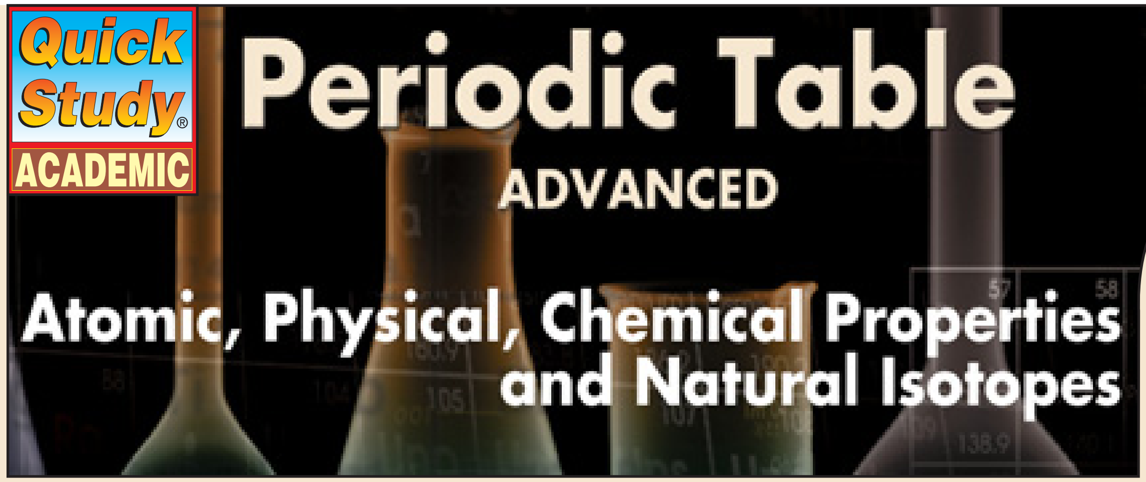
BarCharts, Inc.®

WORLD'S #1 ACADEMIC OUTLINE

QuickStudy



Quick Study® ACADEMIC

Periodic Table

ADVANCED

Atomic, Physical, Chemical Properties and Natural Isotopes

Periodic Table ADVANCED

Atomic Number: number of protons

Atomic Weight: weighted average of atomic masses of natural isotopes

☢ - mass number of the most stable isotope for each radioactive element

Electronegativity: Pauling scale; measures ability of atom to attract electrons in a chemical bond

Atomic Radius: given in "pm"; 1 pm = 1x10⁻¹²m

Ionic Radius: given in "pm"; 1 pm = 1x10⁻¹²m

Electron Affinity: energy released in the formation of an anion: given in "eV"

1st Ionization Potential: energy required to remove one electron, forming a cation; given in "eV"

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 H 1.008 Hydrogen $1s^1$ Oxidation States 1 Electroneg. 2.2 Atomic Radius 37 Ionic Radius – Electron Affinity 0.75 1st Ion. Pot. 13.60																	2 He 4.003 Helium $1s^2$ Oxidation States – Electroneg. – Atomic Radius – Ionic Radius – Electron Affinity Unstable Anion 1st Ion. Pot. 24.59
3 Li 6.94 Lithium $1s^22s^1$ Oxidation States 1 Electroneg. 0.98 Atomic Radius 152 Ionic Radius (+1)76 Electron Affinity 0.62 1st Ion. Pot. 5.39	4 Be 9.01 Beryllium $1s^22s^2$ Oxidation States 2 Electroneg. 1.57 Atomic Radius 111 Ionic Radius (+2)45 Electron Affinity Unstable Anion 1st Ion. Pot. 9.32											5 B 10.81 Boron $1s^22s^2p^1$ Oxidation States 3 Electroneg. 2.04 Atomic Radius 80 Ionic Radius – Electron Affinity 0.28 1st Ion. Pot. 8.30	6 C 12.01 Carbon $1s^22s^2p^2$ Oxidation States 4,2 Electroneg. 2.55 Atomic Radius 77 Ionic Radius (+4)16 Electron Affinity 1.26 1st Ion. Pot. 11.26	7 N 14.01 Nitrogen $1s^22s^2p^3$ Oxidation States ±3,5,4,2 Electroneg. 3.04 Atomic Radius 74 Ionic Radius (+3)16 Electron Affinity Unstable Anion 1st Ion. Pot. 14.53	8 O 16.00 Oxygen $1s^22s^2p^4$ Oxidation States -2 Electroneg. 3.44 Atomic Radius 74 Ionic Radius (-2)140 Electron Affinity 1.46 1st Ion. Pot. 13.62	9 F 19.00 Fluorine $1s^22s^2p^5$ Oxidation States -1 Electroneg. 3.98 Atomic Radius 71 Ionic Radius (-1)133 Electron Affinity 3.40 1st Ion. Pot. 17.42	10 Ne 20.18 Neon $1s^22s^2p^6$ Oxidation States – Electroneg. – Atomic Radius – Ionic Radius – Electron Affinity Unstable Anion 1st Ion. Pot. 21.57
11 Na 22.99 Sodium $[Ne]3s^1$ Oxidation States 1 Electroneg. 0.93 Atomic Radius 186 Ionic Radius (+1)102 Electron Affinity 0.55 1st Ion. Pot. 5.14	12 Mg 24.31 Magnesium $[Ne]3s^2$ Oxidation States 2 Electroneg. 1.31 Atomic Radius 160 Ionic Radius (+2)72 Electron Affinity Unstable Anion 1st Ion. Pot. 7.65											13 Al 26.98 Aluminum $[Ne]3s^2p^1$ Oxidation States 3 Electroneg. 1.61 Atomic Radius 143 Ionic Radius (+3)54 Electron Affinity 0.44 1st Ion. Pot. 5.99	14 Si 28.09 Silicon $[Ne]3s^2p^2$ Oxidation States 4 Electroneg. 1.90 Atomic Radius 118 Ionic Radius (+4)40 Electron Affinity 1.39 1st Ion. Pot. 8.15	15 P 30.97 Phosphorus $[Ne]3s^2p^3$ Oxidation States ±3,5,4 Electroneg. 2.19 Atomic Radius 110 Ionic Radius (+5)17 Electron Affinity 0.75 1st Ion. Pot. 10.49	16 S 32.07 Sulfur $[Ne]3s^2p^4$ Oxidation States ±2,4,6 Electroneg. 2.58 Atomic Radius 103 Ionic Radius (-2)184 Electron Affinity 2.08 1st Ion. Pot. 10.36	17 Cl 35.45 Chlorine $[Ne]3s^2p^5$ Oxidation States ±1,3,5,7 Electroneg. 3.16 Atomic Radius 99 Ionic Radius (-1)181 Electron Affinity 3.61 1st Ion. Pot. 12.97	18 Ar 39.95 Argon $[Ne]3s^2p^6$ Oxidation States – Electroneg. – Atomic Radius – Ionic Radius – Electron Affinity Unstable Anion 1st Ion. Pot. 15.76
19 K 39.10 Potassium $[Ar]4s^1$ Oxidation States 1 Electroneg. 0.82 Atomic Radius 227 Ionic Radius (+1)151 Electron Affinity 0.50 1st Ion. Pot. 4.34	20 Ca 40.08 Calcium $[Ar]4s^2$ Oxidation States 2 Electroneg. 1.00 Atomic Radius 197 Ionic Radius (+2)100 Electron Affinity 0.04 1st Ion. Pot. 6.11	21 Sc 44.96 Scandium $[Ar]3d^14s^2$ Oxidation States 3 Electroneg. 1.36 Atomic Radius 161 Ionic Radius (+3)75 Electron Affinity 0.19 1st Ion. Pot. 6.56	22 Ti 47.87 Titanium $[Ar]3d^24s^2$ Oxidation States 4 Electroneg. 1.54 Atomic Radius 145 Ionic Radius (+4)61 Electron Affinity 0.08 1st Ion. Pot. 6.83	23 V 50.94 Vanadium $[Ar]3d^34s^2$ Oxidation States 5.3 Electroneg. 1.63 Atomic Radius 131 Ionic Radius (+5)54 Electron Affinity 0.53 1st Ion. Pot. 6.75	24 Cr 52.00 Chromium $[Ar]3d^54s^1$ Oxidation States 6,3,2 Electroneg. 1.66 Atomic Radius 125 Ionic Radius (+3)62 Electron Affinity 0.67 1st Ion. Pot. 6.77	25 Mn 54.94 Manganese $[Ar]3d^54s^2$ Oxidation States 7,6,4,2,3 Electroneg. 1.55 Atomic Radius 137 Ionic Radius (+2)67 Electron Affinity Unstable Anion 1st Ion. Pot. 7.43	26 Fe 55.85 Iron $[Ar]3d^64s^2$ Oxidation States 2,3 Electroneg. 1.83 Atomic Radius 124 Ionic Radius (+3)55 Electron Affinity 0.151 1st Ion. Pot. 7.90	27 Co 58.93 Cobalt $[Ar]3d^74s^2$ Oxidation States 2,3 Electroneg. 1.88 Atomic Radius 125 Ionic Radius (+2)65 Electron Affinity 0.66 1st Ion. Pot. 7.88	28 Ni 58.69 Nickel $[Ar]3d^84s^2$ Oxidation States 2,3 Electroneg. 1.91 Atomic Radius 125 Ionic Radius (+2)69 Electron Affinity 1.16 1st Ion. Pot. 7.64	29 Cu 63.55 Copper $[Ar]3d^{10}4s^1$ Oxidation States 2,1 Electroneg. 1.90 Atomic Radius 128 Ionic Radius (+2)73 Electron Affinity 1.24 1st Ion. Pot. 7.73	30 Zn 65.39 Zinc $[Ar]3d^{10}4s^2$ Oxidation States 2 Electroneg. 1.65 Atomic Radius 133 Ionic Radius (+2)74 Electron Affinity Unstable Anion 1st Ion. Pot. 9.39	31 Ga 69.72 Gallium $[Ar]3d^{10}4s^2p^1$ Oxidation States 3 Electroneg. 1.81 Atomic Radius 122 Ionic Radius (+3)62 Electron Affinity 0.3 1st Ion. Pot. 5.10	32 Ge 72.61 Germanium $[Ar]3d^{10}4s^2p^2$ Oxidation States 4 Electroneg. 2.01 Atomic Radius 123 Ionic Radius (+4)53 Electron Affinity 1.23 1st Ion. Pot. 7.90	33 As 74.92 Arsenic $[Ar]3d^{10}4s^2p^3$ Oxidation States ±3,5 Electroneg. 2.18 Atomic Radius 125 Ionic Radius (+3)58 Electron Affinity 0.81 1st Ion. Pot. 9.81	34 Se 78.96 Selenium $[Ar]3d^{10}4s^2p^4$ Oxidation States ±2,4,6 Electroneg. 2.55 Atomic Radius 116 Ionic Radius (-2)198 Electron Affinity 2.02 1st Ion. Pot. 9.75	35 Br 79.90 Bromine $[Ar]3d^{10}4s^2p^5$ Oxidation States ±1,5 Electroneg. 2.96 Atomic Radius 114 Ionic Radius (-1)196 Electron Affinity 3.36 1st Ion. Pot. 11.81	36 Kr 83.80 Krypton $[Ar]3d^{10}4s^2p^6$ Oxidation States – Electroneg. – Atomic Radius – Ionic Radius – Electron Affinity Unstable Anion 1st Ion. Pot. 14.00
37 Rb 85.47 Rubidium $[Kr]5s^1$ Oxidation States 1 Electroneg. 0.82 Atomic Radius 248 Ionic Radius (+1)161 Electron Affinity 0.49 1st Ion. Pot. 4.18	38 Sr 87.62 Strontium $[Kr]5s^2$ Oxidation States 2 Electroneg. 0.95 Atomic Radius 215 Ionic Radius (+2)126 Electron Affinity 0.11 1st Ion. Pot. 5.70	39 Y 88.91 Yttrium $[Kr]4d^15s^2$ Oxidation States 3 Electroneg. 1.22 Atomic Radius 178 Ionic Radius (+3)102 Electron Affinity 0.31 1st Ion. Pot. 6.22	40 Zr 91.22 Zirconium $[Kr]4d^25s^2$ Oxidation States 4 Electroneg. 1.33 Atomic Radius 159 Ionic Radius (+4)84 Electron Affinity 0.43 1st Ion. Pot. 6.63	41 Nb 92.91 Niobium $[Kr]4d^45s^1$ Oxidation States 5,3 Electroneg. 1.60 Atomic Radius 143 Ionic Radius (+5)64 Electron Affinity 0.90 1st Ion. Pot. 6.76	42 Mo 95.94 Molybdenum $[Kr]4d^55s^1$ Oxidation States 6,5,4,3,2 Electroneg. 2.16 Atomic Radius 136 Ionic Radius (+6)59 Electron Affinity 0.75 1st Ion. Pot. 7.09	43 Tc 98☢ Technetium $[Kr]4d^55s^2$ Oxidation States 7 Electroneg. 2.10 Atomic Radius 135 Ionic Radius – Electron Affinity 0.55 1st Ion. Pot. 7.28	44 Ru 101.1 Ruthenium $[Kr]4d^75s^1$ Oxidation States 2,3,4,6,8 Electroneg. 2.20 Atomic Radius 133 Ionic Radius (+3)68 Electron Affinity 1.05 1st Ion. Pot. 7.36	45 Rh 102.9 Rhodium $[Kr]4d^85s^1$ Oxidation States 2,3,4 Electroneg. 2.28 Atomic Radius 135 Ionic Radius (+3)67 Electron Affinity 1.14 1st Ion. Pot. 7.46	46 Pd 106.4 Palladium $[Kr]4d^{10}$ Oxidation States 2,4 Electroneg. 2.20 Atomic Radius 138 Ionic Radius (+2)64 Electron Affinity 0.56 1st Ion. Pot. 8.34	47 Ag 107.9 Silver $[Kr]4d^{10}5s^1$ Oxidation States 1 Electroneg. 1.93 Atomic Radius 145 Ionic Radius (+1)115 Electron Affinity 1.30 1st Ion. Pot. 7.58	48 Cd 112.4 Cadmium $[Kr]4d^{10}5s^2$ Oxidation States 2 Electroneg. 1.69 Atomic Radius 149 Ionic Radius (+2)95 Electron Affinity Unstable Anion 1st Ion. Pot. 8.99	49 In 114.8 Indium $[Kr]4d^{10}5s^2p^1$ Oxidation States 3 Electroneg. 1.78 Atomic Radius 163 Ionic Radius (+3)80 Electron Affinity 0.30 1st Ion. Pot. 5.79	50 Sn 118.7 Tin $[Kr]4d^{10}5s^2p^2$ Oxidation States 4,2 Electroneg. 1.96 Atomic Radius 141 Ionic Radius (+4)45 Electron Affinity 1.11 1st Ion. Pot. 7.34	51 Sb 121.8 Antimony $[Kr]4d^{10}5s^2p^3$ Oxidation States ±3,5 Electroneg. 2.05 Atomic Radius 145 Ionic Radius (+3)76 Electron Affinity 1.07 1st Ion. Pot. 8.64	52 Te 127.6 Tellurium $[Kr]4d^{10}5s^2p^4$ Oxidation States ±2,4,6 Electroneg. 2.10 Atomic Radius 143 Ionic Radius (-2)221 Electron Affinity 1.97 1st Ion. Pot. 9.01	53 I 126.9 Iodine $[Kr]4d^{10}5s^2p^5$ Oxidation States ±1,5,7 Electroneg. 2.66 Atomic Radius 133 Ionic Radius (-1)220 Electron Affinity 3.06 1st Ion. Pot. 10.45	54 Xe 131.3 Xenon $[Kr]4d^{10}5s^2p^6$ Oxidation States – Electroneg. 2.60 Atomic Radius – Ionic Radius – Electron Affinity Unstable Anion 1st Ion. Pot. 12.13
55 Cs 132.9 Cesium $[Xe]6s^1$ Oxidation States 1 Electroneg. 0.79 Atomic Radius 265 Ionic Radius (+1)174 Electron Affinity 0.47 1st Ion. Pot. 3.89	56 Ba 137.3 Barium $[Xe]6s^2$ Oxidation States 2 Electroneg. 0.89 Atomic Radius 217 Ionic Radius (+2)142 Electron Affinity 0.15 1st Ion. Pot. 5.21	57 La 138.9 Lanthanum $[Xe]5d^16s^2$ Oxidation States 3 Electroneg. 1.10 Atomic Radius 187 Ionic Radius (+3)116 Electron Affinity 0.5 1st Ion. Pot. 5.77	72 Hf 178.5 Hafnium $[Xe]4f^{14}5d^26s^2$ Oxidation States 4 Electroneg. 1.3 Atomic Radius 156 Ionic Radius (+4)83 Electron Affinity ~0 1st Ion. Pot. 6.83	73 Ta 180.9 Tantalum $[Xe]4f^{14}5d^36s^2$ Oxidation States 5 Electroneg. 1.5 Atomic Radius 143 Ionic Radius (+5)64 Electron Affinity 0.32 1st Ion. Pot. 7.89	74 W 183.8 Tungsten $[Xe]4f^{14}5d^46s^2$ Oxidation States 6,5,4,3,2 Electroneg. 1.7 Atomic Radius 137 Ionic Radius (+6)60 Electron Affinity 0.86 1st Ion. Pot. 7.98	75 Re 186.2 Rhenium $[Xe]4f^{14}5d^56s^2$ Oxidation States 7,6,4,2,-1 Electroneg. 1.9 Atomic Radius 137 Ionic Radius (+7)53 Electron Affinity 0.15 1st Ion. Pot. 7.88	76 Os 190.2 Osmium $[Xe]4f^{14}5d^66s^2$ Oxidation States 2,3,4,6,8 Electroneg. 2.2 Atomic Radius 134 Ionic Radius (+4)63 Electron Affinity 1.10 1st Ion. Pot. 8.7	77 Ir 192.2 Iridium $[Xe]4f^{14}5d^76s^2$ Oxidation States 2,3,4,6 Electroneg. 2.2 Atomic Radius 136 Ionic Radius (+4)63 Electron Affinity 1.57 1st Ion. Pot. 9.1	78 Pt 195.1 Platinum $[Xe]4f^{14}5d^96s^1$ Oxidation States 2,4 Electroneg. 2.2 Atomic Radius 139 Ionic Radius (+4)63 Electron Affinity 2.13 1st Ion. Pot. 9.0	79 Au 197.0 Gold $[Xe]4f^{14}5d^{10}6s^1$ Oxidation States 3,1 Electroneg. 2.4 Atomic Radius 144 Ionic Radius (+3)85 Electron Affinity 2.31 1st Ion. Pot. 9.23	80 Hg 200.6 Mercury $[Xe]4f^{14}5d^{10}6s^2$ Oxidation States 2,1 Electroneg. 1.9 Atomic Radius 150 Ionic Radius (+2)102 Electron Affinity Unstable Anion 1st Ion. Pot. 10.44	81 Tl 204.4 Thallium $[Xe]4f^{14}5d^{10}6s^2p^1$ Oxidation States 3,1 Electroneg. 1.8 Atomic Radius 170 Ionic Radius (+1)159 Electron Affinity 0.2 1st Ion. Pot. 6.11	82 Pb 207.2 Lead $[Xe]4f^{14}5d^{10}6s^2p^2$ Oxidation States 4,2 Electroneg. 1.8 Atomic Radius 175 Ionic Radius (+2)119 Electron Affinity 0.36 1st Ion. Pot. 7.42	83 Bi 209.0 Bismuth $[Xe]4f^{14}5d^{10}6s^2p^3$ Oxidation States 3,5 Electroneg. 1.9 Atomic Radius 155 Ionic Radius (+3)103 Electron Affinity 0.95 1st Ion. Pot. 7.29	84 Po 209☢ Polonium $[Xe]4f^{14}5d^{10}6s^2p^4$ Oxidation States 4,2 Electroneg. 2.0 Atomic Radius 118 Ionic Radius (+4)– Electron Affinity 1.9 1st Ion. Pot. 8.42	85 At 210☢ Astatine $[Xe]4f^{14}5d^{10}6s^2p^5$ Oxidation States ±1,3,5,7 Electroneg. 2.2 Atomic Radius – Ionic Radius – Electron Affinity 2.8 1st Ion. Pot. -	86 Rn 222☢ Radon $[Xe]4f^{14}5d^{10}6s^2p^6$ Oxidation States – Electroneg. – Atomic Radius – Ionic Radius – Electron Affinity Unstable Anion 1st Ion. Pot. 10.75
87 Fr 223☢ Francium $[Rn]7s^1$ Oxidation States 1 Electroneg. 0.7 Atomic Radius – Ionic Radius – Electron Affinity 0.46 1st Ion. Pot. –	88 Ra 226☢ Radium $[Rn]7s^2$ Oxidation States 2 Electroneg. 0.9 Atomic Radius – Ionic Radius (+2)162 Electron Affinity – 1st Ion. Pot. 5.28	89 Ac 227☢ Actinium $[Rn]6d^17s^2$ Oxidation States 3 Electroneg. 1.1 Atomic Radius 188 Ionic Radius (+3) - Electron Affinity – 1st Ion. Pot. 5.17	104 Rf 261☢ Rutherfordium $[Rn]5f^{14}6d^27s^2$ disc.1964	105 Db 262☢ Dubnium $[Rn]5f^{14}6d^37s^2$ disc.1967	106 Sg 266☢ Seaborgium $[Rn]5f^{14}6d^47s^2$ disc.1974	107 Bh 264☢ Bohrium $[Rn]5f^{14}6d^57s^2$ disc.1981	108 Hs 269☢ Hassium $[Rn]5f^{14}6d^67s^2$ disc.1984	109 Mt 268☢ Meitnerium $[Rn]5f^{14}6d^77s^2$ disc.1982	110 Ds 281☢ Darmstadtium $[Rn]5f^{14}6d^97s^1$ Darmstats, Germany	111 Uuu 272☢ Unununium disc.1994 Darmstats, Germany	112 Uub 277☢ Ununbium disc.1996 Darmstats, Germany	113 Uut 284 Ununtrium disc.2004 Dubna, Russia	114 Uuq 289☢ Ununquadium disc.1999 Dubna, Russia	115 Uup 288 Ununpentium disc.2004 Dubna, Russia	116 ? ? Not discovered - -	117 ? ? Not discovered - -	118 ? ? Not discovered - -

ALKALI METALS

ALKALINE EARTH METALS

HALOGENS

NOBLE GASES

LANTHANIDE SERIES	58 Ce 140.1 Cerium $[Xe]4f^15d^16s^2$ Oxidation States 3,4 Electroneg. 1.12 Atomic Radius 183 Ionic Radius (+3)114 Electron Affinity – 1st Ion. Pot. 5.54	59 Pr 140.9 Praseodymium $[Xe]4f^36s^2$ Oxidation States 3,4 Electroneg. 1.13 Atomic Radius 182 Ionic Radius (+3)113 Electron Affinity – 1st Ion. Pot. 5.46	60 Nd 144.2 Neodymium $[Xe]4f^46s^2$ Oxidation States 3 Electroneg. 1.14 Atomic Radius 181 Ionic Radius (+3)114 Electron Affinity – 1st Ion. Pot. 5.53	61 Pm 145☢ Promethium $[Xe]4f^56s^2$ Oxidation States 3 Electroneg. – Atomic Radius 181 Ionic Radius (+3)109 Electron Affinity – 1st Ion. Pot. 5.55	62 Sm 150.4 Samarium $[Xe]4f^66s^2$ Oxidation States 3,2 Electroneg. 1.17 Atomic Radius 180 Ionic Radius (+3)108 Electron Affinity – 1st Ion. Pot. 5.64	63 Eu 152.0 Europium $[Xe]4f^76s^2$ Oxidation States 3,2 Electroneg. – Atomic Radius 199 Ionic Radius (+3)107 Electron Affinity – 1st Ion. Pot. 5.67	64 Gd 157.3 Gadolinium $[Xe]4f^75d^16s^2$ Oxidation States 3 Electroneg. 1.20 Atomic Radius 179 Ionic Radius (+3)105 Electron Affinity – 1st Ion. Pot. 6.15	65 Tb 158.9 Terbium $[Xe]4f^96s^2$ Oxidation States 3,4 Electroneg. – Atomic Radius 176 Ionic Radius (+3)118 Electron Affinity – 1st Ion. Pot. 5.86	66 Dy 162.5 Dysprosium $[Xe]4f^{10}6s^2$ Oxidation States 3 Electroneg. 1.22 Atomic Radius 175 Ionic Radius (+3)103 Electron Affinity – 1st Ion. Pot. 5.94	67 Ho 164.9 Holmium $[Xe]4f^{11}6s^2$ Oxidation States 3 Electroneg. 1.23 Atomic Radius 174 Ionic Radius – Electron Affinity – 1st Ion. Pot. 6.02	68 Er 167.3 Erbium $[Xe]4f^{12}6s^2$ Oxidation States 3 Electroneg. 1.24 Atomic Radius 173 Ionic Radius (+3)100 Electron Affinity – 1st Ion. Pot. 6.11	69 Tm 168.9 Thulium $[Xe]4f^{13}6s^2$ Oxidation States 3,2 Electroneg. 1.25 Atomic Radius 173 Ionic Radius (+3)109 Electron Affinity – 1st Ion. Pot. 6.18	70 Yb 173.0 Ytterbium $[Xe]4f^{14}6s^2$ Oxidation States 3,2 Electroneg. – Atomic Radius 194 Ionic Radius (+3)99 Electron Affinity – 1st Ion. Pot. 6.25	71 Lu 175.0 Lutetium $[Xe]4f^{14}5d^16s^2$ Oxidation States 3 Electroneg. 1.0 Atomic Radius 172 Ionic Radius (+3)98 Electron Affinity – 1st Ion. Pot. 5.43
ACTINIDE SERIES	90 Th 232.0 Thorium $[Rn]6d^27s^2$ Oxidation States 4 Electroneg. 1.3 Atomic Radius 180 Ionic Radius (+4)94 Electron Affinity – 1st Ion. Pot. 6.08	91 Pa 231.0 Protactinium $[Rn]5f^26d^17s^2$ Oxidation States 5,4 Electroneg. 1.5 Atomic Radius 161 Ionic Radius (+5)78 Electron Affinity – 1st Ion. Pot. 5.89	92 U 238.0 Uranium $[Rn]5f^36d^17s^2$ Oxidation States 6,5,4,3 Electroneg. 1.7 Atomic Radius 139 Ionic Radius (+6)73 Electron Affinity – 1st Ion. Pot. 6.19	93 Np 237☢ Neptunium $[Rn]5f^46d^17s^2$ Oxidation States 6,5,4,3 Electroneg. 1.3 Atomic Radius – Ionic Radius (+5)75 Electron Affinity – 1st Ion. Pot. 6.27	94 Pu 244☢ Plutonium $[Rn]5f^67s^2$ Oxidation States 6,5,4,3 Electroneg. 1.3 Atomic Radius 151 Ionic Radius (+4)86 Electron Affinity – 1st Ion. Pot. 6.06	95 Am 243☢ Americium $[Rn]5f^77s^2$ Oxidation States 6,5,4,3 Electroneg. – Atomic Radius 131 Ionic Radius (+3)98 Electron Affinity – 1st Ion. Pot. 5.99	96 Cm 247☢ Curium $[Rn]5f^76d^17s^2$ Oxidation States 3 Electroneg. – Atomic Radius – Ionic Radius (+3)97 Electron Affinity – 1st Ion. Pot. 6.02	97 Bk 247☢ Berkelium $[Rn]5f^97s^2$ Oxidation States 4,3 Electroneg. – Atomic Radius – Ionic Radius (+3)96 Electron Affinity – 1st Ion. Pot. 6.23	98 Cf 251☢ Californium $[Rn]5f^{10}7s^2$ Oxidation States 3 Electroneg. – Atomic Radius – Ionic Radius (+3)95 Electron Affinity – 1st Ion. Pot. 6.30	99 Es 252☢ Einsteinium $[Rn]5f^{11}7s^2$ Oxidation States 3 Electroneg. – Atomic Radius – Ionic Radius – Electron Affinity – 1st Ion. Pot. 6.42	100 Fm 257☢ Fermium $[Rn]5f^{12}7s^2$ Oxidation States 3 Electroneg. – Atomic Radius – Ionic Radius – Electron Affinity – 1st Ion. Pot. 6.50	101 Md 258☢ Mendelevium $[Rn]5f^{13}7s^2$ Oxidation States 3,2 Electroneg. – Atomic Radius – Ionic Radius – Electron Affinity – 1st Ion. Pot. 6.58	102 No 259☢ Nobelium $[Rn]5f^{14}7s^2$ Oxidation States 3,2 Electroneg. – Atomic Radius – Ionic Radius – Electron Affinity – 1st Ion. Pot. 6.65	103 Lr 262☢ Lawrencium $[Rn]5f^{14}6d^17s^2$ Oxidation States 3 Electroneg. – Atomic Radius – Ionic Radius – Electron Affinity – 1st Ion. Pot. –

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ISBN 142320003-9

9 781423 200031

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6 54614 00003 3

$4.95 U.S. / $7.50 CAN
REFERENCE: CRC Handbook of Chemistry and Physics • 81st edition, 2000-2001
CONTENT ADVISOR: Mark Jackson, PhD Chemistry Professor - Florida Atlantic University
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Customer Hotline # 1.800.230.9522
March 2005

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Physical Properties

NATURAL FORM

🟪 solid - for solid, most stable crystal form
🟦 liquid
⬜ gas

H_2 gas																	He gas
Li bcc	Be hex											B rhom	C hex	N_2 gas	O_2 gas	F_2 gas	Ne gas
Na bcc	Mg hex											Al fcc	Si fcc	P cubic	S ortho	Cl_2 gas	Ar gas
K bcc	Ca fcc	Sc hex	Ti hex	V bcc	Cr bcc	Mn bcc	Fe bcc	Co hex	Ni fcc	Cu fcc	Zn hex	Ga ortho	Ge fcc	As rhom	Se hex	Br_2 liquid	Kr gas
Rb bcc	Sr fcc	Y hex	Zr hex	Nb bcc	Mo bcc	Tc hex	Ru hex	Rh fcc	Pd fcc	Ag fcc	Cd hex	In tetra	Sn tetra	Sb rhom	Te hex	I_2 ortho	Xe gas
Cs bcc	Ba bcc	La hex	Hf hex	Ta bcc	W bcc	Re hex	Os hex	Ir fcc	Pt fcc	Au fcc	Hg liquid	Tl hex	Pb fcc	Bi rhom	Po cubic	At –	Rn gas
Fr –	Ra bcc	Ac fcc															
				Ce fcc	Pr hex	Nd hex	Pm hex	Sm rhom	Eu bcc	Gd hex	Tb hex	Dy hex	Ho hex	Er hex	Tm hex	Yb fcc	Lu hex
				Th fcc	Pa tetra	U ortho	Np ortho	Pu mono	Am hex	Cm hex	Bk hex	Cf hex	Es hex	Fm –	Md –	No –	Lr –

cubic = SIMPLE CUBIC, bcc = BODY CENTERED CUBIC fcc = FACE CENTERED CUBIC;
hex = HEXAGONAL; ortho = ORTHOHOMBIC; rhom = RHOMBOHEDRAL;
tetra = TETRAGONAL mono = MONOCLINIC; – = unknown

DENSITY

🟩 Solid, liquid: g/cm³ (20°C and 1atm)
⬜ gas: g/liter (0°C and 1atm)

H_2 .089*																	He *.179
Li 0.53	Be 1.85											B 2.34	C 2.26	N_2 *1.25	O_2 *1.43	F_2 *1.70	Ne *.90
Na 0.97	Mg 1.74											Al 2.70	Si 2.33	P 1.82	S 2.07	Cl_2 *3.21	Ar *1.78
K 0.89	Ca 1.54	Sc 2.99	Ti 4.51	V 6.0	Cr 7.15	Mn 7.3	Fe 7.87	Co 8.86	Ni 8.90	Cu 8.96	Zn 7.14	Ga 5.91	Ge 5.32	As 5.72	Se 4.80	Br_2 3.12	Kr *3.73
Rb 1.53	Sr 2.64	Y 4.47	Zr 6.52	Nb 8.57	Mo 10.2	Tc 11	Ru 12.1	Rh 12.4	Pd 12.0	Ag 10.5	Cd 8.69	In 7.31	Sn 7.26	Sb 6.68	Te 6.24	I_2 4.92	Xe *5.89
Cs 1.93	Ba 3.62	La 6.15	Hf 13.3	Ta 16.4	W 19.3	Re 20.8	Os 22.6	Ir 22.5	Pt 21.5	Au 19.3	Hg 13.53	Tl 11.8	Pb 11.3	Bi 9.79	Po 9.2	At –	Rn *9.73
Fr –	Ra 5.0	Ac 10.0															
				Ce 6.77	Pr 6.77	Nd 7.01	Pm 7.26	Sm 7.52	Eu 5.24	Gd 7.90	Tb 8.23	Dy 8.55	Ho 8.80	Er 9.07	Tm 9.32	Yb 6.90	Lu 9.84
				Th 11.7	Pa 15.4	U 19.1	Np 20.2	Pu 19.7	Am 13.6	Cm 13.5	Bk 14.8	Cf –	Es –	Fm –	Md –	No –	Lr –

ENTHALPY OF VAPORIZATION

kJ/mole
Liquid ➜ Gas ΔH$_{vap}$ at boiling point

References: CRC; The Elements, 3rd ed., J. Emsley, 1998

H_2 0.90																	He 0.08
Li 134.7	Be 308.8											B 480.0	C 711.0	N_2 5.57	O_2 6.82	F_2 6.62	Ne 1.71
Na 89.04	Mg 128.7											Al 294.0	Si 383.0	P 12.40	S 45.0	Cl_2 20.41	Ar 6.43
K 77.5	Ca 150.0	Sc 305.0	Ti 429.0	V 458.6	Cr 348.8	Mn 219.7	Fe 351.0	Co 382.4	Ni 371.8	Cu 304.6	Zn 115.5	Ga 254.0	Ge 334.0	As 31.9	Se 95.48	Br_2 29.96	Kr 9.08
Rb 69.2	Sr 139.0	Y 393.0	Zr 581.6	Nb 696.6	Mo 594.1	Tc 585.0	Ru 567.8	Rh 495.4	Pd 393.0	Ag 255.1	Cd 99.87	In 226.4	Sn 290.4	Sb 67.9	Te 114.1	I_2 41.57	Xe 12.57
Cs 65.9	Ba 140.0	La 399.6	Hf 661.1	Ta 753.1	W 799.1	Re 707.1	Os 627.6	Ir 563.6	Pt 510.5	Au 324.0	Hg 59.11	Tl 162.1	Pb 179.5	Bi 151.0	Po 101.0	At –	Rn 18.1
Fr –	Ra 136.8	Ac 418.0															
				Ce 314.0	Pr 333.0	Nd 284.0	Pm –	Sm 192.0	Eu 176.0	Gd 312.0	Tb 391.0	Dy 293.0	Ho 251.0	Er 293.0	Tm 247.0	Yb 159.0	Lu 428.0
				Th 543.9	Pa 481.0	U 423.0	Np 337.0	Pu 344.0	Am –	Cm 387.0	Bk 310.0	Cf 196.0	Es 133.0	Fm –	Md –	No –	Lr –

BOILING POINT

°C and 1atm; Liquid ↔ Gas
sp = sublimation point

H_2 -253																	He -269
Li 1342	Be 2471											B 4000	C 3825sp	N_2 -196	O_2 -183	F_2 -188	Ne -246
Na 883	Mg 1090											Al 2519	Si 3265	P 280	S 445	Cl_2 -34	Ar -186
K 759	Ca 1484	Sc 2836	Ti 3287	V 3407	Cr 2671	Mn 2061	Fe 2861	Co 2927	Ni 2913	Cu 2562	Zn 907	Ga 2204	Ge 2833	As 603sp	Se 685	Br_2 59	Kr -153
Rb 688	Sr 1382	Y 3345	Zr 4409	Nb 4744	Mo 4639	Tc 4265	Ru 4150	Rh 3695	Pd 2963	Ag 2162	Cd 767	In 2072	Sn 2602	Sb 1587	Te 988	I_2 184	Xe -108
Cs 671	Ba 1897	La 3464	Hf 4603	Ta 5458	W 5555	Re 5596	Os 5012	Ir 4428	Pt 3825	Au 2856	Hg 357	Tl 1473	Pb 1749	Bi 1564	Po 962	At –	Rn -62
Fr –	Ra –	Ac 3198															
				Ce 3443	Pr 3520	Nd 3074	Pm 3000	Sm 1794	Eu 1529	Gd 3273	Tb 3230	Dy 2567	Ho 2700	Er 2868	Tm 1950	Yb 1196	Lu 3402
				Th 4788	Pa –	U 4131	Np –	Pu 3228	Am 2011	Cm 3100	Bk –	Cf –	Es –	Fm –	Md –	No –	Lr –

ENTHALPY OF FUSION

kJ/mole
Solid ➜ Liquid ΔH$_{fus}$ at Melting point

H_2 0.12																	He –
Li 3.00	Be 7.9											B 50.2	C 117	N_2 0.71	O_2 0.44	F_2 0.51	Ne 0.33
Na 2.60	Mg 8.48											Al 10.71	Si 50.21	P 0.66	S 1.72	Cl_2 6.4	Ar 1.18
K 2.33	Ca 8.54	Sc 14.10	Ti 14.15	V 21.5	Cr 21.0	Mn 12.91	Fe 13.81	Co 16.2	Ni 17.48	Cu 13.26	Zn 7.32	Ga 5.59	Ge 36.94	As 24.44	Se 6.69	Br_2 10.57	Kr 1.64
Rb 2.19	Sr 7.43	Y 11.4	Zr 21.0	Nb 30.0	Mo 37.48	Tc 33.29	Ru 38.59	Rh 26.59	Pd 16.74	Ag 11.30	Cd 6.19	In 3.28	Sn 7.03	Sb 19.87	Te 17.49	I_2 15.52	Xe 2.27
Cs 2.09	Ba 7.12	La 6.20	Hf 27.2	Ta 36.57	W 52.31	Re 60.43	Os 57.85	Ir 41.12	Pt 22.17	Au 12.55	Hg 2.29	Tl 4.14	Pb 4.77	Bi 11.3	Po –	At –	Rn 2.89
Fr –	Ra 7.15	Ac 14.2															
				Ce 5.46	Pr 6.89	Nd 7.14	Pm 7.7	Sm 8.62	Eu 9.21	Gd 10.0	Tb 10.15	Dy 11.06	Ho 17.0	Er 19.9	Tm 16.84	Yb 7.66	Lu 22.0
				Th 13.81	Pa 12.34	U 9.14	Np 3.20	Pu 2.82	Am 14.39	Cm 15.0	Bk –	Cf –	Es –	Fm –	Md –	No –	Lr –

MELTING POINT

°C and 1atm; Solid ↔ Liquid
tp = triple point

H_2 -259																	He –
Li 181	Be 1287											B 2075	C 4492tp	N_2 -210	O_2 -219	F_2 -220tp	Ne -249
Na 98	Mg 650											Al 660	Si 1414	P 44	S 120	Cl_2 -102	Ar -189
K 64	Ca 842	Sc 1541	Ti 1668	V 1910	Cr 1907	Mn 1246	Fe 1538	Co 1495	Ni 1455	Cu 1085	Zn 420	Ga 30	Ge 939	As 817tp	Se 221	Br_2 -7	Kr -157tp
Rb 39	Sr 777	Y 1522	Zr 1855	Nb 2477	Mo 2623	Tc 2157	Ru 2334	Rh 1964	Pd 1555	Ag 962	Cd 321	In 157	Sn 232	Sb 631	Te 450	I_2 114	Xe -112tp
Cs 28	Ba 727	La 918	Hf 2233	Ta 3017	W 3422	Re 3186	Os 3033	Ir 2446	Pt 1768	Au 1064	Hg -39	Tl 304	Pb 328	Bi 271	Po 254	At 302	Rn -71
Fr 27	Ra 700	Ac 1051															
				Ce 798	Pr 931	Nd 1021	Pm 1042	Sm 1074	Eu 822	Gd 1313	Tb 1356	Dy 1412	Ho 1474	Er 1529	Tm 1545	Yb 819	Lu 1663
				Th 1750	Pa 1572	U 1135	Np 644	Pu 640	Am 1176	Cm 1345	Bk 1050	Cf 900	Es 860	Fm 1527	Md 827	No 827	Lr 1627

SPECIFIC HEAT CAPACITY

J/(g K) (at 25°C and 1atm)

H_2 14.30																	He 5.19
Li 3.58	Be 1.83											B 1.03	C 0.71	N_2 1.04	O_2 0.92	F_2 0.82	Ne 1.03
Na 1.23	Mg 1.02											Al 0.90	Si 0.71	P 0.77	S 0.71	Cl_2 0.48	Ar 0.52
K 0.76	Ca 0.65	Sc 0.57	Ti 0.52	V 0.49	Cr 0.45	Mn 0.48	Fe 0.45	Co 0.42	Ni 0.44	Cu 0.39	Zn 0.39	Ga 0.37	Ge 0.32	As 0.33	Se 0.32	Br_2 0.23	Kr 0.25
Rb 0.36	Sr 0.30	Y 0.30	Zr 0.28	Nb 0.27	Mo 0.25	Tc –	Ru 0.24	Rh 0.24	Pd 0.25	Ag 0.24	Cd 0.23	In 0.23	Sn 0.23	Sb 0.21	Te 0.20	I_2 0.15	Xe 0.16
Cs 0.24	Ba 0.20	La 0.20	Hf 0.14	Ta 0.14	W 0.13	Re 0.14	Os 0.13	Ir 0.13	Pt 0.13	Au 0.13	Hg 0.14	Tl 0.13	Pb 0.13	Bi 0.12	Po –	At –	Rn 0.09
Fr –	Ra –	Ac 0.12															
				Ce 0.19	Pr 0.19	Nd 0.19	Pm –	Sm 0.20	Eu 0.18	Gd 0.24	Tb 0.18	Dy 0.17	Ho 0.17	Er 0.17	Tm 0.16	Yb 0.16	Lu 0.15
				Th 0.11	Pa –	U 0.12	Np –	Pu –	Am –	Cm –	Bk –	Cf –	Es –	Fm –	Md –	No –	Lr –

THERMAL CONDUCTIVITY

W/(cm K) (at 25°C and 1atm, W = watt)

H_2 0.002																	He 0.002
Li 0.85	Be 2.00											B 0.27	C 1.96	N_2 <0.001	O_2 0.003	F_2 <0.001	Ne <0.001
Na 1.41	Mg 1.56											Al 2.37	Si 1.49	P 0.002	S 0.003	Cl_2 <0.001	Ar <0.001
K 1.03	Ca 2.01	Sc 0.16	Ti 0.22	V 0.31	Cr 0.94	Mn 0.08	Fe 0.80	Co 1.00	Ni 0.91	Cu 4.01	Zn 1.16	Ga 0.41	Ge 0.60	As 0.50	Se 0.02	Br_2 0.001	Kr <0.001
Rb 0.58	Sr 0.35	Y 0.17	Zr 0.23	Nb 0.54	Mo 1.38	Tc 0.51	Ru 1.17	Rh 1.50	Pd 0.72	Ag 4.29	Cd 0.97	In 0.82	Sn 0.67	Sb 0.24	Te 0.03	I_2 0.004	Xe <0.001
Cs 0.36	Ba 0.18	La 0.13	Hf 0.23	Ta 0.58	W 1.74	Re 0.48	Os 0.88	Ir 1.47	Pt 0.72	Au 3.17	Hg 0.08	Tl 0.46	Pb 0.35	Bi 0.08	Po 0.20	At 0.02	Rn <0.001
Fr –	Ra –	Ac –															
				Ce 0.11	Pr 0.13	Nd 0.17	Pm 0.15	Sm 0.13	Eu 0.14	Gd 0.10	Tb 0.11	Dy 0.11	Ho 0.16	Er 0.15	Tm 0.17	Yb 0.39	Lu 0.16
				Th 0.54	Pa –	U 0.28	Np 0.06	Pu 0.07	Am –	Cm –	Bk –	Cf –	Es –	Fm –	Md –	No –	Lr –

ELEMENTAL ABUNDANCE IN THE EARTH'S CRUST

1. Oxygen
2. Silicon
3. Aluminum
4. Iron
5. Calcium
6. Sodium
7. Magnesium
8. Potassium
9. Titanium
10. Hydrogen

mg of element per kg of crust

H 1400																	He 0.008
Li 20	Be 2.8											B 10	C 200	N 19	O 461000	F 585	Ne 0.005
Na 23600	Mg 23300											Al 82300	Si 282000	P 1050	S 350	Cl 145	Ar 3.5
K 20900	Ca 41500	Sc 22	Ti 5650	V 120	Cr 102	Mn 950	Fe 56300	Co 25	Ni 84	Cu 60	Zn 70	Ga 19	Ge 1.5	As 1.8	Se 0.05	Br 2.4	Kr <0.001
Rb 90	Sr 370	Y 33	Zr 165	Nb 20	Mo 1.2	Tc synthetic	Ru 0.001	Rh 0.001	Pd 0.015	Ag 0.075	Cd 0.15	In 0.25	Sn 2.3	Sb 0.2	Te 0.001	I 0.45	Xe <0.001
Cs 3	Ba 425	La 39	Hf 3	Ta 2	W 1.3	Re <0.001	Os 0.002	Ir 0.001	Pt 0.005	Au 0.004	Hg 0.085	Tl 0.85	Pb 14	Bi 0.009	Po <0.001	At <0.001	Rn <0.001
Fr <0.001	Ra <0.001	Ac <0.001															
				Ce 66.5	Pr 9.2	Nd 41.5	Pm <0.001	Sm 7.05	Eu 2.0	Gd 6.2	Tb 1.2	Dy 5.2	Ho 1.3	Er 3.5	Tm 0.52	Yb 3.2	Lu 0.8
				Th 9.6	Pa <0.001	U 2.7	Np synthetic	Pu synthetic	Am synthetic	Cm synthetic	Bk synthetic	Cf synthetic	Es synthetic	Fm synthetic	Md synthetic	No synthetic	Lr synthetic

QuickStudy

Chemical Properties & Common Uses

M = Generic symbol for element in compound; E = Element raw material form; A = Alloy, blend or mixture; C = Compound; **Bold = Most Important Use**

1 Alkali metals; compounds with M(1+) valences

Cs Cesium
E - Photoelectric cells
E - Atomic clocks, infrared lamps

Rb Rubidium
E - Photoelectric cells
E - Vacuum tubes, heart research

K Potassium
C - Fertilizer, glass, lenses
C - Matches, gunpowder, salt substitute

Na Sodium
E - Street lights A - Nuclear reactor coolant, batteries C - Salt, soda, glass

Li Lithium
E - **Pacemaker Batteries**
A - Lubricant additive, alloys used in space
C - Glass & pharmaceuticals

H Hydrogen H_2
H(1+) **compounds,**
acids: metal hydrides H(1-)
E - Rocket fuel, hydrogenation of fats
E - Petroleum desulfurization, H_2O, ammonia

2 Alkaline earth metals; compounds with M(2+) valences

Ba Barium
A - Sparkplugs, vacuum tubes
C - Fireworks, flourescent lamps

Sr Strontium
C - Nuclear batteries in bouys
V - Fireworks, phosphorescent paint

Ca Calcium
E - Metallurgy A-Cable insulation, batteries
C - Fertilizer, concrete, plaster of Paris

Mg Magnesium
E - Flashbulbs A-Airplanes, racing bikes
C - Fireplace bricks, pigments, fillers

Be Beryllium
E - X-ray tube windows
A - Watch springs, sparkfree tools

3 Metal; compounds and ligand complexes M(3+)

$_2$**La** Lanthanum

Y Yttrium
C - Color TV screens, radar, lasers
C - Camera lenses, fireproof bricks

Sc Scandium
E - Leak detectors, A - Space industry materials C - Seed germinating agents

4 Metal; compounds: M(2+...4+); ligand complexes: M(1-,0,1+)

Hf Hafnium
E - Nuclear submarines
E - Controls nuclear reactors
E - Gas scavenger in vacuum tubes

Zr Zirconium
E - Nuclear fuel rods, catalytic converters
A - Percussion caps
C - Furnace bricks

Ti Titanium titanate TiO_4(4-)
metatitanate TiO_3(2-)
E - Heat exchanger A - Airplane motors
A - Bone pins C - Pigments for paint/paper

5 Metal; compounds: M(2+...5+); ligand complexes: M(1-,0,1+)

Ta Tantalum
E - Condensers
A - **Weights**, cutting tools
E - Vacuum tube filaments

Nb Niobium
A - Cutting tools, pipelines
A - Super magnets, welding rods

V Vanadium
vanadate VO_4(3-)
E - Construction materials, tools
E - Springs, jet engines

6 Metal; compounds: M(2+...6+); ligand complexes: M(2-...1+)

W Tungsten
tungstate WO_4(2-)
E - **Lamp filaments**, TV, welding electrodes
A - Rocket nozzles
C - Cutting & boring tools

Mo Molybdenum
molybdate MoO_3, MoO_4(2-)
dimolybdate Mo_2O_7(2-)
Mo-cyanate Mo-CN_8(4-)
E - **Filament in electric heaters**
A - Rocket motors C - Lubricant

Cr Chromium
chromate CrO_4(2-)
dichromate Cr_2O_7(2-)
E - **Plating for car parts**
A - Tools, knives C - Camouflage paint
C - Stereo, video tape, lasers

7 Metal; compounds: M(1+...7+); ligand complexes: M(3-...1+)

Re Rhenium
tungstate WO_4(2-)
A - Oven filaments, electrodes, jewelry
A - Plating, thermocouples

Tc Technetium ☢
synthetic
E - Radiation source for medical research

Mn Manganese
permanganate MnO_4(1-)
A - Tools, axles, steel for rail switches
C - Safes, plows, batteries

8 Metal; compounds: M(1+...8+); ligand complexes: M(2-...1+)

Os Osmium
A - Fountain pen points, compass needles, clock bearings, decorations

Ru Ruthenium
E - Eye treatment, thickness meters for egg shells
A - Fountain pen point, electrical contacts

Fe Iron
Fe-cyanate $Fe(CN)_6$(3-and4-)
ferrate FeO_4(2-)
A - Bikes,cars, bridges, magnets, machines
C - Nails, tools, tin cans

9 Metal; compounds: M(2+...6+); ligand complexes: M(2-...1+)

Ir Iridium
E - Cancer irradiation
A - Hypodermic needles, helicopter spark plugs, standard one-meter bar

Rh Rhodium
rhenate ReO_4(1-)
E - **Headlight reflectors**, telephone
E - Relays, fountain pen points
A - Airplane spark plugs

Co Cobalt
cobaltate CoO_4(4- 3-)
Co-cyanate Co(CN)6 (3- and 4-)
E -Gamma radiation A-Permanent magnet
A - **Razor blades** C - Catalytic converter

10 Metal; compounds: M(1+...6+); ligand complexes: M(1-,0,1+)

Pt Platinum
E - Crucibles, nitric acid production
A - Dental crowns C - Anti-tumor agent

Pd Palladium
E - Catalytic converters, hydrogen seperation A - Dental crowns, tel. relays

Ni Nickel
E - Coins A-Knives, forks, spoons
E - White gold C-Rechargeable batteries

11 Metal; compounds: M(1+...3+); ligand complexes: M(1-,0,1+)

Au Gold
E - Precious metal A - Jewelry
A - Electrical contacts, dental crowns

Ag Silver
E - Mirror, batteries; A - Silverware
C - Photograph film and paper

Cu Copper
E - Cable, wire A - Pennies, bells
A - Bronze sculpture, Statue of Liberty

12 Metal; compounds and ligand complexes: M(2+)

Hg Mercury Hg_2(2+)
E - Barometers, thermometers, street lights A -Dental fillings C -Seed protection

Cd Cadmium
E -Rechargeable batteries A-Nuclear reactor regulator C -Red/yellow pigments

Zn Zinc
E - Anti-corrosion coating, batteries
A-Water/gas valves C -White rubber pigment

13 Metal; compounds and ligand complexes: M(1+...3+)

Tl Thallium
E - Thermometer filling
C - Insecticides, infrared detectors
C - Heart muscle research

In Indium
E - Solar cells, mirrors
A - Regulator in nuclear power
C - Photo cells, transistors
C - Blood and lung research

Ga Gallium
E - Quartz thermometers
C - Computer memory, transistors laser
C - Laser diodes, used to locate tumors

Al Aluminum
E - Window frames, doorknobs, tube
E - Cable, foil, fireworks, flashbulbs
A - Cars, rockets, planes

B Boron metalloid
B(2+,3+,3-)
compounds: borates (BO_4, BO_3)
tetraborates B_4O_7(2-), boranes, borides
C - Tennis rackets, regulator in nuclear plants, heat resistant glass, eye disinfectant

14 Metal; compounds and ligand complexes: M(2+,4+)

Pb Lead metal
E - Radiation protection
A - Batteries, roof coverings, solders
A - Ammunition C - Gas additives

Sn Tin metal
hydroxy stannate $Sn(OH)_6$(-2)
A - Cups, plates, coins, organ pipes
C - Opalescent glass, enamel

Ge Germanium metalloid
germanate GeO_2(2-) GeO_3(2-)
E - Infrared prisms, reflector in projectors
E - Wide angle lenses A - Dentistry

Si Silicon metalloid
silicates SiO_4(-4) silanes (Si-hydrides) Si(4-) silicides silicic acid H_4SiO_4
E - Microchips, solar cells C - Tools
C - Quartz, cement, glass, grease, oils

C Carbon
C(2+,4+,4-) carbonate CO_3(2-)
bicarbonate HCO_3(1-), acetate $C_2H_3O_2$(1-)
oxalate C_2O_4(2-), carbides (4-)
E - Pencils, diamonds, steel, controls nuclear reaction
E - Tire colorant
C - Plastics, life

15 Solid; compounds: M(3+,5+,3-)

Bi Bismuth
E - Catalyst in rubber production
A - Fuses, sprinklers
C - Glass, ceramics

Sb Antimony
A - Solder, bearings, lead batteries
C - Mascara, infrared detectors

As Arsenic
arsenide (3-)
E - Shotgun pellets
A - Metal for mirrors
C - Glass, lasers
C - Light-emmiting diodes=LED

P Phosphorus
phosphide (3-)
phosphate (PO_4(-3)
phosphoric acid H_3PO_4
E - Fireworks, matches C - Pesticides
C - Fertilizer, detergents, toothpaste

N Nitrogen N_2 gas
N(3-...5+); ammonium NH_4(1+)
cyanide CN(1-) nitrate NO_3(1-)
nitrite NO_2(1-) nitride N(3-) oxides - NOx
azide N_3(1-) diimide N_2(2-) amide NH_2(1-)
acid: nitric HNO_3 nitrous HNO_2
E - Cryogenic surgery, liquid coolant, ammonia production
C - Rocket fuel

16 Solid; compounds: M(2+,4+,6+,2-)

Po Polonium ☢ metal
E - **Nuclear batteries**, neutron source
E - Antistatic agents, film cleaner

Te Tellurium metalloid
tellurate TeO_4(2-)
E - **Vulcanization of rubber**, percussion caps, battery plate protector
A - Electric resistors

Se Selenium
Selenides Se(2-)
selenate SeO_4(2)
acids of SeOx
E - **Light meters**, copy machines, solar cells
C - Anti-dandruff shampoo

S Sulfur solid
sulfide S(2-) sulfate SO_4(2-) sulfite SO_3(2-)
thiosulfate S_2O_3(2-) thio...(S added or subst. for an O)
acids: sulfuric H_2SO_4, sulfurous H_2SO_3
E - Matches, fireworks, batteries, vulcanization of rubber
C - **Permanent wave lotion**

O Oxygen o(2-,1-) O_2 gas
ozone O_3 oxide (2-)
peroxide O_2(2-)
hydroxide OH(1-)
E - Combustion, steel production
E - Water purification
C - Sand, water, cement

17 Halogens, X2, compounds: M(1-), Halide (1-), Acid=HX

At Astinate ☢ metalloid
E, A, C - Seldom found in nature

I Iodine I_2 solid
acid: HI, iodide(1-)
iodate IO_3(1-)
periodate IO_4(1-)
E - Disinfectant, halogen lamps
C - Ink pigments, salt additive

Br Bromine Br_2 liquid
acid: HBr
bromides Br(1-)
bromate BrO_3(1-)
C - Photographic film, tear gas
C - fire retardants, disinfectant

Cl Chlorine Cl_2 gas
chloride Cl(1-) chlorate ClO_3(1-)
chlorite ClO2(1-) hypochlorite ClO(1-)
perchlorate ClO4(1-) acid: hydrochloric HCl,
perchloric $HClO_4$, chloric $HClO_3$
E - Water purification
C - Bleach, hydrochloric acid, PVC plastics, stain removers

F Fluorine F_2 gas
fluoride(1-) acid: HF
hydrofluoric, oxyfluorides-halofluorides
C - Toothpaste additives, teflon
C - Uranium enrichment
C - Refrigerator coolants

18 Noble Gases; not reactive; unstable low temperature complexes

Rn Radon ☢
E- Earthquake prediction, health threat in homes built on granite

Xe Xenon Forms compounds with F
E - UV lamps, sun lamps, electronic flashes, projection lamps, paint testers

Kr Krypton
E - **Flourescent bulbs**, flashbulbs
E - UV lasers, wavelength standard

Ar Argon
E - Light bulbs, gas discharge tubes lasers
E - Geiger counters, welding blanket gas

Ne Neon
E - Neon lights, fog lamps, TV tubes
E - Lasers, voltage detectors

He Helium
E - Balloons, blimps, lasers
E - Diving bell atmosphere, leak detectors
E - Nuclear power plant coolant

MAJOR NATURAL ISOTOPES WITH % OF OCCURRENCE

Isotopes have the same number of protons, but different numbers of neutrons.
Isotopes not listed are radioactive or synthetic.

H
1 - 99.98%
2 - 0.02%

He
4 - ~100%

Li
6 - 7.5%
7 - 92.5%

Be
9 - 100%

B
10 - 19.9%
11 - 80.1%

C
12 - 98.9%
13 - 1.1%

N
14 - 99.63%
15 - 0.37%

O
16 - 99.8%
18 - 0.2%

F
19 - 100%

Ne
20 - 90.5%
21 - 0.3%
22 - 9.3%

Na
23 - 100%

Mg
24 - 79.0%
25 - 10.0%
26 - 11.0%

Al
27 - 100%

Si
28 - 92.2%
29 - 4.7%
30 - 3.1%

P
31 - 100%

S
32 - 95.0%
33 - 0.8%
34 - 4.2%

Cl
35 - 75.8%
37 - 24.2%

Ar
36 - 0.3%
40 - 99.6%

K
39 - 93.3%
41 - 6.7%

Ca
40 - 96.9%
42 - 0.7%
44 - 2.1%

Sc
45 - 100%

Ti
46 - 8.0%
47 - 7.3%
48 - 73.8%
49 - 5.5%
50 - 5.4%

V
50 - 0.3%
51 - 99.7%

Cr
50 - 4.4%
52 - 83.8%
53 - 9.5%
54 - 2.4%

Mn
55 - 100%

Fe
54 - 5.9%
56 - 91.7%
57 - 2.1%

Co
59 - 100%

Ni
58 - 68.1%
60 - 26.2%
61 - 1.1%
62 - 3.6%
64 - 0.9%

Cu
63 - 69.2%
65 - 30.8%

Zn
64 - 48.6%
66 - 27.9%
67 - 4.1%
68 - 18.8%

Ga
69 - 60.1%
71 - 39.9%

Ge
70 - 21.2%
72 - 27.7%
73 - 7.7%
74 - 35.9%
78 - 7.4%

As
75 - 100%

Se
74 - 0.9%
76 - 9.4%
77 - 7.6%
78 - 23.8%
80 - 49.6%
82 - 8.7%

Br
79 - 50.7%
81 - 49.3%

Kr
80 - 2.3%
82 - 11.6%
83 - 11.5%
84 - 57.0%
86 - 17.3%

Rb
85 - 72.2%
87 - 27.8%

Sr
86 - 9.9%
87 - 7.0%
88 - 82.6%

Y
89 - 100%

Zr
90 - 51.5%
91 - 11.2%
92 - 17.2%
94 - 17.4%
96 - 2.8%

Nb
93 - 100%

Mo
92 - 14.8%
94 - 9.3%
95 - 15.9%
96 - 16.7%
97 - 9.6%
98 - 24.1%
100 - 9.6%

Tc ☢
93 - synthetic

Ru
96 - 5.5%
98 - 1.9%
99 - 12.7%
100 - 12.6%
101 - 17.1%
102 - 31.6%
104 - 18.6%

Rh
103 - 100%

Pd
102 - 1.02%
104 - 11.1%
105 - 22.3%
106 - 27.3%
108 - 26.5%
110 - 11.7%

Ag
107 - 51.8%
109 - 48.2%

Cd
106 - 0.9%
108 - 0.9%
110 - 12.5%
111 - 12.8%
112 - 24.1%
113 - 12.2%
114 - 28.7%
116 - 7.5%

In
113 - 4.3%
115 - 95.7%

Sn
112 - 1.0%
116 - 14.5%
117 - 7.7%
118 - 24.2%
119 - 8.6%
120 - 32.6%
122 - 4.6%
124 - 5.8%

Sb
121 - 57.4%
123 - 42.6%

Te
122 - 2.6%
123 - 0.9%
124 - 4.8%
125 - 7.1%
126 - 18.9%
128 - 31.7%
130 - 33.9%

I
127 - 100%

Xe
128 - 1.9%
129 - 26.4%
130 - 4.1%
131 - 21.2%
132 - 26.9%
134 - 10.4%
136 - 8.9%

Cs
133 - 100%

Ba
134 - 2.4%
135 - 6.6%
136 - 7.9%
137 - 11.2%
138 - 71.7%

La
138 - 0.1%
139 - 99.9%

Ce
140 - 88.4%
142 - 11.1%

Pr
141 - 100%

Nd
142 - 27.1%
143 - 12.2%
144 - 23.8%
145 - 8.3%
146 - 17.2%
148 - 5.8%
150 - 5.6%

Pm ☢
145 - synthetic

Sm
144 - 3.1%
147 - 15.0%
148 - 11.3%
149 - 13.8%
150 - 7.4%
152 - 26.7%
154 - 22.7%

Eu
151 - 47.8%
153 - 52.2%

Gd
154 - 2.2%
155 - 14.8%
156 - 20.5%
157 - 15.7%
158 - 24.8%
160 - 21.9%

Tb
159 - 100%

Dy
160 - 2.3%
161 - 18.9%
162 - 25.5%
163 - 24.9%
164 - 28.2%

Ho
165 - 100%

Er
164 - 1.6%
166 - 33.6%
167 - 23.0%
168 - 26.8%
170 - 14.9%

Tm
169 - 100%

Yb
170 - 3.1%
171 - 14.3%
172 - 21.9%
173 - 16.1%
174 - 31.8%
176 - 12.7%

Lu
175 - 97.4%
176 - 2.6%

Hf
176 - 5.2%
177 - 18.6%
178 - 27.3%
179 - 13.6%
180 - 35.1%

Ta
180 - 0.01%
181 - 99.99%

W
182 - 26.3%
183 - 14.3%
184 - 30.7%
186 - 28.6%

Re
185 - 37.4%
187 - 62.6%

Os
186 - 1.6%
187 - 1.6%
188 - 13.3%
189 - 16.1%
190 - 26.4%
192 - 41.0%

Ir
191 - 37.3%
193 - 62.7%

Pt
194 - 32.9%
195 - 33.8%
196 - 25.3%
198 - 7.2%

Au
197 - 100%

Hg
198 - 10.0%
199 - 16.9%
200 - 23.1%
201 - 13.2%
202 - 29.9%
204 - 6.9%

Tl
203 - 29.5%
205 - 70.5%

Pb
204 - 1.4%
206 - 24.1%
207 - 22.1%
208 - 52.4%

Bi
209 - 100%

Po ☢
209 - 100%

At ☢
210 - 100%

Rn ☢
222 - 100%

Fr ☢
223 - 100%

Ra ☢
226 - 100%

Ac ☢
227 - 100%

Th ☢
232 - 100%

Pa ☢
231 - 100%

U ☢
235 - 0.7%
238 - 99.3%

Elements > #92 are synthetic and radioactive