

Monovalent Metals

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

Sodium - at 23K, ok

H metallic @ high pressure \square

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)

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

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

$$\rightarrow k' = k$$

Look for lowest energy transition between bands.

For Cu threshold d-band \rightarrow s-band is $\approx 2 \text{ eV}$.

Orange: $2 \rightarrow 2.1 \text{ eV}$

Red: $1.65 \rightarrow 2 \text{ eV}$

Thus, red light is reflected and other colors are absorbed. \rightarrow Copper color.

For silver the lowest interband transition is above 4 eV above the visible. \rightarrow All visible reflected. \rightarrow Silver color & use in mirrors.

For gold: yellow, orange, and red are reflected.

\rightarrow Gold color.

Divalent Metals

3.

d not as important

Ca, Sr, Ba ^{free el.} 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

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

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

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

absorb. \& refl. dHvA

Tetravalent

Lead \& Tin

Lead compare to Al

$$n_h^{\text{II}} = n_e^{\text{III}} \quad \text{derive?}$$

Semimetals

4.

$$n_v \ll 10^{22}/\text{cm}^3$$

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

Pentavalent metals: As, Sb, Bi

- > Transition metals (d)
- > Rare earths (f) localized
- > Alloys Stoichiometric... basis
Disorder ...elaborate

NIST, text, FS elements

Nd Fe B
Sm Co

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

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

INDIA

Atomic Properties of the Elements

PERIODIC TABLE

18
VIII A

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

Physical Measurement Laboratory

www.nist.gov/ptl

Reference Data

www.nist.gov/std

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 ¹³³Cs
Planck constant
speed of light in vacuum
elementary charge
electron mass
proton mass
fine-structure constant
Rydberg constant
Boltzmann constant

c 299 792 458 m s⁻¹ (exact)
 h 6.626 07 × 10⁻³⁴ J s
 e 1.602 177 × 10⁻¹⁹ C
 m_e 9.108 38 × 10⁻³¹ kg
 m_p 0.510 989 MeV
 α 1/137.035 999
 R_∞ 10 973 731.569 m⁻¹
 $R_\infty c$ 3.289 841 960 × 10¹⁶ Hz
 k 1.380 6 × 10⁻²³ J K⁻¹

- Solids
- Liquids
- Gases
- Artificially Prepared

Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Period	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	H Hydrogen 1.007 94 1s ¹	He Helium 4.002 602 1s ²																
2	Li Lithium 6.941 2s ¹ 2s ²	Be Beryllium 9.012 182 2s ²	B Boron 10.81 2s ² 2p ¹	C Carbon 12.011 2s ² 2p ²	N Nitrogen 14.007 2s ² 2p ³	O Oxygen 15.999 2s ² 2p ⁴	F Fluorine 18.998 4032 2s ² 2p ⁵	Ne Neon 20.1797 2s ² 2p ⁶										
3	Na Sodium 22.989 76928 3s ¹	Mg Magnesium 24.3050 3s ²	Al Aluminum 26.981 5386 3s ² 3p ¹	Si Silicon 28.085 3s ² 3p ²	P Phosphorus 30.973 762 3s ² 3p ³	S Sulfur 32.06 3s ² 3p ⁴	Cl Chlorine 35.45 3s ² 3p ⁵	Ar Argon 39.948 3s ² 3p ⁶										
4	K Potassium 39.0983 4s ¹	Ca Calcium 40.078 4s ²	Sc Scandium 44.955 912 3d ¹ 4s ²	Ti Titanium 47.867 3d ² 4s ²	V Vanadium 50.9415 3d ³ 4s ²	Cr Chromium 51.9961 3d ⁵ 4s ¹	Mn Manganese 54.938 045 3d ⁵ 4s ²	Fe Iron 55.845 3d ⁶ 4s ²	Co Cobalt 58.933 195 3d ⁷ 4s ²	Ni Nickel 58.6934 3d ⁸ 4s ²	Cu Copper 63.546 3d ¹⁰ 4s ¹	Zn Zinc 65.38 3d ¹⁰ 4s ²	Ga Gallium 69.723 4s ² 4p ¹	Ge Germanium 72.63 4s ² 4p ²	As Arsenic 74.921 60 4s ² 4p ³	Se Selenium 78.96 4s ² 4p ⁴	Br Bromine 79.904 4s ² 4p ⁵	Kr Krypton 83.798 4s ² 4p ⁶
5	Rb Rubidium 85.4678 5s ¹	Sr Strontium 87.62 5s ²	Y Yttrium 88.905 85 4d ¹ 5s ²	Zr Zirconium 91.224 4d ² 5s ²	Nb Niobium 92.906 38 4d ⁴ 5s ¹	Mo Molybdenum 95.95 4d ⁵ 5s ¹	Tc Technetium (98) 4d ⁵ 5s ²	Ru Ruthenium 101.07 4d ⁷ 5s ¹	Rh Rhodium 102.905 50 4d ⁸ 5s ¹	Pd Palladium 106.42 4d ¹⁰	Ag Silver 107.868 2 4d ¹⁰ 5s ¹	Cd Cadmium 112.411 4d ¹⁰ 5s ²	In Indium 114.818 5s ² 5p ¹	Sn Tin 118.710 5s ² 5p ²	Sb Antimony 121.760 5s ² 5p ³	Te Tellurium 127.60 5s ² 5p ⁴	I Iodine 126.904 47 5s ² 5p ⁵	Xe Xenon 131.29 5s ² 5p ⁶
6	Cs Cesium 132.905 4518 6s ¹	Ba Barium 137.327 6s ²	La Lanthanum 138.904 7 5d ¹ 6s ²	Hf Hafnium 178.49 5d ² 6s ²	Ta Tantalum 180.947 88 5d ⁴ 6s ²	W Tungsten 183.84 5d ⁴ 6s ²	Re Rhenium 186.207 5d ⁵ 6s ²	Os Osmium 190.23 5d ⁶ 6s ²	Ir Iridium 192.225 5d ⁷ 6s ²	Pt Platinum 195.084 5d ⁹ 6s ¹	Au Gold 196.966 569 5d ¹⁰ 6s ¹	Hg Mercury 200.59 5d ¹⁰ 6s ²	Tl Thallium 204.38 6s ² 6p ¹	Pb Lead 207.2 6s ² 6p ²	Bi Bismuth 208.980 40 6s ² 6p ³	Po Polonium (209) 6s ² 6p ⁴	At Astatine (210) 6s ² 6p ⁵	Rn Radon (222) 6s ² 6p ⁶
7	Fr Francium (223) 7s ¹	Ra Radium (226) 7s ²	Ac Actinium (227) 6d ¹ 7s ²	Rf Rutherfordium (261) 6d ² 7s ²	Db Dubnium (268) 6d ³ 7s ²	Sg Seaborgium (271) 6d ⁴ 7s ²	Bh Bohrium (270) 6d ⁵ 7s ²	Hs Hassium (277) 6d ⁶ 7s ²	Mt Meitnerium (276) 6d ⁷ 7s ²	Ds Darmstadtium (281) 6d ⁸ 7s ²	Rg Roentgenium (280) 6d ⁹ 7s ²	Cn Copernicium (285) 6d ¹⁰ 7s ²	Uut Ununium (284) 7s ² 7p ¹	Fl Flerovium (289) 7s ² 7p ²	Uup Ununpentium (288) 7s ² 7p ³	Lv Livermorium (293) 7s ² 7p ⁴	Uus Ununseptium (294) 7s ² 7p ⁵	Uuo Ununoctium (294) 7s ² 7p ⁶
			La Lanthanum 138.904 7 5d ¹ 6s ²	Ce Cerium 140.116 5d ¹ 6s ²	Pr Praseodymium 140.907 65 5d ¹ 6s ²	Nd Neodymium 144.242 5d ¹ 6s ²	Pm Promethium (145) 5d ¹ 6s ²	Sm Samarium 150.36 5d ¹ 6s ²	Eu Europium 151.964 5d ¹ 6s ²	Gd Gadolinium 157.25 5d ¹ 6s ²	Tb Terbium 158.925 15 5d ¹ 6s ²	Dy Dysprosium 162.500 5d ¹ 6s ²	Ho Holmium 164.930 32 5d ¹ 6s ²	Er Erbium 167.259 5d ¹ 6s ²	Tm Thulium 168.934 21 5d ¹ 6s ²	Yb Ytterbium 173.054 5d ¹ 6s ²	Lu Lutetium 174.967 5d ¹ 6s ²	
			Ac Actinium (227) 6d ¹ 7s ²	Th Thorium 232.038 06 6d ² 7s ²	Pa Protactinium 231.038 88 5f ¹ 6d ¹ 7s ²	U Uranium 238.028 91 5f ³ 6d ¹ 7s ²	Np Neptunium (237) 5f ⁴ 6d ¹ 7s ²	Pu Plutonium (244) 5f ⁶ 6d ¹ 7s ²	Am Americium (243) 5f ⁷ 7s ²	Cm Curium (247) 5f ⁷ 6d ¹ 7s ²	Bk Berkelium (247) 5f ⁷ 6d ² 7s ²	Cf Californium (251) 5f ⁷ 6d ² 7s ²	Es Einsteinium (252) 5f ⁷ 6d ¹ 7s ²	Fm Fermium (257) 5f ⁷ 6d ² 7s ²	Md Mendelevium (258) 5f ⁷ 6d ² 7s ²	No Nobelium (259) 5f ⁷ 6d ¹ 7s ²	Lr Lawrencium (262) 5f ⁷ 6d ¹ 7s ²	

¹Based upon ¹²C. () indicates the mass number of the longest-lived isotope.
²IUPAC 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
NIST SP 966 (March 2013)