - SN compounds 686, 721–746
 - see also* S_4N_4 , S_2N_2 , $(\text{SN})_x$, S–N–X compounds,
 - Sulfur imides, S–N–O compounds, Sulfur-nitrogen anions, Sulfur-nitrogen cations
 - singlet state S_2 661
 - standard reduction potentials of S species 706
 - terrestrial distribution 647
 - triplet state S_2 661
 - uses 651, 653
 - uses of radioactive ^{35}S 661, 714
 - volt-equivalent diagram of S species 706
 - see also* Chalcogenides
 - Sulfur chloride pentafluoride SF_5Cl
 - photolytic reduction to S_2F_{10} 687
 - reaction with O_2 640
 - synthetically useful reactions of 688, 689
 - Sulfur dioxide 698–701
 - atmospheric pollution by 646, 698–700, 699
 - chemical reactions 700
 - clathrate hydrate 700
 - industrial production 698, 708
 - insertion into M–C bonds 702, 703
 - as ligand 701–703
 - molecular and physical properties 700, 780
 - in M–S–O phase diagrams 677
 - solvent for chemical reactions 662, 701
 - toxicity 700
 - uses 700
 - see also* Wackenroder's solution, Sulfuric acid production
 - Sulfur imides, $\text{S}_{8-n}(\text{NH})_n$ 735–735
 - Sulfur-nitrogen anions, S_xN_y^- 733–734
 - Sulfur-nitrogen cations, S_xN_y^+ 730–733
 - Sulfur-nitrogen-halogen compounds 736–740
 - cyclo*-(NSF)_n 736–738
 - $\text{N}_3\text{S}_3\text{Cl}_3$ 738
 - $\text{N}_3\text{S}_3\text{X}_3\text{O}_3$ 738
 - $\text{S}_4\text{N}_3\text{Cl}$ and $\text{S}_4\text{N}_4\text{Cl}_2$ 739
 - thiazyl halides NSX 736–738
 - Sulfur-nitrogen-oxygen compounds 740
 - amides of H_2SO_4 741
 - see also* Sulfamic acid, Sulfamide
 - hydrazine derivatives of H_2SO_4 743
 - hydroxylamine derivatives of H_2SO_4 743–746
 - imido and nitrido derivatives of H_2SO_4 743
 - sulfur-nitrogen oxides 740, 741
 - Sulfur trioxide
 - chemical reactions 703, 704
 - molecular and physical properties 703, 704
 - monomeric 703, 704
 - polymeric 703, 704
 - polymorphism 703, 704
 - preparation by catalytic oxidation of SO_2 700, 708
 - reaction with F_2 640
 - reaction with SF_6 695
 - trimeric 703, 704
 - see also* Sulfuric acid production
 - Sulfuric acid 706, 712
 - amides of 741–743
 - autoprotolysis in anhydrous 710
 - contact process 646, 700, 708–710, 981
 - D_2SO_4 710, 711
 - history 646, 708
 - hydrates 710
 - hydrazine derivatives of 744
 - hydroxylamine derivatives of 744–746
 - imido derivatives of 743, 744
 - ionic dissociation equilibria in anhydrous 711
 - lead chamber process 646, 708
 - nitrido derivatives of 743, 744
 - physical properties
 - physical properties of D_2SO_4
 - production from sulfide ores 708
 - production from sulfur 652–652, 708

- production statistics 407, 708, 710
 solvent system 711
 uses 710
- Sulfurous acid, H_2SO_3 652, 700, 705, 717, 718
- Sulfuryl chloride 694, 695
- Sulfuryl fluoride 688, 694
 mixed fluoride halides 694
- Super acids
 $\text{HF}/\text{SO}_3/\text{SbF}_5$
 $\text{HSO}_3\text{F}/\text{SbF}_5$
- Superconductivity
 in Chevrel phases 1018, 1031
 high temperature 945, 1182–3, 1232
 of metal sulfides 680
 use of Nb/Zr in magnets 978
- Superheavy elements 30, 1253
- Supernucleophiles 1139
- Superoxo complexes of O_2 616, 1127
- Superphosphate fertilizer 474, 525
- Swarts reaction 560
- Symmetry elements 1290–1292
- Symmetry operations 1290–1292
- Synergic bonding
 in alkene complexes 926, 927
 in CO and CN^- complexes 931
 in cobalt cyanides 1122
see also Back (π) bonding
- Synthesis gas 1106
- Talc 109
- Tanabe-Sugano diagrams
 for d^2 ions 997
 for d^3 ions 1029
 for d^6 ions 1096, 1128
 for d^8 ions 1156
 for Mn^{II} 1156
- Tantalates 987
- Tantalite 977
- Tantalum
 abundance 977
 alkyls and aryls 999
 carbene complex 926
 carbonylate anions 999–1000
 chalcogenides 987
 complexes
 +5 oxidation state 994
 +4 oxidation state 944–996
 compounds with oxoanions 993
 cyclopentadienyls 1000–1001
 discovery 976
 halides and oxohalides 988–999
 organometallic compounds
 oxides 929, 982, 983, 999–1000
 production and uses 977
see also Group 5 elements
- Technetates 1050
- Technetium
 abundance 1041
 carbonyls 928, 1062–1063
 chalcogenides 1049
 complexes
 +7 oxidation state 1054
 +6 oxidation state 1055
 +5 oxidation state 1055
 +4 oxidation state 1056
 +3 oxidation state 1057–1058
 +2 oxidation state 1058
 lower oxidation states 1061
 cyclopentadienyls 1067–1068
 discovery 1040
 halides and oxohalides 1051–1054
 nuclear medicine, role in 1042
 organometallic compounds 1062–1067
 oxides 1045
 production and uses 1041
see also Group 7 elements
- Tectites 394
- Tecto-silicates 414–416, 347
- Teflon (PTFE) 304, 791
- Tellurates 782
- Telluric acid, $\text{Te}(\text{OH})_6$ 782
- Tellurides 765, 766
- Tellurites 781
- Tellurium
 abundance 748
 allotropy 751
 atomic and physical properties 753, 754
 chemical reactivity 754–759
 coordination geometries 756–757
 dioxide 779, 780
 discovery 747
 halide complexes 776
 halides 767–776
 hydride, H_2Te 759, 766
 nitrate 786
 nitride, Te_3N_4 783
 organo compounds 786–788
 oxides 779–780
 oxoacids 781–783
 oxohalides 777
 polyatomic anions 762–5
 polyatomic cations
 Te_n^{m+} 759, 761
 $[\text{Te}_n\text{Se}_{4-n}]^{2+}$ 761
 production and uses 748, 749
 redox properties 755–756
 sulfide, TeS_7 783
 toxicity 759
 trioxide 780
- Tellurocyanate ion, TeCN^- 779
- Telluropolythionates 783
- Tellurous acid 781
- Terbium 1229
 +4 oxidation state 1237, 1239
see also Lanthanide elements
- Tetracyanoethylene complexes, bonding in 931
- Tetrafluoroethylene complexes, bonding in 932
- Tetrafluoronitronium cation NF_4^+ 439
- Tetrahalogenophosphonium cations PX_4^+ 499–500
- Tetrahedral complexes 914
- Tetrahydroaluminate ion, as ligand 231

- Tetrahydroborates
 of Al 260, 228, 229
 of Ga 231
 of Zr and Hf 969
 use in synthesis 166–168
- Tetrametaphosphimate conformers 542
- Tetrathionates, $S_4O_6^{2-}$, preparation and structure 717, 718
- Thallium
 abundance 217
 chalcogenides 252–254
 III–V compounds 255–258
 discovery 217
 halide complexes 240
 lower halides 241
 monohalides 241, 242
 organometallic compounds 261, 265
 oxides 246
 production 221
 similarity of Tl^I to alkali metals 226
 trihalides 239
 triiodide $Tl^I[I_3]^-$ 239, 240
see also Group 13 elements
- Thiazyl halides NSX 736–738
- Thioarsenites 580
- Thiocarbonyl (CS) complexes 319
- Thiocyanates 320, 324
 as ambidentate ligands 326–327, 907, 920
- Thioethers as ligands 673
- Thionitrosyl (NS) complexes 453, 454
- Thionyl bromide 694
- Thionyl chloride 693, 694
 relation to SO_2 and Me_2SO as ionizing solvent 694
- Thionyl fluoride 688, 693, 694
 mixed fluoride chloride 694
- Thiophosphoryl
 halides, PSX_3 500, 502
 pseudohalides 501
- Thioselenates 783
- Thiosulfates, $S_2O_3^{2-}$ 705, 714, 715
 as ligands 714, 715
 redox reactions in analysis 714, 715
 structure 714, 715
 use in photography 714, 1186, 1187
- Thiosulfuric acid, $H_2S_2O_3$ 705, 714
 isomeric $H_2S.SO_3$ 714
 redox interconversions in water 714
- Thio-urea 317
- Thiovanadyl ion
- Thixotropy 356, 968
- Thorium
 abundance 1253
 bis(cyclooctatetraene) 942
 production and uses 1255
 radioactive decay series 1254
 redox behaviour 1265–1267
 use as a nuclear fuel 1258, 1259
see also Actinide elements
- Thortveitite 348
- Three-centre bonds
 in Al trialkyls and triaryls 258
 in beryllium alkyls 127
 BHB bond 64, 151ff
 BBB bond 158
- BHM bond 177
 H_3^+ ion 37
 in magnesium alkyls 127
- Thulium 1228
see also Lanthanide elements
- Thymine 61, 62
- Thyroxine 794, 795
- Tin
 abundance 368
 allotropes 373
 alloys 370
 in antiquity 367, 368
 atomic properties 371–372
 bis(cyclopentadienyl) 402
 chalcogenides 389
 chemical reactivity and group trends 373
 cluster anions 374, 393
 cluster complexes 383, 395
 compounds, use of 385, 400
 dibromide 380
 dichloride 379, 380
 difluoride 379
 dihalides 375, 377–381
 diiodide 380
 dioxide 384, 386, 387, 388, 400
 halogeno complexes 377–381, 399
 hydrides 375
 hydroxo species 383, 395
 isolation and purification 369
 metal-metal bonded compounds 391, 396, 399–404
 monomeric $Sn(OAr)_2$ 391
 monoxide 377, 383, 387, 388
 nitrates 387
 organometallic compounds 396–403
 oligomerization 396
 production statistics 400
 toxic action 400
 uses of 400
 oxoacid salts 387, 388
 physical properties 371, 373
 production statistics 368, 379
 pseudohalogen derivatives 389
 sulfide 389
 tetrahalides 375, 381, 385
 uses 370, 385
- Titanates 963–964
 ferroelectric properties 963
- Titanium
 abundance 955
 alkoxides 967
 alkyls and aryls 973
 alum 970
 bronzes 964
 carbonyls 973
 complexes
 +4 oxidation state 967–969
 +3 oxidation state 969–971
 lower oxidation states 971–975
 with S 670, 672
 compounds with oxoanions 966
 cyclooctatetraene complex 943
 cyclopentadienyls 973–975
 dioxide 959

- discovery 954
 estimation using H_2O_2 968
 halides 964–966
 mixed metal oxides (titanates) 963–964
 nonstoichiometric oxide phases 642, 961
 organometallic compounds 972–975
 production and uses 955–956
 “sponge” 956
 sulfides 962
see also Group 4 elements
 “Titanocene” 973
 Tobermorite gel 252
 Tolman’s cone angle 494
 Tooth enamel 477
 Toothpastes, calcium compounds in 528
 “Tops and bottoms” process 1146
Trans-effect 1164
 in $[\text{OsNCl}_5]^{2-}$ 1085
 in Pt^{II} complexes 1163, 1164
 in Rh^{III} complexes 1127
Trans-influence 1164, 1165
 in $[\text{OsNCl}_5]^{2-}$ 1085
 in Pt^{II} complexes 1165
 Transactinide elements 1280–4
 Transferrin 1103
 Transistor action 331, 332
 chemistry of manufacture 332
 discovery 331
 Transition element ions
 coordination chemistry 905–943
 see also individual elements
 Transition elements
 definition of 905
 characteristic properties 905
 see also Transition element ions and individual elements
 Transuranium elements
 discovery of 21, 29, 1252
 extraction from reactor wastes 1262
 see also Actinide elements
 Tricalcium aluminate, $\text{Ca}_3\text{Al}_2\text{O}_6$, structure 251
 see also Portland cement
 Tricalcium phosphate $[\text{Ca}_5(\text{PO}_4)_3\text{OH}]$ 524
 Tri-capped trigonal prismatic complexes 917
 Tridymite 343
 Trigonal bipyramidal complexes 914
 Trigonal prismatic complexes 915
 Triperiodic acid *see* Periodic acids
 Triphosphoric acid $\text{H}_5\text{P}_3\text{O}_{10}$ 512
 “Triple-decker” complexes 1170
 Tris(dimethylamino)phosphine 533
 Trithiocarbonates 317
 Trithionates, $\text{S}_3\text{O}_6^{2-}$, preparation and structure 717, 718
 Tritium
 atomic properties 34
 discovery 33
 physical properties 35
 preparation of tritiated compounds 42
 radioactivity of 42
 synthesis 41
 uses as a tracer 42
 Tropylium (cycloheptatrienyl) 942
 Tungstates 1009–1016
 Tungsten
 abundance 1003
 benzene tricarbonyl 941
 blues 1008
 bronzes 1016
 carbonyls 928, 1037–1038
 carbyne complexes 929
 chalcogenides 1017–1018
 complexes
 +6 oxidation state 1023–1024
 +5 oxidation state 1024, 1025
 +4 oxidation state 1025–1027
 +3 oxidation state 1027–1031
 +2 oxidation state 1031–1034
 with S 670
 cyclopentadienyl derivatives 1039
 discovery 1002
 halides and oxohalides 1019–1023
 hexacarbonyl 928, 1038
 heteropolyacids and salts 1014–1016
 isopolyacids and salts 1009–1014
 nonstoichiometric oxides 1008
 organometallic compounds 829, 940, 941, 1037–1039
 oxides 1007–1009
 production and uses 1003
 see also Group 6 elements
 Tungstic acid 1010
 Tungstocene 1038
 Turnbull’s blue 1094
 Tutton salts
 of copper 1190
 of vanadium 993
 Type metal 547, 549
 Tyrian purple 790, 791, 793
u (ungerade), definition of 938
 Ultramarines 354, 359
 Units
 conversion factors 1293
 non-SI 1293
 SI, definitions *see* inside back cover
 SI, derived *see* inside back cover
 Universe
 expansion of 2, 5
 origin of 1, 2
 Uranium
 abundance 1253
 bis(cyclooctatetraene) 942
 isotopic enrichment 1259
 production 1255
 radioactive decay series 1254
 redox behaviour 1265–1267
 variable atomic weight 17
 see also Actinide elements
 Uranium hexafluoride 1259, 1269–1271
 Uranium oxides, nonstoichiometry in 643
 “Uranocene” 1279
 Uranyl ion 1266, 1269, 1273–1274
 Urea 305, 311, 323, 422
 hydrazine production from 429
 phosphate 524
 Wöhler’s synthesis 408

- Valence, periodic trends in 27
 Valence bond theory of transition metal complexes 921–924
 Valinomycin 96
 Vanadates 981, 983–987
 Vanadium
 abundance 977
 accumulation in blood of invertebrates 999
 alkyls and aryls 999
 biochemistry of 999
 bronzes 987
 carbonyl 928, 1000
 chalcogenides 988
 complexes
 +5 oxidation state 994
 +4 oxidation state 994–996
 +3 oxidation state 996–998
 +2 oxidation state 998
 compounds with oxoanions 993
 cyclopentadienyls 939, 1000
 discovery 976
 dithiolene complexes 674, 675
 halides and oxohalides 988–993
 hexacarbonyl 828, 928,
 isopolyacids and salts 983–987
 nonstoichiometric oxides 982
 organometallic compounds 927, 939, 941, 942,
 997–1001
 oxides 981–983
 production and uses 977
see also Group 5 elements
 Vanadocene 1000
 Vanadyl compounds 982, 995, 996
 Van Arkel-de Boer process 956
 Vaska's compound 615, 616, 1135–1137
 Venus, atmosphere of 645, 646
 Vermiculite 349, 357
 Viscose rayon 317
 Vitamin B₁₂ 1138, 1139, 1226
 Volt equivalent
 definition 434
 diagrams 436–438
see also individual elements for volt equivalent diagrams
 Vortmann's sulfate 1127
 Vulcanization of rubber 646
 Wackenroder's solution 717, 719
 Wacker process 1172
 Wade's rules 161, 162, 181, 553, 590, 591
 Water
 acid-base behaviour 48, 628
 aquo complexes 625
 autoprotolysis constant 48
 chemical properties 627
 clathrate hydrates 626, 627
 distribution and availability 621–623
 H bonding in 52–55
 heavy (D₂O) 623
 history 620
 hydrates 625–627
 hydrolysis reactions 627
 ice, polymorphism 624
 ionic product of 48
 Karl Fischer reagent for 627
 lattice water 625
 physical properties 623–625, 754
 pollution of 622
 polywater 632, 633
 purification and recycling 622, 623
 self ionic dissociation of 48
 tritiated (T₂O) 623
 zeolitic water 625
 Water-gas shift reaction 38, 311, 421, 1106
 in Haber-Bosch NH₃ synthesis 421
 Water supplies, treatment of 120
 White arsenic *see* Arsenic oxide, As₂O₃
 "White gold" 1144
 "White lead" 388, 1209
 Wilkinson's catalyst 43, 1134–1135
 Wilson's disease 1198
 Wittig reaction 474, 475, 545
 with arsenic ylides 594
 Wolfram's red salt 1135
 Wolfram 1002
see also Tungsten
 Wolframite 1003, 1004
 Wrought-iron 1073
 Wurtzite structure (ZnS) 679, 1209
 x-Process in stars 13
 X-ray absorption spectroscopy 1036
 Xanthates 317, 646
 γ -S₈ from Cu^I ethyl xanthate 655
 as ligands 693
 XeF₂ 894–894
 bonding 897, 898
 bonding compared with H bond 64
 XeF₄ 894–896
 XeF₆ 894, 895, 896, 898, 900, 901
 Xenate ion, HXeO₄⁻ 901
 Xenon
 atomic and physical properties 890, 891
 carbon bonds 902–903
 chemical reactivity discovered 893
 chloride 896
 clathrates 893
 discovery 889
 fluorides 893–903
 fluorocomplexes 898, 901
 fluorosulfate 899, 900
 nitrogen bonds 902
 oxidation states 894
 oxides 894–896
 oxoanions (xenate, perxenate) 901
 oxofluorides 900
 perchlorate 899
 stereochemistry 894, 895
 trifluoromethyl compounds
 Xerography 750
 Xerox process (xerography) 750
 "Yellow cake" 1255
 Ylides 545
 arsonium 594

- Ytterbium 1228
+2 oxidation state 1237, 1239, 1240, 1241, 1248
see also Lanthanide elements
- Yttrium
abundance 945
complexes 950–953
discovery 944, 1228
halides 949–950
organometallic compounds 953
oxide 949
oxo salts 949
production and uses 945, 946
see also Group 3 elements, Lanthanide elements
- Zeise's salt 930, 931, 1167, 1170
- Zeolite 354–359
- Ziegler-Natta catalysis 260, 261, 972
- Zinc
abundance 1202
alkyls and aryls 1221
biochemistry 1224
chalcogenides 1208, 1209, 1210
coordination chemistry 1215–1217
ferrites 1209
halides 1211–1213
history 1201
organometallic compounds 1221
+2 oxidation state 1215–1217
oxides 1202, 1208
 nonstoichiometry in 642, 1208
production and uses 1202–1203
see also Group 12 elements
- Zinc blende (sphalerite) 1202
 structure 679, 1209
- Zinc-finger proteins 1225
- Zintl phases 78, 257, 393, 553, 762
- Zircon 347, 955
- Zirconates 964
- Zirconium dioxide 244, 955, 967
 “Saffil” fibres 244
- Zirconium
abundance 955
alkyls and aryls 973
borohydride 969
carbonyls 974
complexes
 +4 oxidation state 967–969
 +3 oxidation state 969
 lower oxidation states 971
compounds with oxoanions 966, 1226
cyclopentadienyls 974–975
dioxide (baddeleyite) 275, 955, 961
discovery 954
disulfide 962
halides 964, 966
in nuclear reactors 956, 1461
organometallic compounds 973
production and uses 955
tetrahydroborate 166