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 = 1×10^{-12}m
- ***Ionic Radius:*** given in "pm"; 1 pm = 1×10^{-12}m
- ***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"

Group 1	Group 2	Group 3	Group 4	Group 5	Group 6	Group 7	Group 8	Group 9	Group 10	Group 11	Group 12	Group 13	Group 14	Group 15	Group 16	Group 17	Group 18
1 H 1.008 Hydrogen $1s^1$																	2 He 4.003 Helium $1s^2$
3 Li 6.94 Lithium $1s^2 2s^1$	4 Be 9.01 Beryllium $1s^2 2s^2$											5 B 10.81 Boron $1s^2 2s^2 p^1$	6 C 12.01 Carbon $1s^2 2s^2 p^2$	7 N 14.01 Nitrogen $1s^2 2s^2 p^3$	8 O 16.00 Oxygen $1s^2 2s^2 p^4$	9 F 19.00 Fluorine $1s^2 2s^2 p^5$	10 Ne 20.18 Neon $1s^2 2s^2 p^6$
11 Na 22.99 Sodium [Ne]$3s^1$	12 Mg 24.31 Magnesium [Ne]$3s^2$											13 Al 26.98 Aluminum [Ne]$3s^2 p^1$	14 Si 28.09 Silicon [Ne]$3s^2 p^2$	15 P 30.97 Phosphorus [Ne]$3s^2 p^3$	16 S 32.07 Sulfur [Ne]$3s^2 p^4$	17 Cl 35.45 Chlorine [Ne]$3s^2 p^5$	18 Ar 39.95 Argon [Ne]$3s^2 p^6$
19 K 39.10 Potassium [Ar]$4s^1$	20 Ca 40.08 Calcium [Ar]$4s^2$	21 Sc 44.96 Scandium [Ar]$3d^1 4s^2$	22 Ti 47.87 Titanium [Ar]$3d^2 4s^2$	23 V 50.94 Vanadium [Ar]$3d^3 4s^2$	24 Cr 52.00 Chromium [Ar]$3d^5 4s^1$	25 Mn 54.94 Manganese [Ar]$3d^5 4s^2$	26 Fe 55.85 Iron [Ar]$3d^6 4s^2$	27 Co 58.93 Cobalt [Ar]$3d^7 4s^2$	28 Ni 58.69 Nickel [Ar]$3d^8 4s^2$	29 Cu 63.55 Copper [Ar]$3d^{10} 4s^1$	30 Zn 65.39 Zinc [Ar]$3d^{10} 4s^2$	31 Ga 69.72 Gallium [Ar]$3d^{10} 4s^2 p^1$	32 Ge 72.61 Germanium [Ar]$3d^{10} 4s^2 p^2$	33 As 74.92 Arsenic [Ar]$3d^{10} 4s^2 p^3$	34 Se 78.96 Selenium [Ar]$3d^{10} 4s^2 p^4$	35 Br 79.90 Bromine [Ar]$3d^{10} 4s^2 p^5$	36 Kr 83.80 Krypton [Ar]$3d^{10} 4s^2 p^6$
37 Rb 85.47 Rubidium [Kr]$5s^1$	38 Sr 87.62 Strontium [Kr]$5s^2$	39 Y 88.91 Yttrium [Kr]$4d^1 5s^2$	40 Zr 91.22 Zirconium [Kr]$4d^2 5s^2$	41 Nb 92.91 Niobium [Kr]$4d^4 5s^1$	42 Mo 95.94 Molybdenum [Kr]$4d^5 5s^1$	43 Tc 98∴ Technetium [Kr]$4d^5 5s^2$	44 Ru 101.1 Ruthenium [Kr]$4d^7 5s^1$	45 Rh 102.9 Rhodium [Kr]$4d^8 5s^1$	46 Pd 106.4 Palladium [Kr]$4d^{10}$	47 Ag 107.9 Silver [Kr]$4d^{10} 5s^1$	48 Cd 112.4 Cadmium [Kr]$4d^{10} 5s^2$	49 In 114.8 Indium [Kr]$4d^{10} 5s^2 p^1$	50 Sn 118.7 Tin [Kr]$4d^{10} 5s^2 p^2$	51 Sb 121.8 Antimony [Kr]$4d^{10} 5s^2 p^3$	52 Te 127.6 Tellurium [Kr]$4d^{10} 5s^2 p^4$	53 I 126.9 Iodine [Kr]$4d^{10} 5s^2 p^5$	54 Xe 131.3 Xenon [Kr]$4d^{10} 5s^2 p^6$
55 Cs 132.9 Cesium [Xe]$6s^1$	56 Ba 137.3 Barium [Xe]$6s^2$	57 La 138.9 Lanthanum [Xe]$5d^1 6s^2$	72 Hf 178.5 Hafnium [Xe]$4f^{14} 5d^2 6s^2$	73 Ta 180.9 Tantalum [Xe]$4f^{14} 5d^3 6s^2$	74 W 183.8 Tungsten [Xe]$4f^{14} 5d^4 6s^2$	75 Re 186.2 Rhenium [Xe]$4f^{14} 5d^5 6s^2$	76 Os 190.2 Osmium [Xe]$4f^{14} 5d^6 6s^2$	77 Ir 192.2 Iridium [Xe]$4f^{14} 5d^7 6s^2$	78 Pt 195.1 Platinum [Xe]$4f^{14} 5d^9 6s^1$	79 Au 197.0 Gold [Xe]$4f^{14} 5d^{10} 6s^1$	80 Hg 200.6 Mercury [Xe]$4f^{14} 5d^{10} 6s^2$	81 Tl 204.4 Thallium [Xe]$4f^{14} 5d^{10} 6s^2 p^1$	82 Pb 207.2 Lead [Xe]$4f^{14} 5d^{10} 6s^2 p^2$	83 Bi 209.0 Bismuth [Xe]$4f^{14} 5d^{10} 6s^2 p^3$	84 Po 209∴ Polonium [Xe]$4f^{14} 5d^{10} 6s^2 p^4$	85 At 210∴ Astatine [Xe]$4f^{14} 5d^{10} 6s^2 p^5$	86 Rn 222∴ Radon [Xe]$4f^{14} 5d^{10} 6s^2 p^6$
87 Fr 223∴ Francium [Rn]$7s^1$	88 Ra 226∴ Radium [Rn]$7s^2$	89 Ac 227∴ Actinium [Rn]$6d^1 7s^2$	104 Rf 261∴ Rutherfordium [Rn]$5f^{14} 6d^2 7s^2$ disc.1964	105 Db 262∴ Dubnium [Rn]$5f^{14} 6d^3 7s^2$ disc.1967	106 Sg 266∴ Seaborgium [Rn]$5f^{14} 6d^4 7s^2$ disc.1974	107 Bh 264∴ Bohrium [Rn]$5f^{14} 6d^5 7s^2$ disc.1981	108 Hs 269∴ Hassium [Rn]$5f^{14} 6d^6 7s^2$ disc.1984	109 Mt 268∴ Meitnerium [Rn]$5f^{14} 6d^7 7s^2$ disc.1982	110 Ds 281∴ Darmstadtium [Rn]$5f^{14} 6d^9 7s^1$ 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	Actinide Series
58 Ce 140.1 Cerium [Xe]$4f^1 5d^1 6s^2$	90 Th 232.0 Thorium [Rn]$6d^2 7s^2$
59 Pr 140.9 Praseodymium [Xe]$4f^3 6s^2$	91 Pa 231.0 Protactinium [Rn]$5f^2 6d^1 7s^2$
60 Nd 144.2 Neodymium [Xe]$4f^4 6s^2$	92 U 238.0 Uranium [Rn]$5f^3 6d^1 7s^2$
61 Pm 145∴ Promethium [Xe]$4f^5 6s^2$	93 Np 237∴ Neptunium [Rn]$5f^4 6d^1 7s^2$
62 Sm 150.4 Samarium [Xe]$4f^6 6s^2$	94 Pu 244∴ Plutonium [Rn]$5f^6 7s^2$
63 Eu 152.0 Europium [Xe]$4f^7 6s^2$	95 Am 243∴ Americium [Rn]$5f^7 7s^2$
64 Gd 157.3 Gadolinium [Xe]$4f^7 5d^1 6s^2$	96 Cm 247∴ Curium [Rn]$5f^7 6d^1 7s^2$
65 Tb 158.9 Terbium [Xe]$4f^9 6s^2$	97 Bk 247∴ Berkelium [Rn]$5f^9 7s^2$
66 Dy 162.5 Dysprosium [Xe]$4f^{10} 6s^2$	98 Cf 251∴ Californium [Rn]$5f^{10} 7s^2$
67 Ho 164.9 Holmium [Xe]$4f^{11} 6s^2$	99 Es 252∴ Einsteinium [Rn]$5f^{11} 7s^2$
68 Er 167.3 Erbium [Xe]$4f^{12} 6s^2$	100 Fm 257∴ Fermium [Rn]$5f^{12} 7s^2$
69 Tm 168.9 Thulium [Xe]$4f^{13} 6s^2$	101 Md 258∴ Mendelevium [Rn]$5f^{13} 7s^2$
70 Yb 173.0 Ytterbium [Xe]$4f^{14} 6s^2$	102 No 259∴ Nobelium [Rn]$5f^{14} 7s^2$
71 Lu 175.0 Lutetium [Xe]$4f^{14} 5d^1 6s^2$	103 Lr 262∴ Lawrencium [Rn]$5f^{14} 6d^1 7s^2$

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QuickStudy

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 hex	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, hex = HEXAGONAL; tetra = TETRAGONAL; bcc = BODY CENTERED CUBIC; ortho = ORTHOHOMBIC; mono = MONOCLINIC; fcc = FACE CENTERED CUBIC; rhom = RHOMBOHEDRAL; – = 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 21.5	V 21.0	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+)

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 renate $ReO_4(1-)$
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

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%	Mg 24 - 79.0% 25 - 10.0% 26 - 11.0%	Ti 46 - 8.0% 47 - 7.3% 48 - 73.8% 49 - 5.5% 50 - 5.4%	Ga 69 - 60.1% 71 - 39.9%	Zr 90 - 51.5% 91 - 11.2% 92 - 17.2% 94 - 17.4% 96 - 2.8%
He 4 - ~100%	Al 27 - 100%	V 50 - 0.3% 51 - 99.7%	Ge 70 - 21.2% 72 - 27.7% 73 - 7.7% 74 - 35.9% 78 - 7.4%	Nb 93 - 100%
Li 6 - 7.5% 7 - 92.5%	Si 28 - 92.2% 29 - 4.7% 30 - 3.1%	Cr 50 - 4.4% 52 - 83.8% 53 - 9.5% 54 - 2.4%	As 75 - 100%	Mo 92 - 14.8% 94 - 9.3% 95 - 15.9% 96 - 16.7% 97 - 9.6% 98 - 24.1% 100 - 9.6%
Be 9 - 100%	P 31 - 100%	Mn 55 - 100%	Se 74 - 0.9% 76 - 9.4% 77 - 7.6% 78 - 23.8% 80 - 49.6% 82 - 8.7%	Tc ☢ 93 - synthetic
B 10 - 19.9% 11 - 80.1%	S 32 - 95.0% 33 - 0.8% 34 - 4.2%	Fe 54 - 5.9% 56 - 91.7% 57 - 2.1%	Br 79 - 50.7% 81 - 49.3%	Ru 96 - 5.5% 98 - 1.9% 99 - 12.7% 100 - 12.6% 101 - 17.1% 102 - 31.6% 104 - 18.6%
C 12 - 98.9% 13 - 1.1%	Cl 35 - 75.8% 37 - 24.2%	Co 59 - 100%	Kr 80 - 2.3% 82 - 11.6% 83 - 11.5% 84 - 57.0% 86 - 17.3%	Rh 103 - 100%
N 14 - 99.63% 15 - 0.37%	Ar 36 - 0.3% 40 - 99.6%	Ni 58 - 68.1% 60 - 26.2% 61 - 1.1% 62 - 3.6% 64 - 0.9%	Rb 85 - 72.2% 87 - 27.8%	Pd 102 - 1.02% 104 - 11.1% 105 - 22.3% 106 - 27.3% 108 - 26.5% 110 - 11.7%
O 16 - 99.8% 18 - 0.2%	K 39 - 93.3% 41 - 6.7%	Cu 63 - 69.2% 65 - 30.8%	Sr 86 - 9.9% 87 - 7.0% 88 - 82.6%	Ag 107 - 51.8% 109 - 48.2%
F 19 - 100%	Ca 40 - 96.9% 42 - 0.7% 44 - 2.1%	Zn 64 - 48.6% 66 - 27.9% 67 - 4.1% 68 - 18.8%	Y 89 - 100%	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%
Ne 20 - 90.5% 21 - 0.3% 22 - 9.3%	Sc 45 - 100%			In 113 - 4.3% 115 - 95.7%
Na 23 - 100%				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%	Hf 176 - 5.2% 177 - 18.6% 178 - 27.3% 179 - 13.6% 180 - 35.1%			
La 138 - 0.1% 139 - 99.9%	Ta 180 - 0.01% 181 - 99.99%			
Ce 140 - 88.4% 142 - 11.1%	W 182 - 26.3% 183 - 14.3% 184 - 30.7% 186 - 28.6%			
Pr 141 - 100%	Re 185 - 37.4% 187 - 62.6%			
Nd 142 - 27.1% 143 - 12.2% 144 - 23.8% 145 - 8.3% 146 - 17.2% 148 - 5.8% 150 - 5.6%	Os 186 - 1.6% 187 - 1.6% 188 - 13.3% 189 - 16.1% 190 - 26.4% 192 - 41.0%			
Pm ☢ 145 - synthetic	Ir 191 - 37.3% 193 - 62.7%			
Sm 144 - 3.1% 147 - 15.0% 148 - 11.3% 149 - 13.8% 150 - 7.4% 152 - 26.7% 154 - 22.7%	Pt 194 - 32.9% 195 - 33.8% 196 - 25.3% 198 - 7.2%			
Eu 151 - 47.8% 153 - 52.2%	Au 197 - 100%			
Gd 154 - 2.2% 155 - 14.8% 156 - 20.5% 157 - 15.7% 158 - 24.8% 160 - 21.9%	Hg 198 - 10.0% 199 - 16.9% 200 - 23.1% 201 - 13.2% 202 - 29.9% 204 - 6.9%			
Tb 159 - 100%	Tl 203 - 29.5% 205 - 70.5%			
Dy 160 - 2.3% 161 - 18.9% 162 - 25.5% 163 - 24.9% 164 - 28.2%	Pb 204 - 1.4% 206 - 24.1% 207 - 22.1% 208 - 52.4%			
Ho 165 - 100%	Bi 209 - 100%			
Er 164 - 1.6% 166 - 33.6% 167 - 23.0% 168 - 26.8% 170 - 14.9%	Po ☢ 209 - 100%			
Tm 169 - 100%	At ☢ 210 - 100%			
Yb 170 - 3.1% 171 - 14.3% 172 - 21.9% 173 - 16.1% 174 - 31.8% 176 - 12.7%	Rn ☢ 222 - 100%			
Lu 175 - 97.4% 176 - 2.6%	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			

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 - P