Monovalent Metals

Lithium - martensitic transformation to a mixture of crystalline phases 77K

Sodium - at 23 K, ok

H metallic @ high pressure ☐

Alkali - BCC

Noble - FCC

Alkali BCC: $\frac{k_F^3}{3\pi^2} = n = \frac{2}{a^3}$

$$k_F = 0.62 \left(\frac{2\pi}{a}\right)$$

In Reciprocal : FCC

$$K_{min} = \frac{4\pi}{a}\sqrt{\left(\frac{1}{2}\right)^2+\left(\frac{1}{2}\right)^2} = \frac{4\pi}{a}\sqrt{\frac{1}{2}}$$

$$\frac{K_{min}}{2} = 0.707\left(\frac{2\pi}{a}\right)$$

dHvA very nearly sphere

Hall $-1/nec$ (few %)

Noble Metals: Filled d

6 bands

characterize as s, d

s dep. like free el.

asymmetry magnetoresistance

Optical Properties (Appendix K)

Color freq. dep. of reflectivity (some more others)

Plasmons

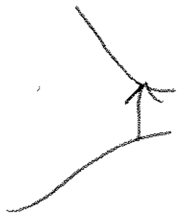
Copper ω_p: red
gold yellow
Silver bule

Tanner?

$k' = k + q + K$, $k_F \approx 10^8 \text{cm}^{-1}$

$q \approx 10^5 \text{cm}^{-1} \approx 0$

$k' = k$



$\hbar\omega = 0.64\ \varepsilon_F$

Copper 4eV
2eV

Divalent Metals

d not as important

Ca, Sr, Ba $\overset{\text{free el.}}{\text{sphere}}$ same vol. first zone

good dHvA Be, Mg, Zn, Cd

Be compensated

Trivalent

Only consider Al ↙ very small

Free El. 2nd 3rd 4th BZ

2nd zone empty

3rd zone narrow tubes occupied

$n_e^{II} + n_e^{III} = \frac{n}{3}$

$n_e^{II} + n_h^{II} = 2\left(\frac{n}{3}\right)$

$n_e^{III} - n_h^{II} = -\frac{n}{3}$ $R_H = \frac{-1}{nec}$ pos. & dens $= \frac{1}{3}$ of n.

absorb. & refl. dHvA

Tetravalent

Lead & Tin

Lead compare to Al

$n_h^{II} = n_e^{III}$ derive?

Semimetals

$n \ll 10^{22}/cm^3$

Graphite $n_e = n_h = 3 \times 10^{18}/cm^3$

Pentavalent metals: As, Sb, Bi

> Transition metals (d)

> Rare earths (f) localized

> Alloys Stoichiometric... basis
Disorder ...elaborate

NIST, text, FS ekments

NdFeB
Sm Co

Poole Cu, Ag, Au 10.8, 9.0, 9.0 eV

www.ee.iitm.ac.in/~hsr/ec301/copper.pdf
INDIA

PERIODIC TABLE

Atomic Properties of the Elements

National Institute of Standards and Technology
U.S. Department of Commerce

Physical Measurement Laboratory
www.nist.gov/pml

Standard Reference Data
www.nist.gov/srd

Frequently used fundamental physical constants

For the most accurate values of these and other constants, visit physics.nist.gov/constants

1 second = 9 192 631 770 periods of radiation corresponding to the transition between the two hyperfine levels of the ground state of ^{133}Cs

speed of light in vacuum	c	299 792 458 m s^{-1}	(exact)
Planck constant	h	6.626 07 × 10^{-34} J s	($\hbar = h/2\pi$)
elementary charge	e	1.602 177 × 10^{-19} C	
electron mass	m_e	9.109 38 × 10^{-31} kg	
	m_ec^2	0.510 999 MeV	
proton mass	m_p	1.672 622 × 10^{-27} kg	
fine-structure constant	α	1/137.035 999	
Rydberg constant	R_∞	10 973 731.569 m^{-1}	
	$R_\infty c$	3.289 841 960 × 10^{15} Hz	
	$R_\infty hc$	13.605 69 eV	
Boltzmann constant	k	1.380 6 × 10^{-23} J K^{-1}	

☐ Solids
▨ Liquids
▨ Gases
☐ Artificially Prepared

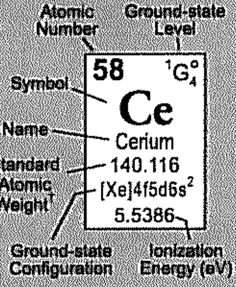
Alkali Earths

Trans. metals (d's imp;)

Period	Group 1 IA	2 IIA	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VIII	9 VIII	10 VIII	11 IB	12 IIB	13 IIIA	14 IVA	15 VA	16 VIA	17 VIIA	18 VIIIA
1	**1** ${}^2S_{1/2}$ **H** Hydrogen 1.008* $1s$ 13.5984																	**2** ${}^1S_0$ **He** Helium 4.002602 $1s^2$ 24.5874
2	**3** ${}^2S_{1/2}$ **Li** Lithium 6.94* $1s^22s$ 5.3917	**4** ${}^1S_0$ **Be** Beryllium 9.012182 $1s^22s^2$ 9.3227											**5** ${}^2P^\circ_{1/2}$ **B** Boron 10.81* $1s^22s^22p$ 8.2980	**6** ${}^3P_0$ **C** Carbon 12.011* $1s^22s^22p^2$ 11.2603	**7** ${}^4S^\circ_{3/2}$ **N** Nitrogen 14.007* $1s^22s^22p^3$ 14.5341	**8** ${}^3P_2$ **O** Oxygen 15.999* $1s^22s^22p^4$ 13.6181	**9** ${}^2P^\circ_{3/2}$ **F** Fluorine 18.9984032 $1s^22s^22p^5$ 17.4228	**10** ${}^1S_0$ **Ne** Neon 20.1797 $1s^22s^22p^6$ 21.5645
3	**11** ${}^2S_{1/2}$ **Na** Sodium 22.98976928 $[\mathrm{Ne}]3s$ 5.1391	**12** ${}^1S_0$ **Mg** Magnesium 24.3050 $[\mathrm{Ne}]3s^2$ 7.6462											**13** ${}^2P^\circ_{1/2}$ **Al** Aluminum 26.9815386 $[\mathrm{Ne}]3s^23p$ 5.9858	**14** ${}^3P_0$ **Si** Silicon 28.085* $[\mathrm{Ne}]3s^23p^2$ 8.1517	**15** ${}^4S^\circ_{3/2}$ **P** Phosphorus 30.973762 $[\mathrm{Ne}]3s^23p^3$ 10.4867	**16** ${}^3P_2$ **S** Sulfur 32.06* $[\mathrm{Ne}]3s^23p^4$ 10.3600	**17** ${}^2P^\circ_{3/2}$ **Cl** Chlorine 35.45* $[\mathrm{Ne}]3s^23p^5$ 12.9676	**18** ${}^1S_0$ **Ar** Argon 39.948 $[\mathrm{Ne}]3s^23p^6$ 15.7596
4	**19** ${}^2S_{1/2}$ **K** Potassium 39.0983 $[\mathrm{Ar}]4s$ 4.3407	**20** ${}^1S_0$ **Ca** Calcium 40.078 $[\mathrm{Ar}]4s^2$ 6.1132	**21** ${}^2D_{3/2}$ **Sc** Scandium 44.955912 $[\mathrm{Ar}]3d4s^2$ 6.5615	**22** ${}^3F_2$ **Ti** Titanium 47.867 $[\mathrm{Ar}]3d^24s^2$ 6.8281	**23** ${}^4F_{3/2}$ **V** Vanadium 50.9415 $[\mathrm{Ar}]3d^34s^2$ 6.7462	**24** ${}^7S_3$ **Cr** Chromium 51.9961 $[\mathrm{Ar}]3d^54s$ 6.7665	**25** ${}^6S_{5/2}$ **Mn** Manganese 54.938045 $[\mathrm{Ar}]3d^54s^2$ 7.4340	**26** ${}^5D_4$ **Fe** Iron 55.845 $[\mathrm{Ar}]3d^64s^2$ 7.9025	**27** ${}^4F_{9/2}$ **Co** Cobalt 58.933195 $[\mathrm{Ar}]3d^74s^2$ 7.8810	**28** ${}^3F_4$ **Ni** Nickel 58.6934 $[\mathrm{Ar}]3d^84s^2$ 7.6399	**29** ${}^2S_{1/2}$ **Cu** Copper 63.546 $[\mathrm{Ar}]3d^{10}4s$ 7.7264	**30** ${}^1S_0$ **Zn** Zinc 65.38 $[\mathrm{Ar}]3d^{10}4s^2$ 9.3942	**31** ${}^2P^\circ_{1/2}$ **Ga** Gallium 69.723 $[\mathrm{Ar}]3d^{10}4s^24p$ 5.9993	**32** ${}^3P_0$ **Ge** Germanium 72.63 $[\mathrm{Ar}]3d^{10}4s^24p^2$ 7.8994	**33** ${}^4S^\circ_{3/2}$ **As** Arsenic 74.92160 $[\mathrm{Ar}]3d^{10}4s^24p^3$ 9.7886	**34** ${}^3P_2$ **Se** Selenium 78.96 $[\mathrm{Ar}]3d^{10}4s^24p^4$ 9.7524	**35** ${}^2P^\circ_{3/2}$ **Br** Bromine 79.904 $[\mathrm{Ar}]3d^{10}4s^24p^5$ 11.8138	**36** ${}^1S_0$ **Kr** Krypton 83.798 $[\mathrm{Ar}]3d^{10}4s^24p^6$ 13.9996
5	**37** ${}^2S_{1/2}$ **Rb** Rubidium 85.4678 $[\mathrm{Kr}]5s$ 4.1771	**38** ${}^1S_0$ **Sr** Strontium 87.62 $[\mathrm{Kr}]5s^2$ 5.6949	**39** ${}^2D_{3/2}$ **Y** Yttrium 88.90585 $[\mathrm{Kr}]4d5s^2$ 6.2173	**40** ${}^3F_2$ **Zr** Zirconium 91.224 $[\mathrm{Kr}]4d^25s^2$ 6.6339	**41** ${}^6D_{1/2}$ **Nb** Niobium 92.90638 $[\mathrm{Kr}]4d^45s$ 6.7589	**42** ${}^7S_3$ **Mo** Molybdenum 95.96 $[\mathrm{Kr}]4d^55s$ 7.0924	**43** ${}^6S_{5/2}$ **Tc** Technetium (98) $[\mathrm{Kr}]4d^55s^2$ 7.1194	**44** ${}^5F_5$ **Ru** Ruthenium 101.07 $[\mathrm{Kr}]4d^75s$ 7.3605	**45** ${}^4F_{9/2}$ **Rh** Rhodium 102.90550 $[\mathrm{Kr}]4d^85s$ 7.4589	**46** ${}^1S_0$ **Pd** Palladium 106.42 $[\mathrm{Kr}]4d^{10}$ 8.3369	**47** ${}^2S_{1/2}$ **Ag** Silver 107.8682 $[\mathrm{Kr}]4d^{10}5s$ 7.5762	**48** ${}^1S_0$ **Cd** Cadmium 112.411 $[\mathrm{Kr}]4d^{10}5s^2$ 8.9938	**49** ${}^2P^\circ_{1/2}$ **In** Indium 114.818 $[\mathrm{Kr}]4d^{10}5s^25p$ 5.7864	**50** ${}^3P_0$ **Sn** Tin 118.710 $[\mathrm{Kr}]4d^{10}5s^25p^2$ 7.3439	**51** ${}^4S^\circ_{3/2}$ **Sb** Antimony 121.760 $[\mathrm{Kr}]4d^{10}5s^25p^3$ 8.6084	**52** ${}^3P_2$ **Te** Tellurium 127.60 $[\mathrm{Kr}]4d^{10}5s^25p^4$ 9.0097	**53** ${}^2P^\circ_{3/2}$ **I** Iodine 126.90447 $[\mathrm{Kr}]4d^{10}5s^25p^5$ 10.4513	**54** ${}^1S_0$ **Xe** Xenon 131.293 $[\mathrm{Kr}]4d^{10}5s^25p^6$ 12.1298
6	**55** ${}^2S_{1/2}$ **Cs** Cesium 132.9054519 $[\mathrm{Xe}]6s$ 3.8939	**56** ${}^1S_0$ **Ba** Barium 137.327 $[\mathrm{Xe}]6s^2$ 5.2117		**72** ${}^3F_2$ **Hf** Hafnium 178.49 $[\mathrm{Xe}]4f^{14}5d^26s^2$ 6.8251	**73** ${}^4F_{3/2}$ **Ta** Tantalum 180.94788 $[\mathrm{Xe}]4f^{14}5d^36s^2$ 7.5496	**74** ${}^5D_0$ **W** Tungsten 183.84 $[\mathrm{Xe}]4f^{14}5d^46s^2$ 7.8640	**75** ${}^6S_{5/2}$ **Re** Rhenium 186.207 $[\mathrm{Xe}]4f^{14}5d^56s^2$ 7.8335	**76** ${}^5D_4$ **Os** Osmium 190.23 $[\mathrm{Xe}]4f^{14}5d^66s^2$ 8.4382	**77** ${}^4F_{9/2}$ **Ir** Iridium 192.217 $[\mathrm{Xe}]4f^{14}5d^76s^2$ 8.9670	**78** ${}^3D_3$ **Pt** Platinum 195.084 $[\mathrm{Xe}]4f^{14}5d^96s$ 8.9588	**79** ${}^2S_{1/2}$ **Au** Gold 196.966569 $[\mathrm{Xe}]4f^{14}5d^{10}6s$ 9.2256	**80** ${}^1S_0$ **Hg** Mercury 200.59 $[\mathrm{Xe}]4f^{14}5d^{10}6s^2$ 10.4375	**81** ${}^2P^\circ_{1/2}$ **Tl** Thallium 204.38* $[\mathrm{Hg}]6p$ 6.1083	**82** ${}^3P_0$ **Pb** Lead 207.2 $[\mathrm{Hg}]6p^2$ 7.4167	**83** ${}^4S^\circ_{3/2}$ **Bi** Bismuth 208.98040 $[\mathrm{Hg}]6p^3$ 7.2855	**84** ${}^3P_2$ **Po** Polonium (209) $[\mathrm{Hg}]6p^4$ 8.414	**85** ${}^2P^\circ_{3/2}$ **At** Astatine (210) $[\mathrm{Hg}]6p^5$ 9.350	**86** ${}^1S_0$ **Rn** Radon (222) $[\mathrm{Hg}]6p^6$ 10.7485
7	**87** ${}^2S_{1/2}$ **Fr** Francium (223) $[\mathrm{Rn}]7s$ 4.0727	**88** ${}^1S_0$ **Ra** Radium (226) $[\mathrm{Rn}]7s^2$ 5.2784		**104** ${}^3F_2$ **Rf** Rutherfordium (265) $[\mathrm{Rn}]5f^{14}6d^27s^2$ 6.01	**105** ${}^4F_{3/2}$ **Db** Dubnium (268) $[\mathrm{Rn}]5f^{14}6d^37s^2$ 6.8	**106** **Sg** Seaborgium (271) $[\mathrm{Rn}]5f^{14}6d^47s^2$ 7.8	**107** **Bh** Bohrium (270) $[\mathrm{Rn}]5f^{14}6d^57s^2$ 7.7	**108** **Hs** Hassium (277) $[\mathrm{Rn}]5f^{14}6d^67s^2$ 7.6	**109** **Mt** Meitnerium (276)	**110** **Ds** Darmstadtium (281)	**111** **Rg** Roentgenium (280)	**112** **Cn** Copernicium (285)	**113** **Uut** Ununtrium (284)	**114** **Fl** Flerovium (289)	**115** **Uup** Ununpentium (288)	**116** **Lv** Livermorium (293)	**117** **Uus** Ununseptium (294)	**118** **Uuo** Ununoctium (294)

RARE EARTH

Lanthanides	**57** ${}^2D_{3/2}$ **La** Lanthanum 138.90547 $[\mathrm{Xe}]5d6s^2$ 5.5769	**58** ${}^1G^\circ_4$ **Ce** Cerium 140.116 $[\mathrm{Xe}]4f5d6s^2$ 5.5386	**59** ${}^4I^\circ_{9/2}$ **Pr** Praseodymium 140.90765 $[\mathrm{Xe}]4f^36s^2$ 5.473	**60** ${}^5I_4$ **Nd** Neodymium 144.242 $[\mathrm{Xe}]4f^46s^2$ 5.5250	**61** ${}^6H^\circ_{5/2}$ **Pm** Promethium (145) $[\mathrm{Xe}]4f^56s^2$ 5.582	**62** ${}^7F_0$ **Sm** Samarium 150.36 $[\mathrm{Xe}]4f^66s^2$ 5.6437	**63** ${}^8S^\circ_{7/2}$ **Eu** Europium 151.964 $[\mathrm{Xe}]4f^76s^2$ 5.6704	**64** ${}^9D^\circ_2$ **Gd** Gadolinium 157.25 $[\mathrm{Xe}]4f^75d6s^2$ 6.1498	**65** ${}^6H^\circ_{15/2}$ **Tb** Terbium 158.92535 $[\mathrm{Xe}]4f^96s^2$ 5.8638	**66** ${}^5I_8$ **Dy** Dysprosium 162.500 $[\mathrm{Xe}]4f^{10}6s^2$ 5.9391	**67** ${}^4I^\circ_{15/2}$ **Ho** Holmium 164.93032 $[\mathrm{Xe}]4f^{11}6s^2$ 6.0215	**68** ${}^3H_6$ **Er** Erbium 167.259 $[\mathrm{Xe}]4f^{12}6s^2$ 6.1077	**69** ${}^2F^\circ_{7/2}$ **Tm** Thulium 168.93421 $[\mathrm{Xe}]4f^{13}6s^2$ 6.1843	**70** ${}^1S_0$ **Yb** Ytterbium 173.054 $[\mathrm{Xe}]4f^{14}6s^2$ 6.2542	**71** ${}^2D_{3/2}$ **Lu** Lutetium 174.9668 $[\mathrm{Xe}]4f^{14}5d6s^2$ 5.4259
Actinides	**89** ${}^2D_{3/2}$ **Ac** Actinium (227) $[\mathrm{Rn}]6d7s^2$ 5.3802	**90** ${}^3F_2$ **Th** Thorium 232.03806 $[\mathrm{Rn}]6d^27s^2$ 6.3067	**91** ${}^4K_{11/2}$ **Pa** Protactinium 231.03588 $[\mathrm{Rn}]5f^26d7s^2$ 5.89	**92** ${}^5L^\circ_6$ **U** Uranium 238.02891 $[\mathrm{Rn}]5f^36d7s^2$ 6.1941	**93** ${}^6L_{11/2}$ **Np** Neptunium (237) $[\mathrm{Rn}]5f^46d7s^2$ 6.2655	**94** ${}^7F_0$ **Pu** Plutonium (244) $[\mathrm{Rn}]5f^67s^2$ 6.0258	**95** ${}^8S^\circ_{7/2}$ **Am** Americium (243) $[\mathrm{Rn}]5f^77s^2$ 5.9738	**96** ${}^9D^\circ_2$ **Cm** Curium (247) $[\mathrm{Rn}]5f^76d7s^2$ 5.9914	**97** ${}^6H^\circ_{15/2}$ **Bk** Berkelium (247) $[\mathrm{Rn}]5f^97s^2$ 6.1978	**98** ${}^5I_8$ **Cf** Californium (251) $[\mathrm{Rn}]5f^{10}7s^2$ 6.2817	**99** ${}^4I^\circ_{15/2}$ **Es** Einsteinium (252) $[\mathrm{Rn}]5f^{11}7s^2$ 6.3676	**100** ${}^3H_6$ **Fm** Fermium (257) $[\mathrm{Rn}]5f^{12}7s^2$ 6.50	**101** ${}^2F^\circ_{7/2}$ **Md** Mendelevium (258) $[\mathrm{Rn}]5f^{13}7s^2$ 6.58	**102** ${}^1S_0$ **No** Nobelium (259) $[\mathrm{Rn}]5f^{14}7s^2$ 6.65	**103** ${}^2P^\circ_{1/2}$ **Lr** Lawrencium (262) $[\mathrm{Rn}]5f^{14}7s^27p$ 4.90



†Based upon ^{12}C. () indicates the mass number of the longest-lived isotope.

*IUPAC conventional atomic weights; standard atomic weights for these elements are expressed in intervals; see iupac.org for an explanation and values.

For a description of the data, visit physics.nist.gov/data

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