PERIODIC TABLE OF THE ELEMENTS
for
Medium Energy Ion Scattering

I	II	III	IV	V	VI	VII

Element name — atomic number / **atomic symbol** / **atomic weight** / *melting point (K)* / Debye temperature (K) @ 300 K / crystal type / *a Ao (c Ao)* / stable isotopes >1% (in decreasing abundance)

[Debye temperatures and thermal vibrations]

The root mean square (rms) vibration amplitude is:

$$\sqrt{\langle u^2 \rangle} = \left(\frac{\hbar}{\theta_D}\right)\sqrt{\frac{3T}{mk}} \quad \text{(m)}$$

where:

$m \equiv$ **atomic mass (weight)** (x 1.673 10^{-27} kg) {approx.}

$\hbar = \frac{h}{2\pi} \equiv 1.05x10^{-34}$ (m^2 kg s^{-1}) {Plank's constant}

$T \equiv$ absolute temperature (K)

$k \equiv$ Boltzman's constant (m^2 kg s^{-2} K^{-1})

$\theta_D \equiv$ Debye temperature (K) {at 300 K}

	I	II	III	IV	V	VI	VII	
								2 **He** 4.0 0.95 (26 at) hcp *3.57* 4 — helium
1 **H** 1.0 *14.01* hcp *3.75 (6.12)* 1 — hydrogen								
3 **Li** 6.9 *452* 440 bcc *3.491* 7,6 — lithium	4 **Be** 9.0 *1550* 1031 hcp *2.27 (3.59)* 11 — beryllium							
11 **Na** 22.9 *1042* 155 bcc *4.225* 23 — sodium	12 **Mg** 24.3 *924* 330 hcp *3.21 (5.21)* 24,26,25 — magnesium							
			5 **B** 10.8 *2600* 1362 *rhomb* 11,10 — boron	6 **C** 12.0 >3800 1550 diamond *3.567* 12,13 — carbon	7 **N** 14.0 63.3 ? cubic *5.66* 14 — nitrogen	8 **O** 15.9 54.7 ? complex 16 — oxygen	9 **F** 18.9 53.5 19 — fluorine	10 **Ne** 20.1 24.5 75 fcc *4.46* 20 — neon
			13 **Al** 27.0 *933.2* 390 fcc *4.05* 27 — aluminium	14 **Si** 28.0 1680 692 diamond *5.430* 28,29,30 — silicon	15 **P** 30.9 317.2 576 complex 31 — phosphorus	16 **S** 32.0 386 ? complex 32,34,33 — sulfur	17 **Cl** 35.4 172.1 complex 35,37 — chlorine	18 **Ar** 39.9 83.7 92 fcc *5.31* 40 — argon
19 **K** 39.0 *336.8* 100 bcc *5.225* 39,41 — potassium	20 **Ca** 40.0 *1120* 230 fcc *5.58* 40 — calcium	21 **Sc** 44.9 *1812* 476 hcp *5.27 (5.27)* 45 — scandium						
			22 **Ti** 47.8 *1948* 380 hcp *2.95 (4.68)* 48,46,47,49,50 — titanium	23 **V** 50.9 *2160* 390 bcc *3.03* 51 — vanadium	24 **Cr** 51.9 *2160* 423 bcc *2.88* 52,53,50,54 — chromium	25 **Mn** 54.8 *924* 363 cubic *complex* 55 — manganese	26 **Fe** 55.8 *1808* 373 bcc *2.87* 56,54,57 — iron	27 **Co** 58.9 *1765* 386 hcp *2.51 (4.07)* 59 — cobalt
28 **Ni** 58.6 *1726* 345 fcc *3.52* 58,60,62,61,64 — nickel	29 **Cu** 63.5 *1356* 310 fcc *3.61* 63,65 — copper	30 **Zn** 65.3 *692.6* 237 hcp *2.66 (4.95)* 64,66,68,67 — zinc	31 **Ga** 69.7 302.9 240 complex 69,71 — gallium	32 **Ge** 72.6 1210.5 403 diamond *5.658* 74,72,70,73,76 — germanium	33 **As** 74.9 1090 (28 at) 275 rhomb 75 — arsenic	34 **Se** 78.9 490 90 hex. Chains 80,78,82,76,77 — selenium	35 **Br** 79.9 265.9 complex 79,81 — bromine	36 **Kr** 83.8 116.5 72 fcc *5.64* 84,86,82,83,80 — krypton
37 **Rb** 85.4 *2520* 59 bcc *5.585* 85,87 — rubidium	38 **Sr** 87.6 *1042* 148 fcc *6.08* 88,86,87 — strontium	39 **Y** 88.9 *1768* 214 hcp *3.65 (5.73)* 89 — yttrium						
			40 **Zr** 91.2 *2125* 250 hcp *3.65 (5.15)* 90,94,92,91,96 — zirconium	41 **Nb** 92.9 *2741* 260 bcc *3.30* 93 — niobium	42 **Mo** 95.9 *2880* 377 bcc *3.15* 98,96,92,95,100 — molybdenem	43 **Tc** [98.9] *2500* 422 hcp *2.74 (4.40)* none — technetium	44 **Ru** 101.0 *2520* 415 hcp *2.71 (4.28)* 102,104,101–98 — ruthenium	45 **Rh** 102.9 *2230* 350 fcc *3.80* 103 — rhodium
46 **Pd** 106.4 *1825* 275 fcc *3.89* 106,105,110,104 — palladium	47 **Ag** 107.8 *1234* 221 fcc *4.09* 107,109 — silver	48 **Cd** 112.4 *594.2* 220 hcp *2.98 (5.62)* 114,112 111,110,113,116 — cadmium	49 **In** 114.8 42929 108 tetr. *3.25* 115,113 — indium	50 **Sn** 118.7 505.1 254 complex *6.49* 120,118,116, 119, 117, 124,122 — tin	51 **Sb** 121.7 903.7 200 rhomb 121,123 — antimony	52 **Te** 127.6 722.6 153 hex chains 130, 128,126,125,124 — tellurium	53 **I** 126.9 386.6 complex 127 — iodine	54 **Xe** 131.2 161.2 64 fcc *6.13* 132,129, 131,134,136,130 — xenon
55 **Cs** 132.9 *1120* 43 bcc *6.045* 133 — caesium	56 **Ba** 137.3 *1000* 116 bcc *5.02* 138,137,136,135 — barium	57 **La** 138. *190* 135 hex. *3.77* 139 — lantahnum	58-71 * — lanthanides					
			72 **Hf** 178.4 *0.95* 213 hcp 180, *3.19 (5.05)* 178,177,179,176, — hafnium	73 **Ta** 180.9 *3269* 225 bcc *3.30* 181 — tantalum	74 **W** 183.8 *3650* 312 bcc *3.16* 184,186, 182,183 — tungsten	75 **Re** 186.2 *3450* 275 hcp *2.76 (4.46)* 187,185 — rhenium	76 **Os** 190.2 *3300* 400 hcp *2.74 (4.32)* 192,190,189,188 — osmium	77 **Ir** 192.2 *2716* 129 fcc *3.84* 193,191 — iridium
78 **Pt** 195.0 *2042* 225 fcc *3.92* 195,194,196,198 — platinum	79 **Au** 196.9 *1336.1* 178 fcc *4.08* 197 — gold	80 **Hg** 200.5 *234.3* 92 rhomb. 202,200, 199,201,198,204 — mercury	81 **Tl** 204.3 576.6 96 hcp *3.46 (5.52)* 205,203 — thallium	82 **Pb** 207.2 600.4 87 fcc *4.95* 208,206,207 — lead	83 **Bi** 208.9 544.4 116 rhomb 109 (alpha) — bismuth	84 **Po** [208.9] 527 sc *3.34* none — polonium	85 **At** [209.9] 520 none — astatine	86 **Rn** [222.0] 202 none — radon
87 **Fr** [223.0] *1585* ? — frankium	88 **Ra** [226.0] *970* ? — radium	89 **Ac** 232 *1320* fcc *5.31* — actinium	90-103 ** — actinides					
			104 **Rf** [261.1] ? ? — rutherfordium	105 **Db** [262.1] ? ? — dubnium	106 **Sg** [263.1] ? — seaborgium	107 **Bh** [264.1] ? — bohrium	108 **Hs** [265.1] ? — hassium	109 **Mt** [278] ? — meitnerium
110 **Ds** [281] ? — dartsatdium	111 **Rg** [282] ? — roentenium	112 **Cn** [285] ? — copernicium	113 **Nh** [286] ? — nihonium	114 **Fl** [289] ? — flerovium	115 **Mc** [290] ? — moscovium	116 **Lv** [293] ? — livermorium	117 **Ts** [294] ? — tennessine	118 **Og** [294] ? — oganesson

58 **Ce** 140.1 *1070* 138 fcc *5.16* 140,142 — cerium	59 **Pr** 140.9 *1208* 100 hex *3.67 (ABAC)* 141 — praesodimium	60 **Nd** 144.2 *1297* 148 hex 142,144,146, 145,143,148,150 — neodymium	61 **Pm** 144.9 *1308* — promethium	62 **Sm** 150.3 *1345* 184 complex 152,154,147, 149,148,150,144 — samarium	63 **Eu** 151.2 *1100* 118 bcc *4.58* 153,151 — europium	64 **Gd** 157.2 *1585* 155 hcp *3.63 (5.78)* 158,156,157,155.. — gadolinium	65 **Tb** 158.9 *1629* 158 hcp *3.60 (5.70)* 159 — terbium	66 **Dy** 162.9 *1680* 158 hcp *3.59 (5.65)* 164,162,163,161.. — dysprosium	67 **Ho** 164.9 *1734* 161 hcp *3.58 (5.62)* 165 — holmium	68 **Er** 167.2 *1770* 163 hcp *3.56 (5.59)* 166,168,167,170.. — erbium	69 **Tm** 168.9 *1818* 167 hcp *3.54 (5.56)* 169 — thulium	70 **Yb** 173.0 *1097* 120 fcc *5.48* 174,172, 173,171,176,170 — ytterbium	71 **Lu** 174.9 *1925* 116 hex. *3.50 (5.55)* 175,176 — lutetium
90 **Th** 232.0 *2000* 100 fcc *5.08* — thorium	91 **Pa** 231.0 *1500* 138 tetr. *3.92 (3.24)* — protactinium	92 **U** 238.0 *1405.4* 300 complex 238 alpha — uranium	93 **Np** 237.0 ? 163 complex — neptunium	94 **Pu** 244.0 ? complex — plutonium	95 **Am** 243.0 ? hex *3.64 (ABAC)* — americum	96 **Cm** 247.0 ? — curium	97 **Bk** 247.0 ? — berkelium	98 **Cf** 251.0 ? — californium	99 **Es** 252.0 ? — einsteinium	100 **Fm** 257.0 ? — fermium	101 **Md** 258.0 ? — mendelevim	102 **No** 259.1 ? — nobelium	103 **Lr** [262.1] ? ? hcp *3.77 (ABAC)* — lawrencium

* Lanthanides

** Actinides

The Debye temperatures are mostly from – *www.knowledgedoor.com*

with references from – *J. Phy.s and Chem. Ref. Data*, vol. 8

and, of course, – Kittle C. *Intro. to Sol. St. Phys.*, 8th ed.

and also - *CRC Handbook of Chemistry and Physics*

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