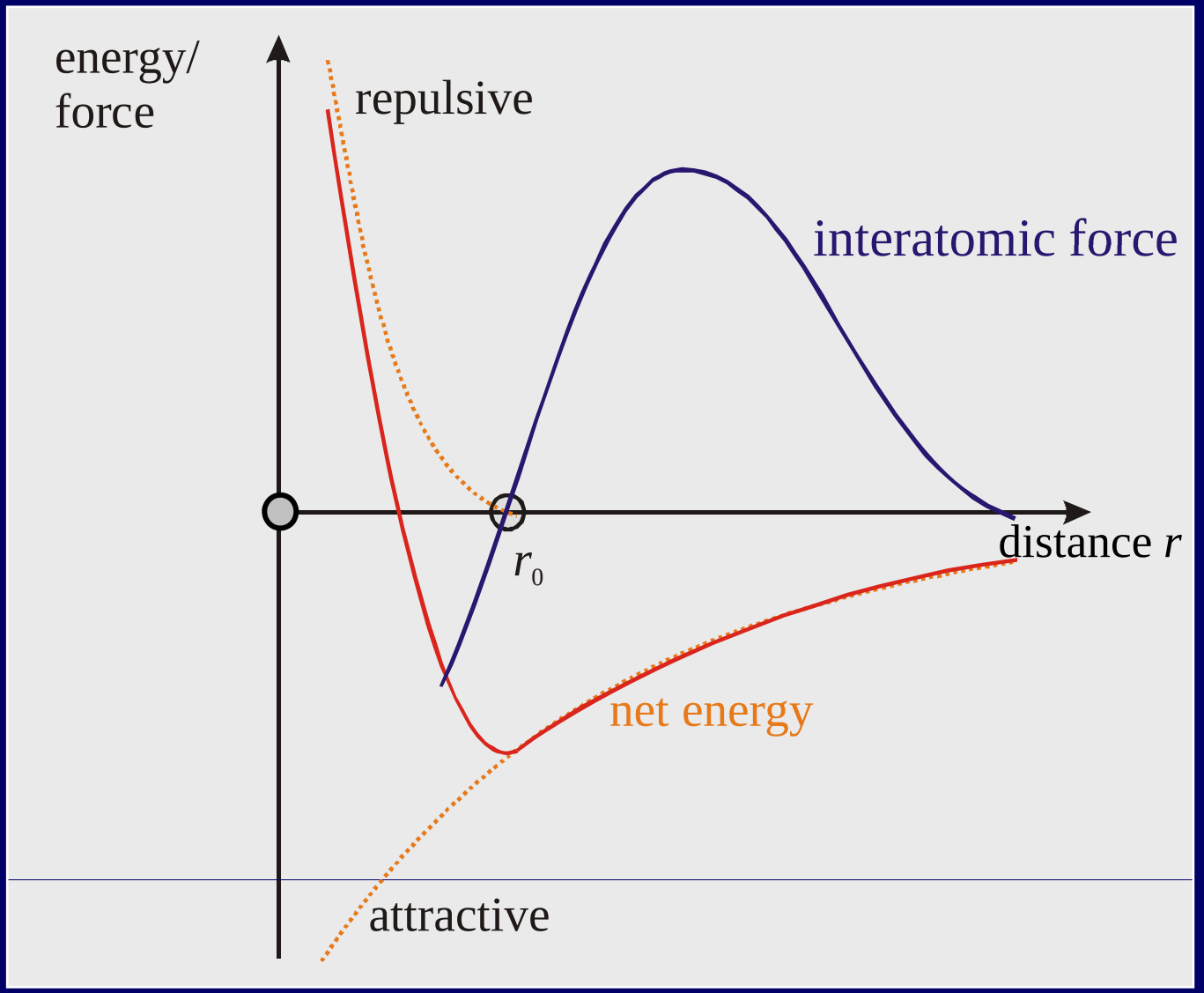
last lecture

- Introduction to materials science and engineering
- Atoms / electron configuration

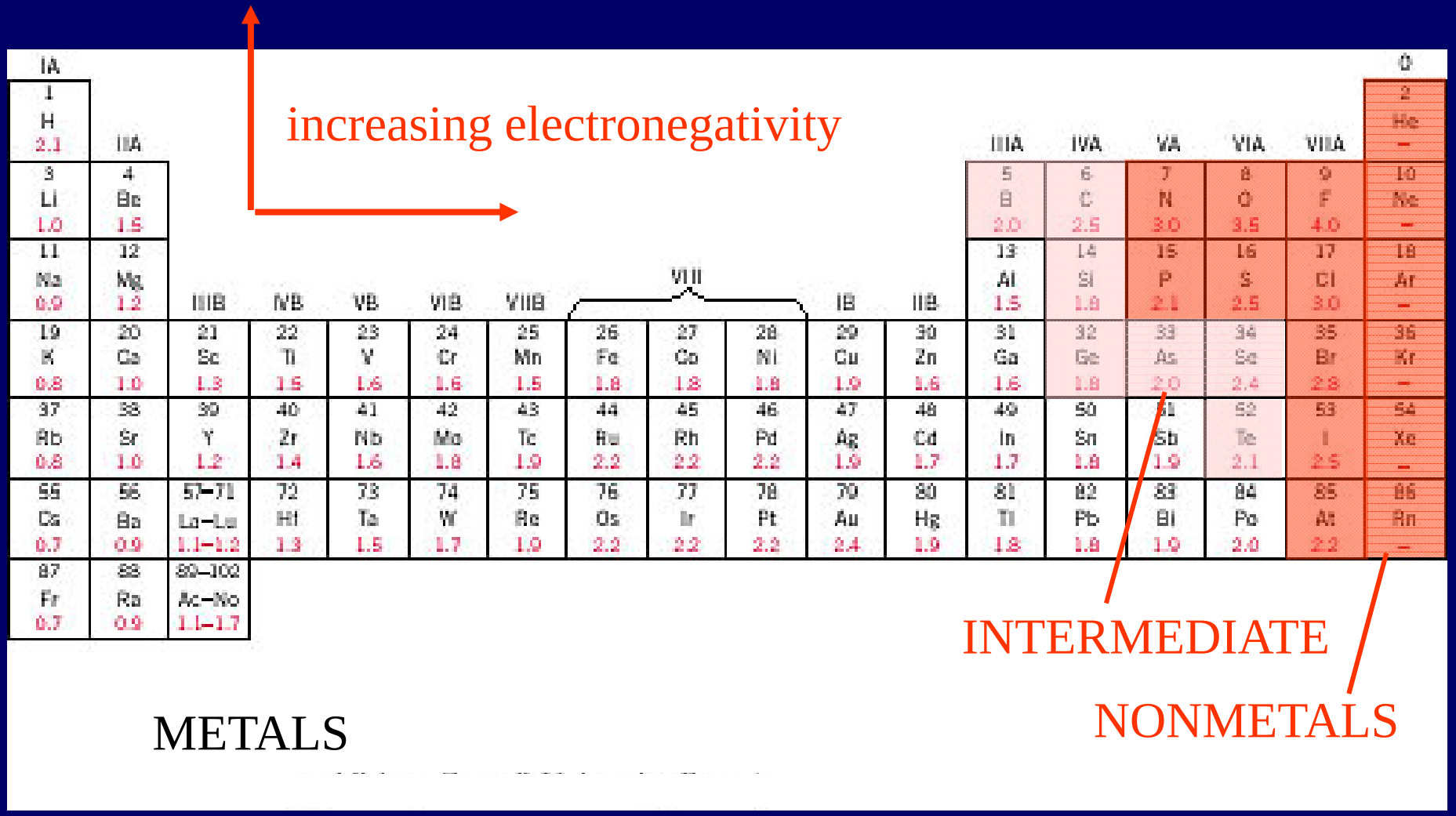
today

- Bonding in solids
- Structure of crystal solids

Bonding Forces and Energies

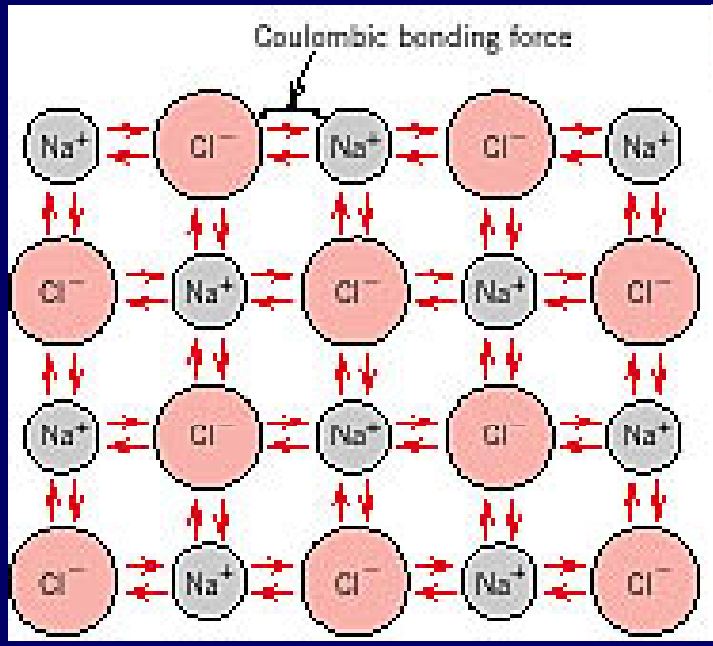


The Periodic Table



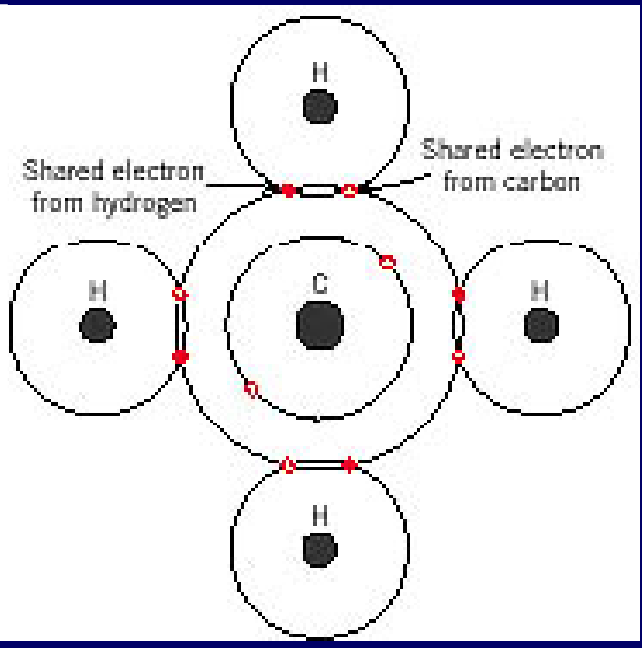
Ionic Bonding

e.g. sodium chloride

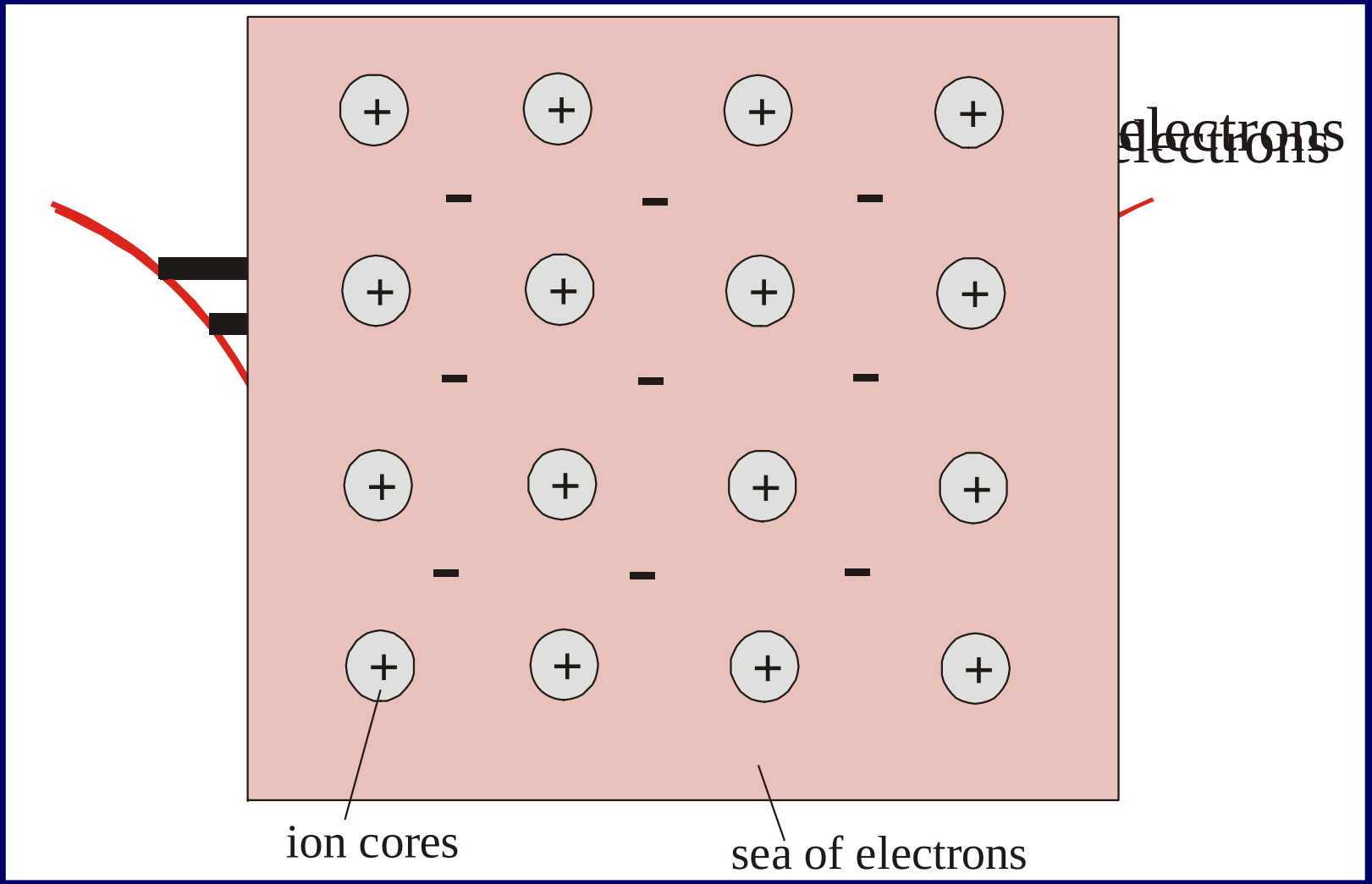


Covalent Bonding

e.g. methane



Metallic Bonding



Bonding Energies

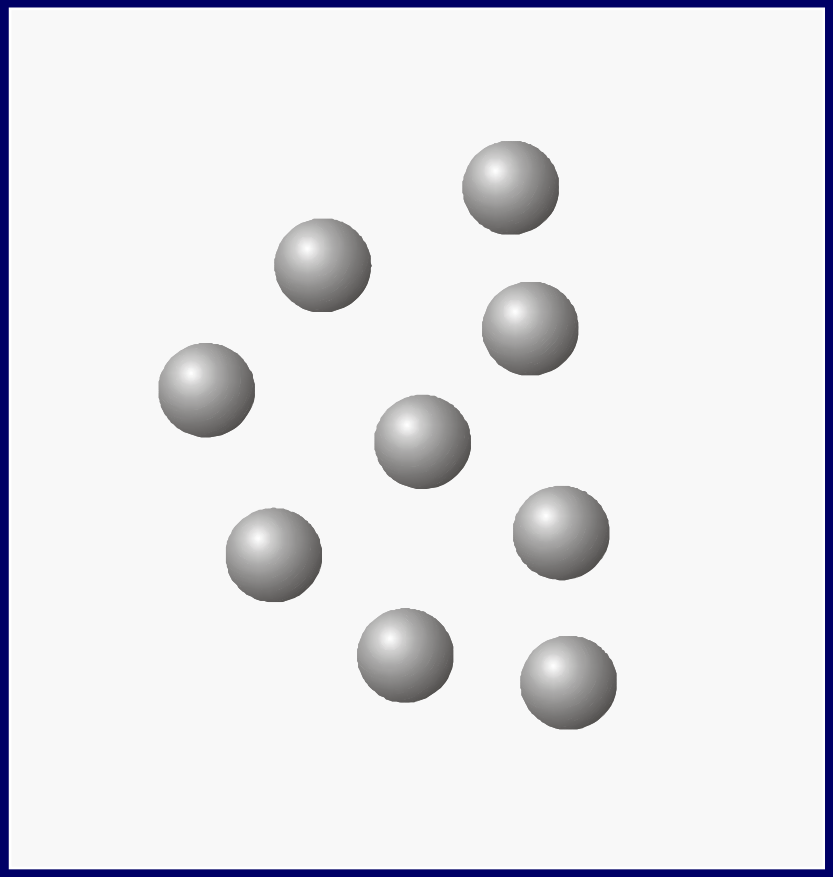
Bonding Type	Substance	Bonding Energy		Melting Temperature (°C)
		kJ/mol (kcal/mol)	eV/Atom, Ion, Molecule	
Ionic	NaCl	640 (153)	3.3	801
	MgO	1000 (239)	5.2	2800
Covalent	Si	450 (108)	4.7	1410
	C (diamond)	713 (170)	7.4	>3550
Metallic	Hg	68 (16)	0.7	−39
	Al	324 (77)	3.4	660
	Fe	406 (97)	4.2	1538
	W	849 (203)	8.8	3410

high

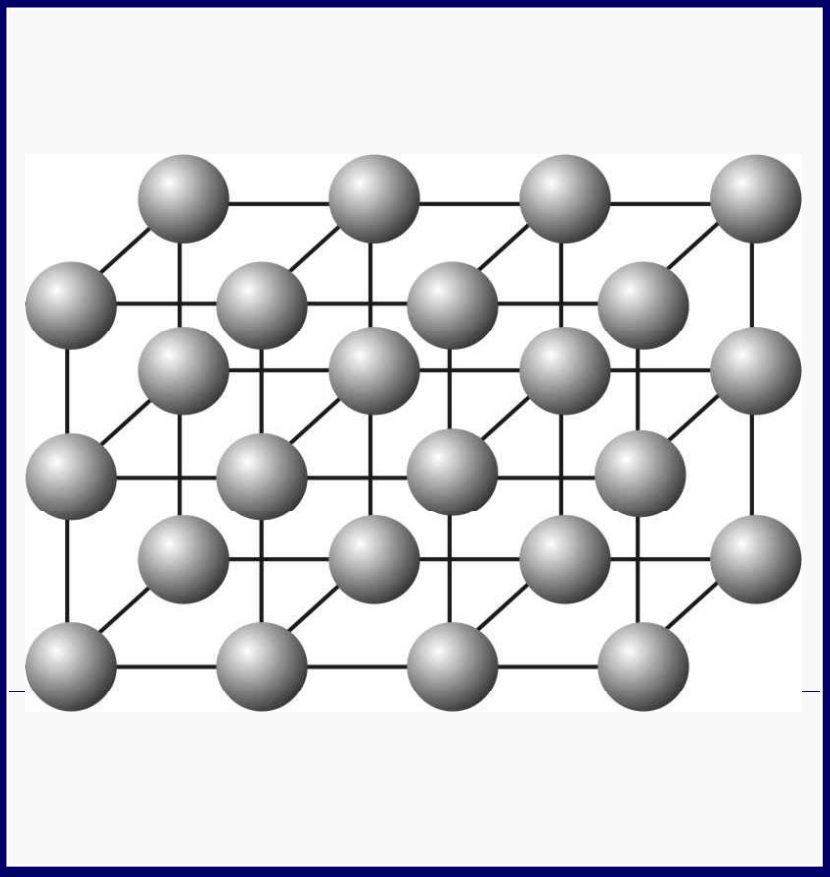
Crystalline Structures

Crystalline Structures

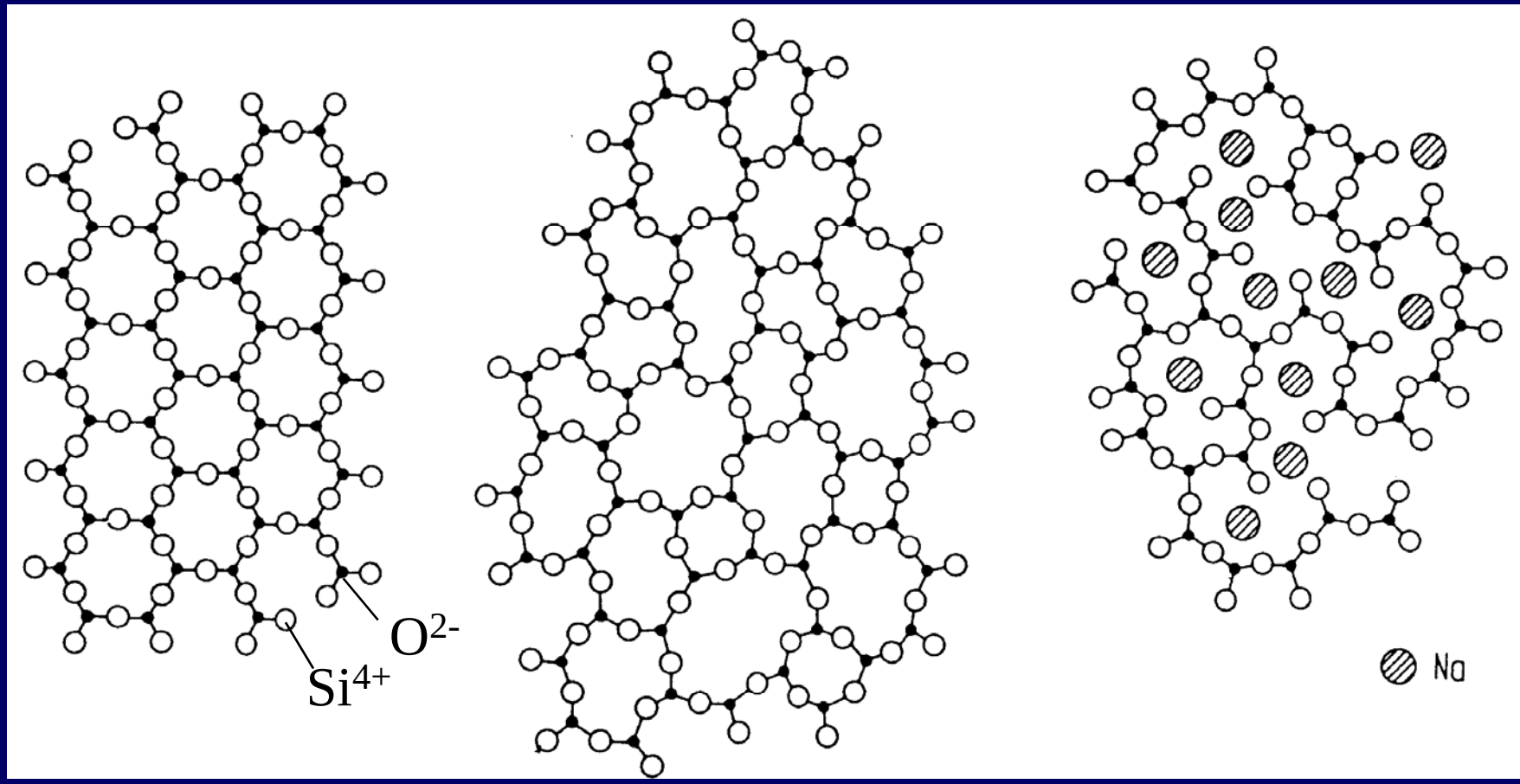
amorphous



crystalline



Example: Glass

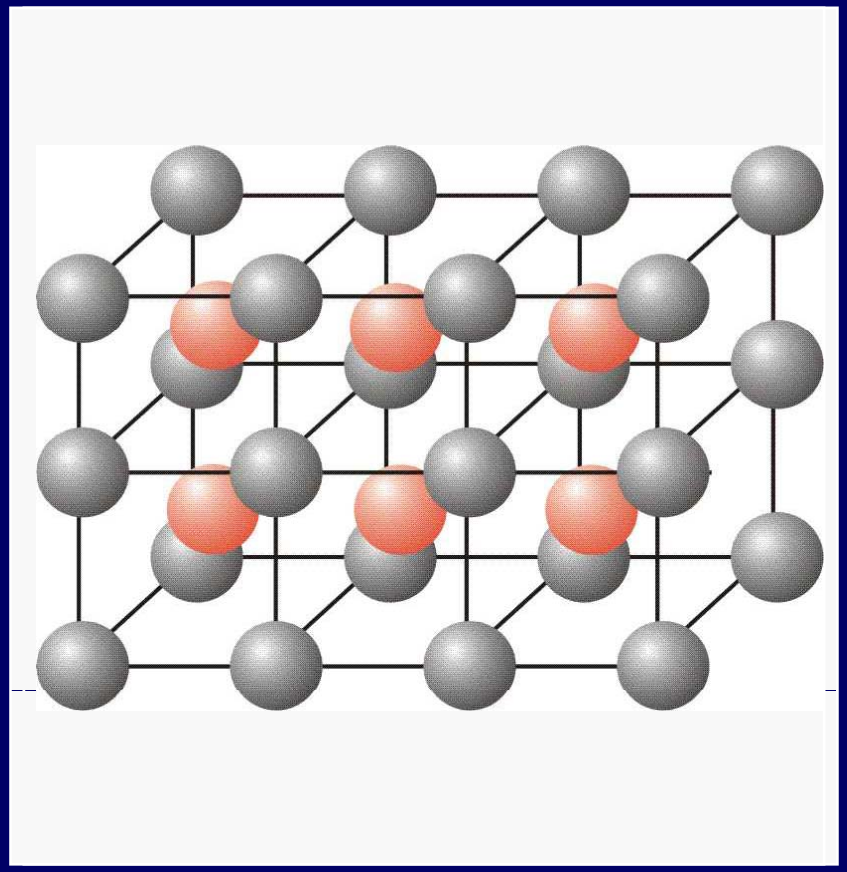


quartz
(crystalline)

quartz glass
(amorphous)

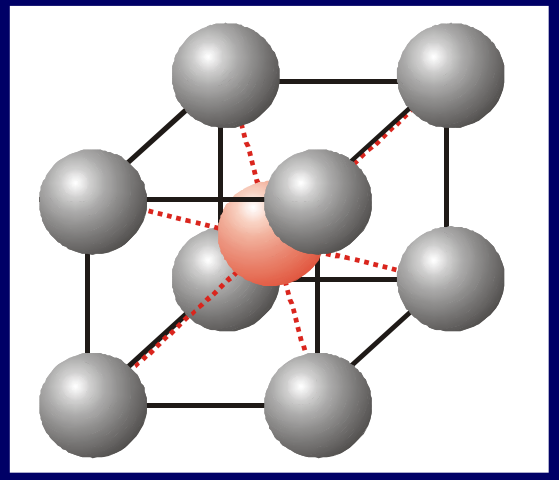
glass
(amorphous)

Crystalline Structures

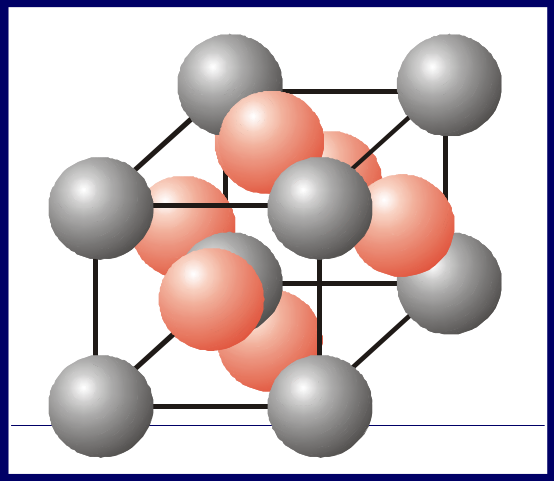


simple cubic

body-centered cubic (bcc)



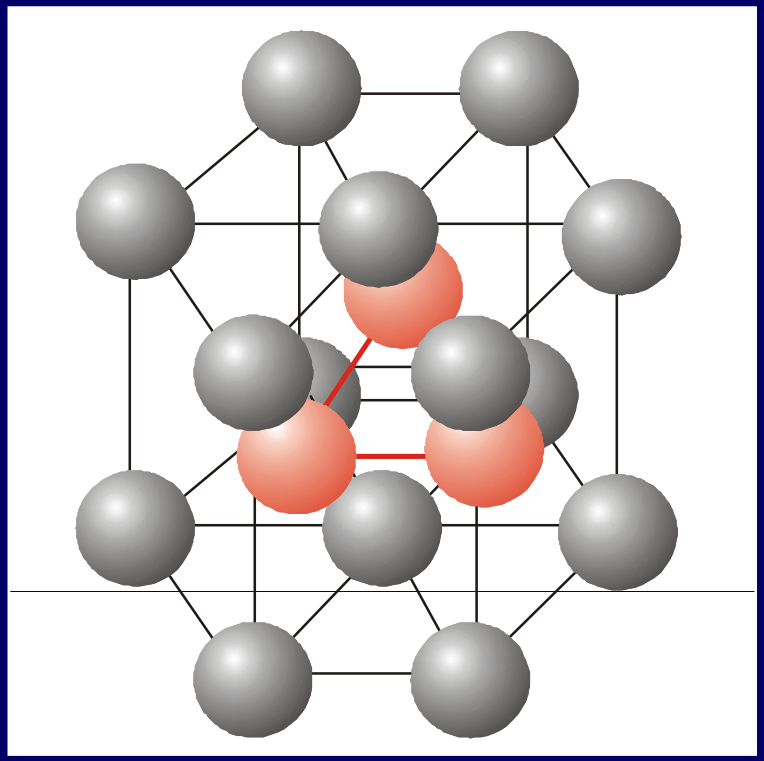
bcc

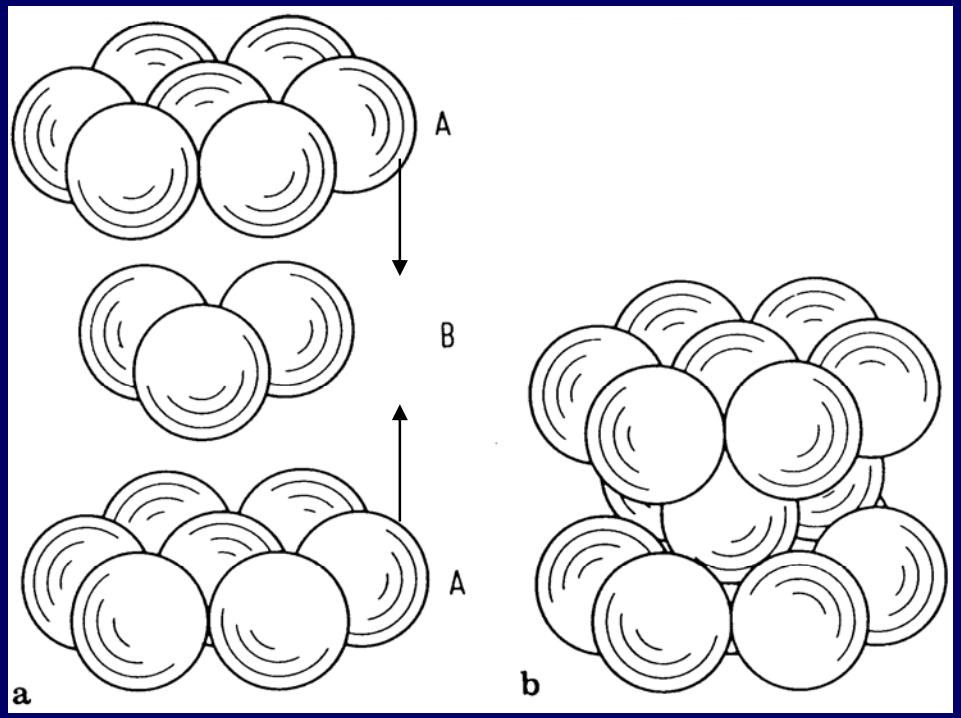


fcc

Hexagonal Crystal Structures

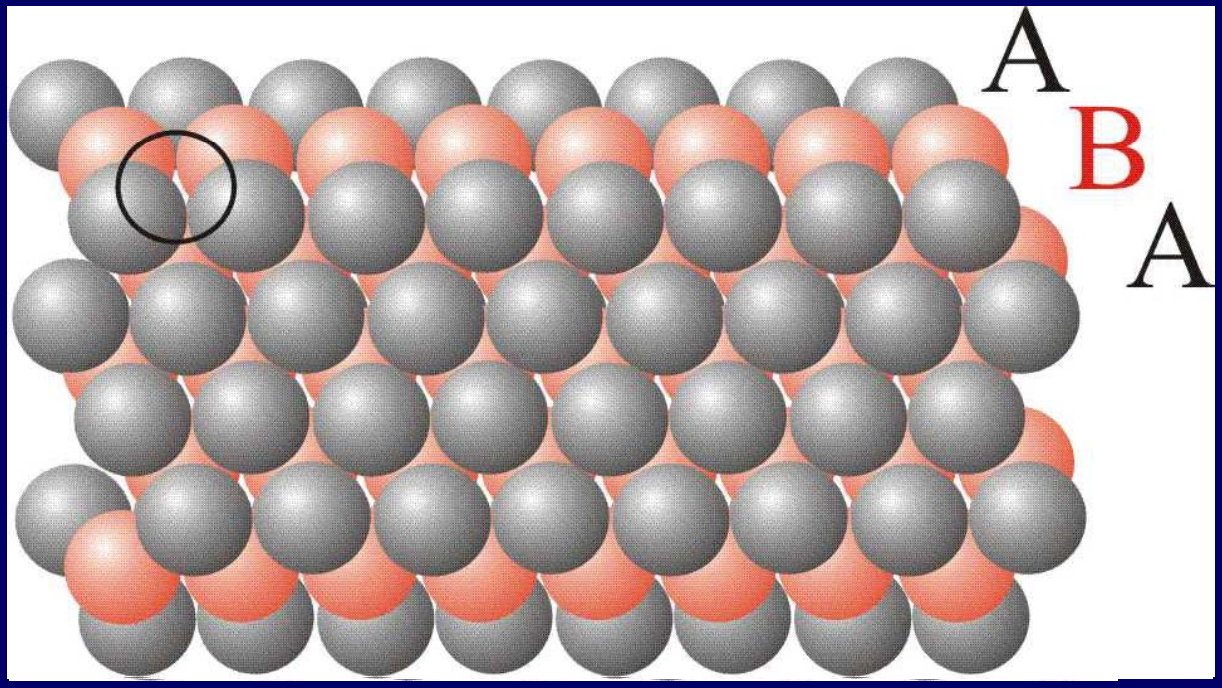
hcp unit cell





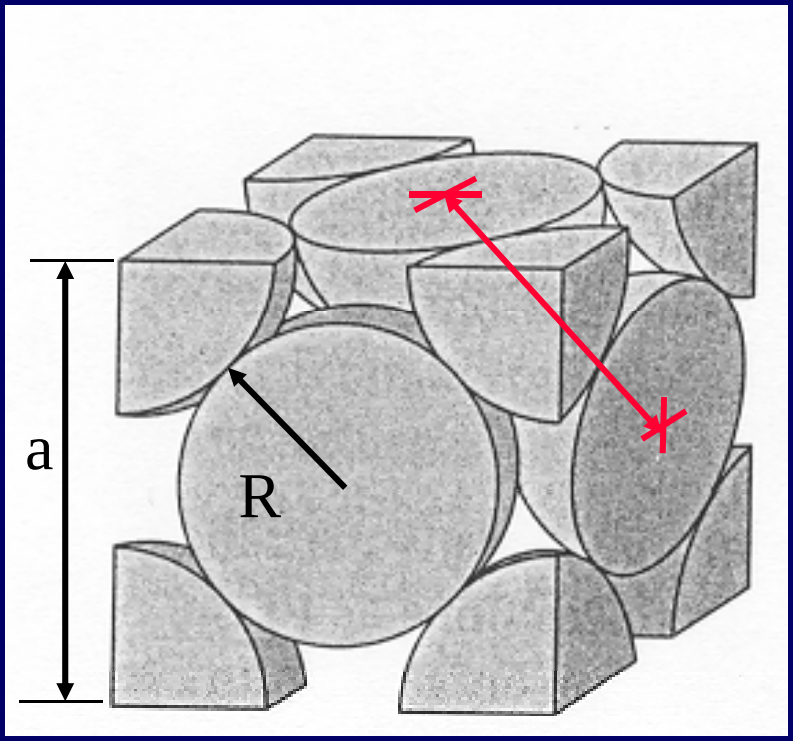
Stacking Sequence of Close-Packed Structures

first plane A, second plane B and third plane A: hcp

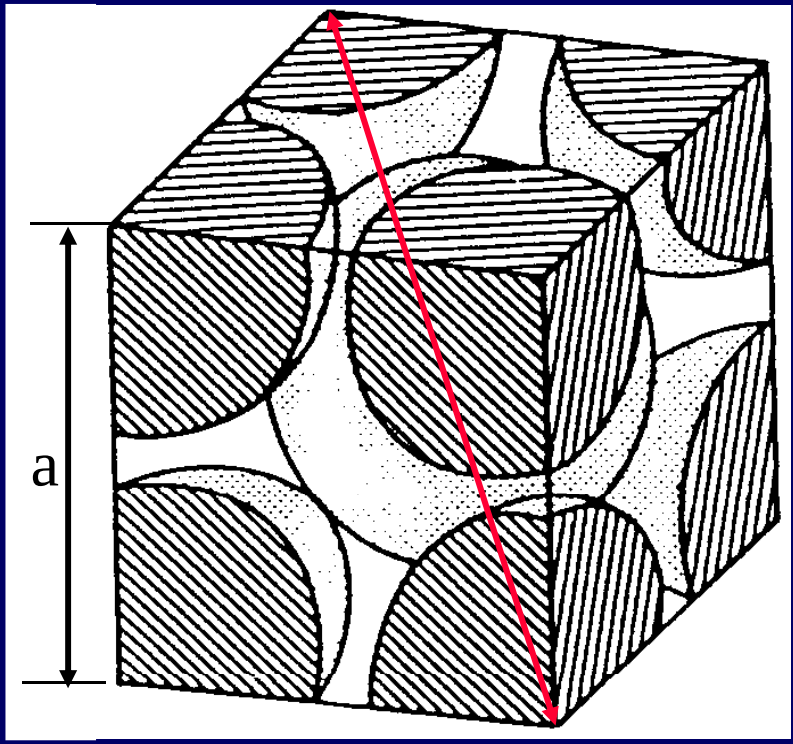


FCC and BCC Solid Sphere Model

fcc unit cell



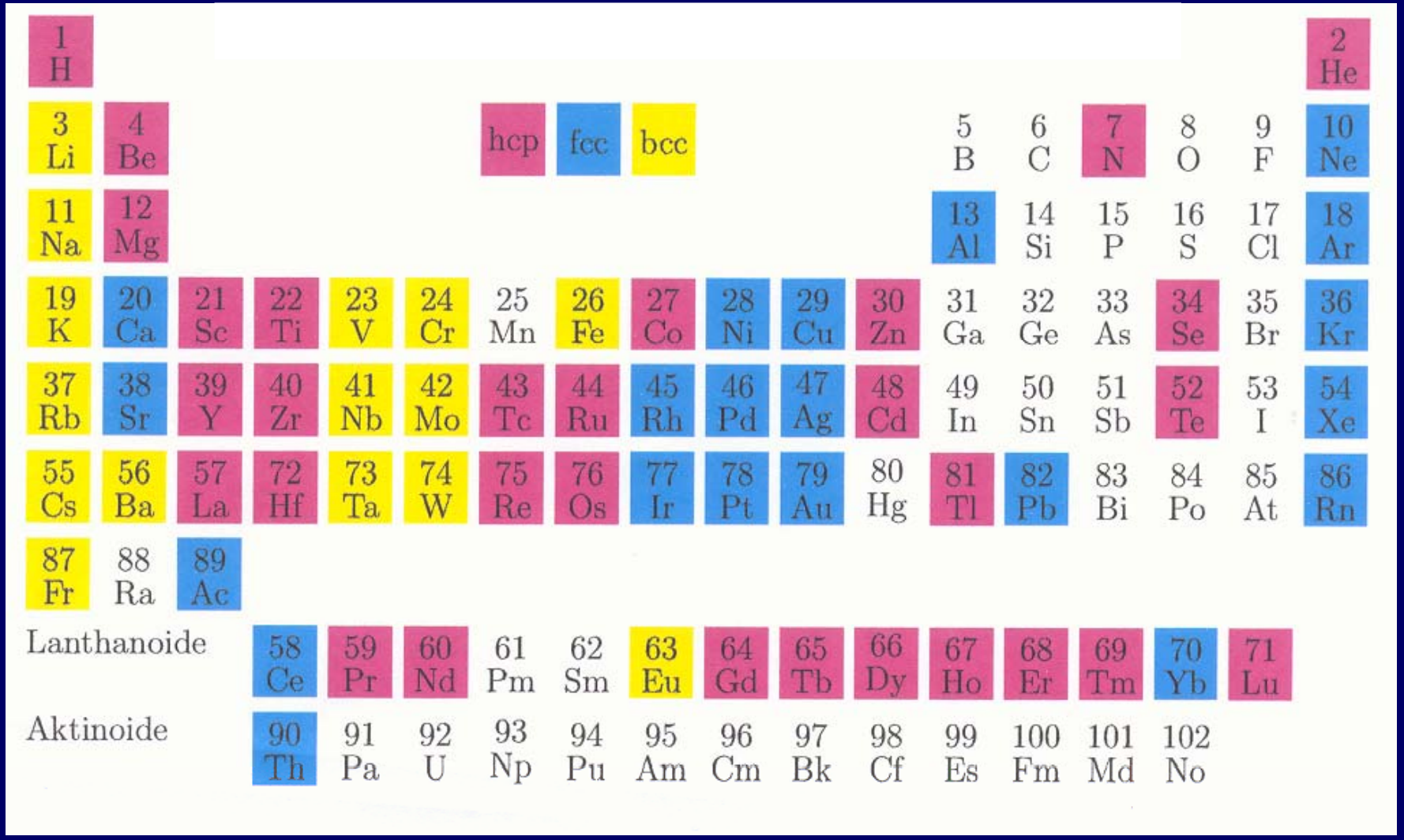
bcc unit cell



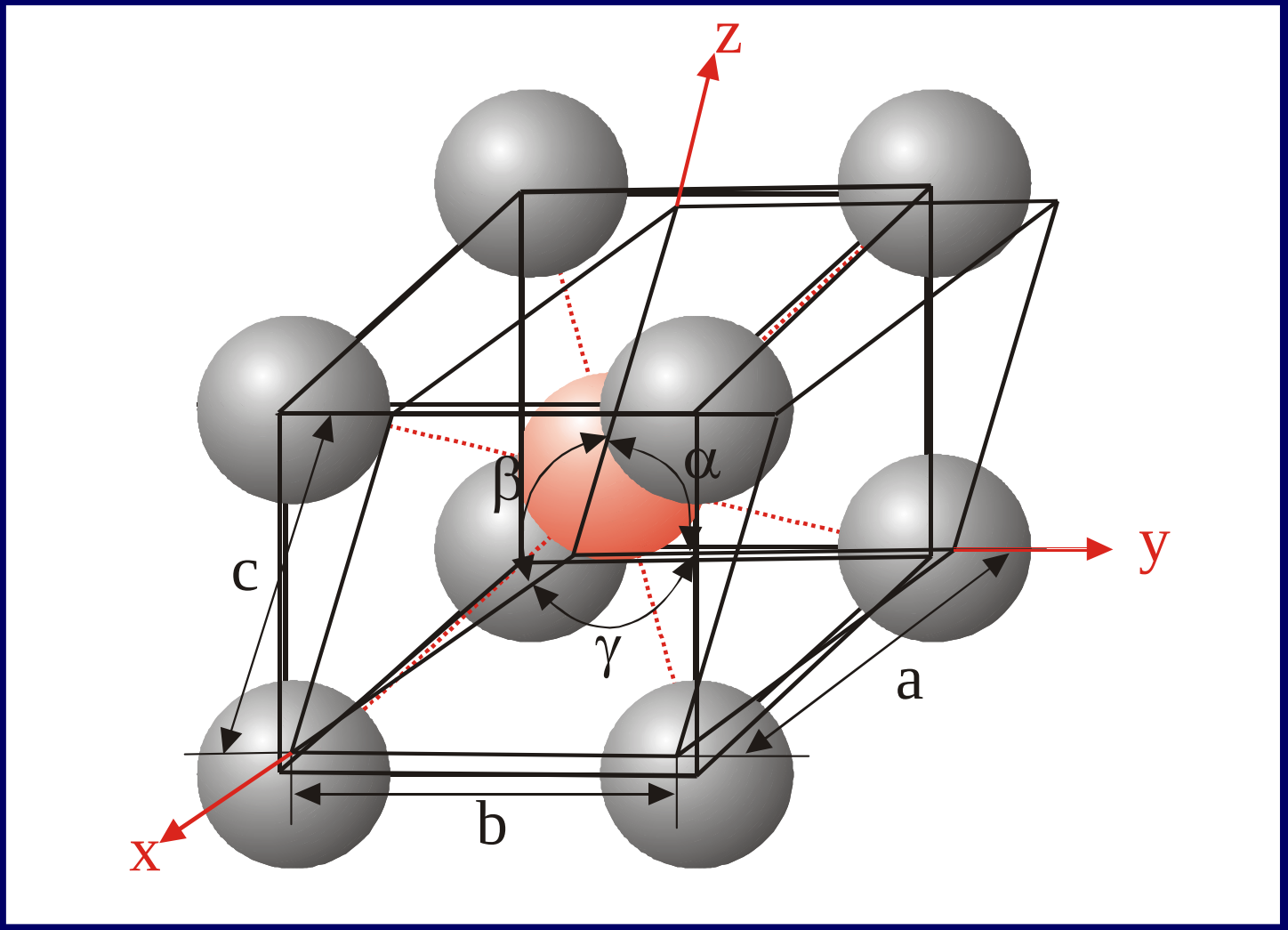
R = atomic radius

a = unit cell length / lattice constant

Crystalline Structures of Materials

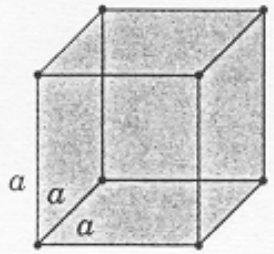


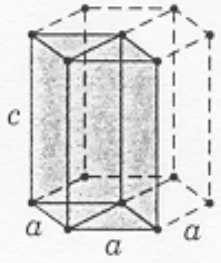
Lattice Parameters

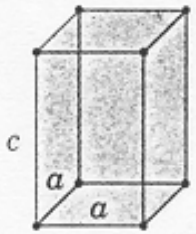


Crystal Systems

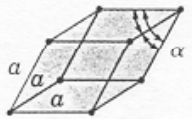
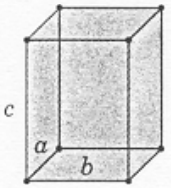
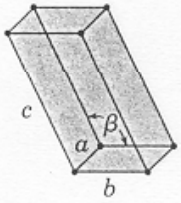
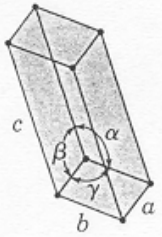
Cubic	$a = b = c$	$\alpha = \beta = \gamma = 90°$
Hexagonal	$a = b \neq c$	$\alpha = \beta = 90°, \gamma = 120°$
Tetragonal	$a = b \neq c$	$\alpha = \beta = \gamma = 90°$







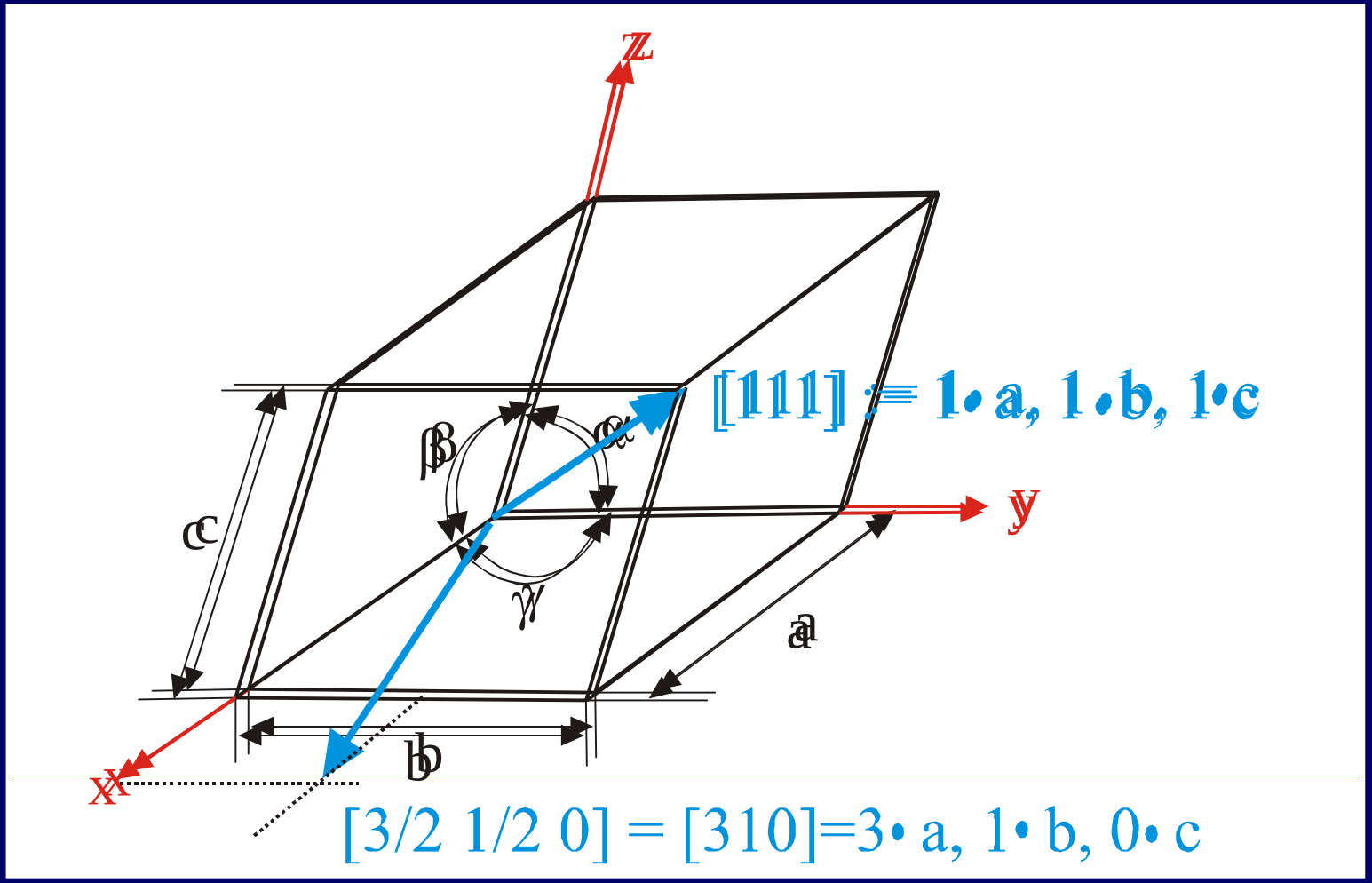
Crystal Systems

Rhombohedral	$a = b = c$	$\alpha = \beta = \gamma \neq 90°$	
Orthorhombic	$a \neq b \neq c$	$\alpha = \beta = \gamma = 90°$	
Monoclinic	$a \neq b \neq c$	$\alpha = \gamma = 90° \neq \beta$	
Triclinic	$a \neq b \neq c$	$\alpha \neq \beta \neq \gamma \neq 90°$	

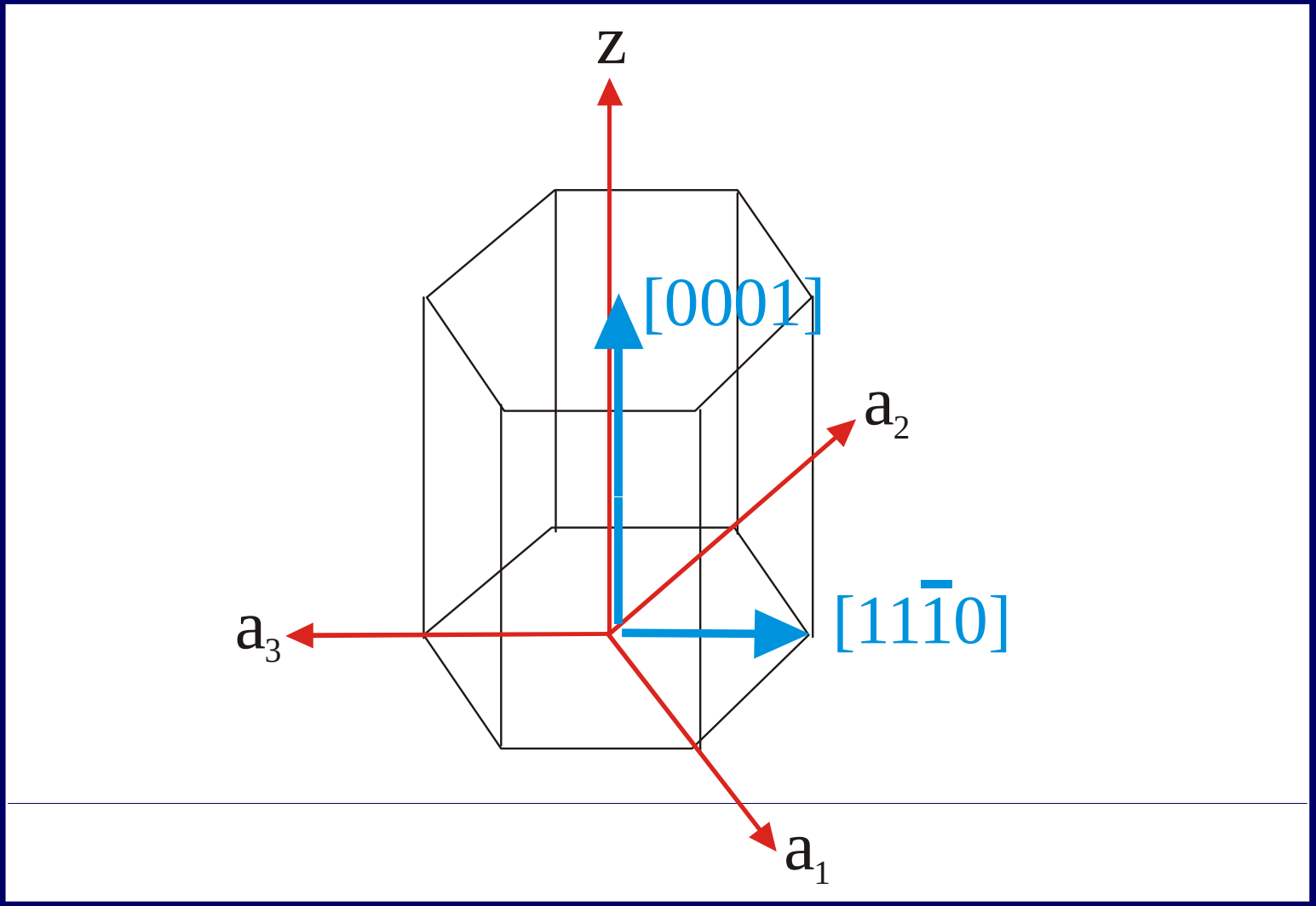
How to define a direction

- Vector of convenient length (pass through origin)
- Project the vector to the axes (and measure in a, b, and c)
- Multiply or divide these numbers by common factor to get smallest set of integers
- Write them down as [uvw]

Miller Indices: Crystallographic Directions



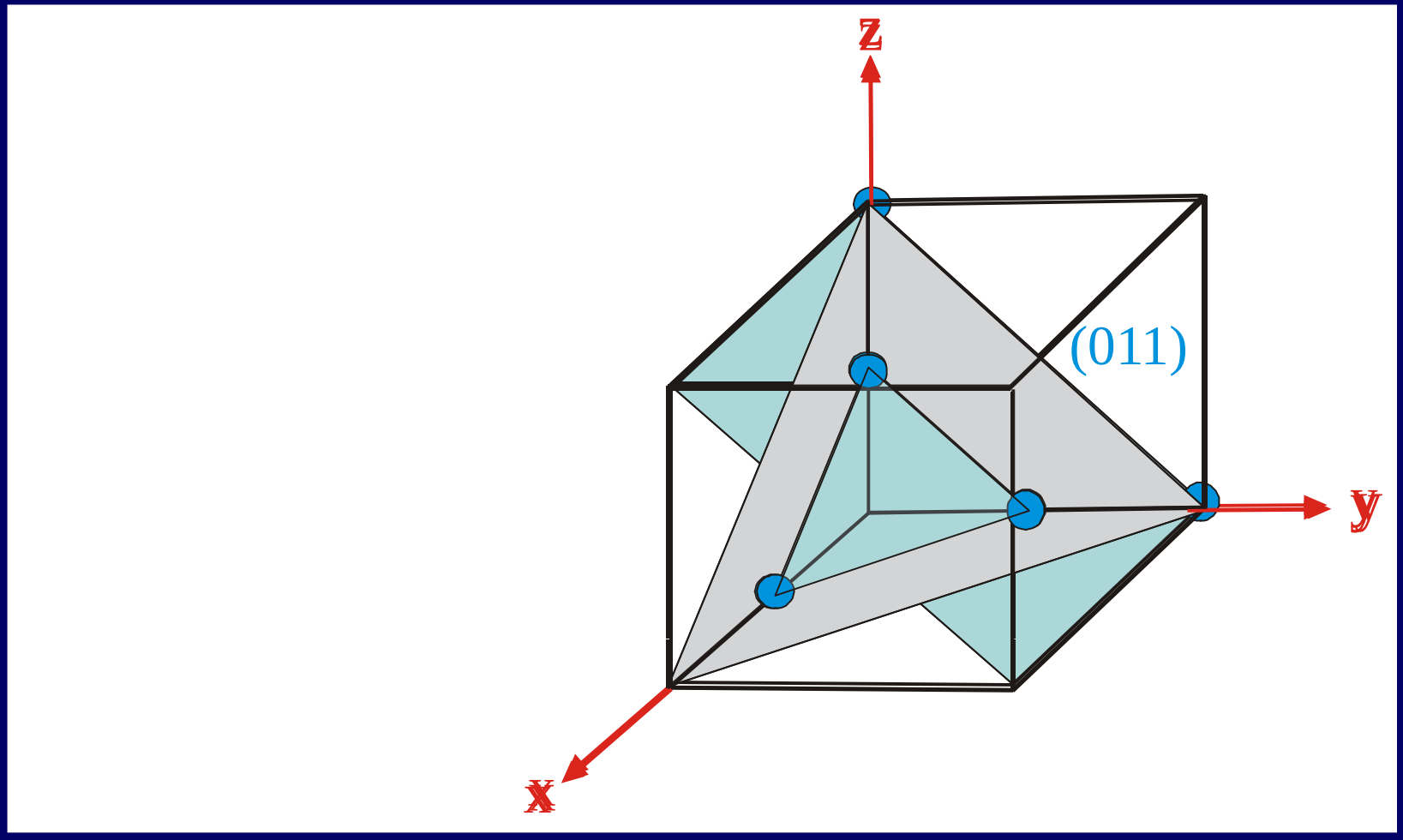
Miller Indices: Crystallographic Directions (Miller Bravais)



How to define a plane

- Plane may not include origin!
- Determine the intercepts with appropriate axes as a, b, and c
- Take reciprocals (no intercept means infinity $\rightarrow$ reciprocal of infinity = 0)
- Multiply or divide these numbers by common factor to get smallest set of integers
- Write them down as (hkl)

Miller Indices: Lattice Planes



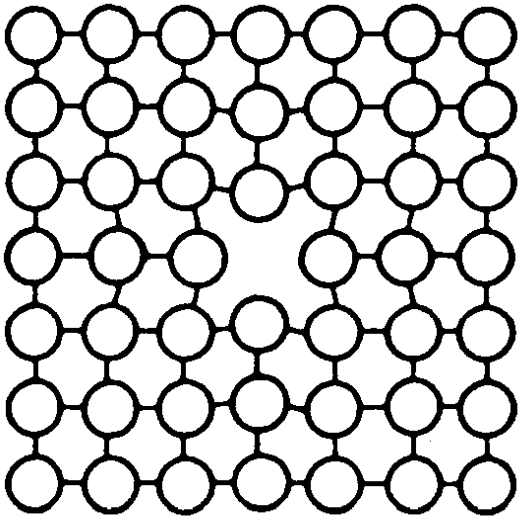
Defects

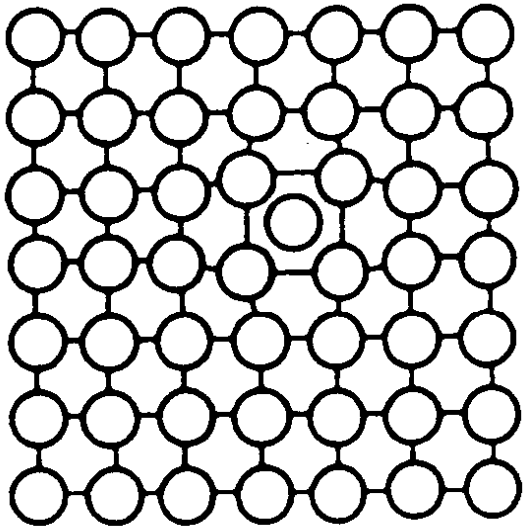
- Point defects
- Linear defects
- 2-dimensional defects

Point Defects

vacancy

self-interstitial

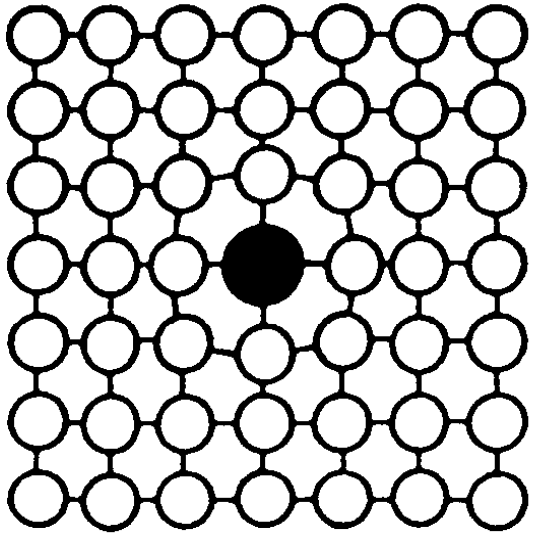


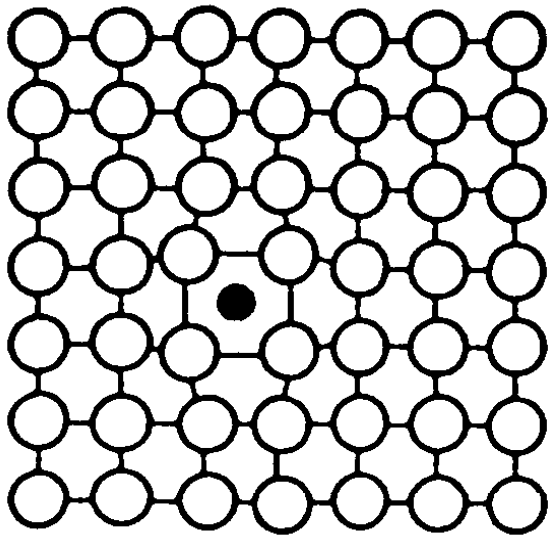


Impurity Atoms

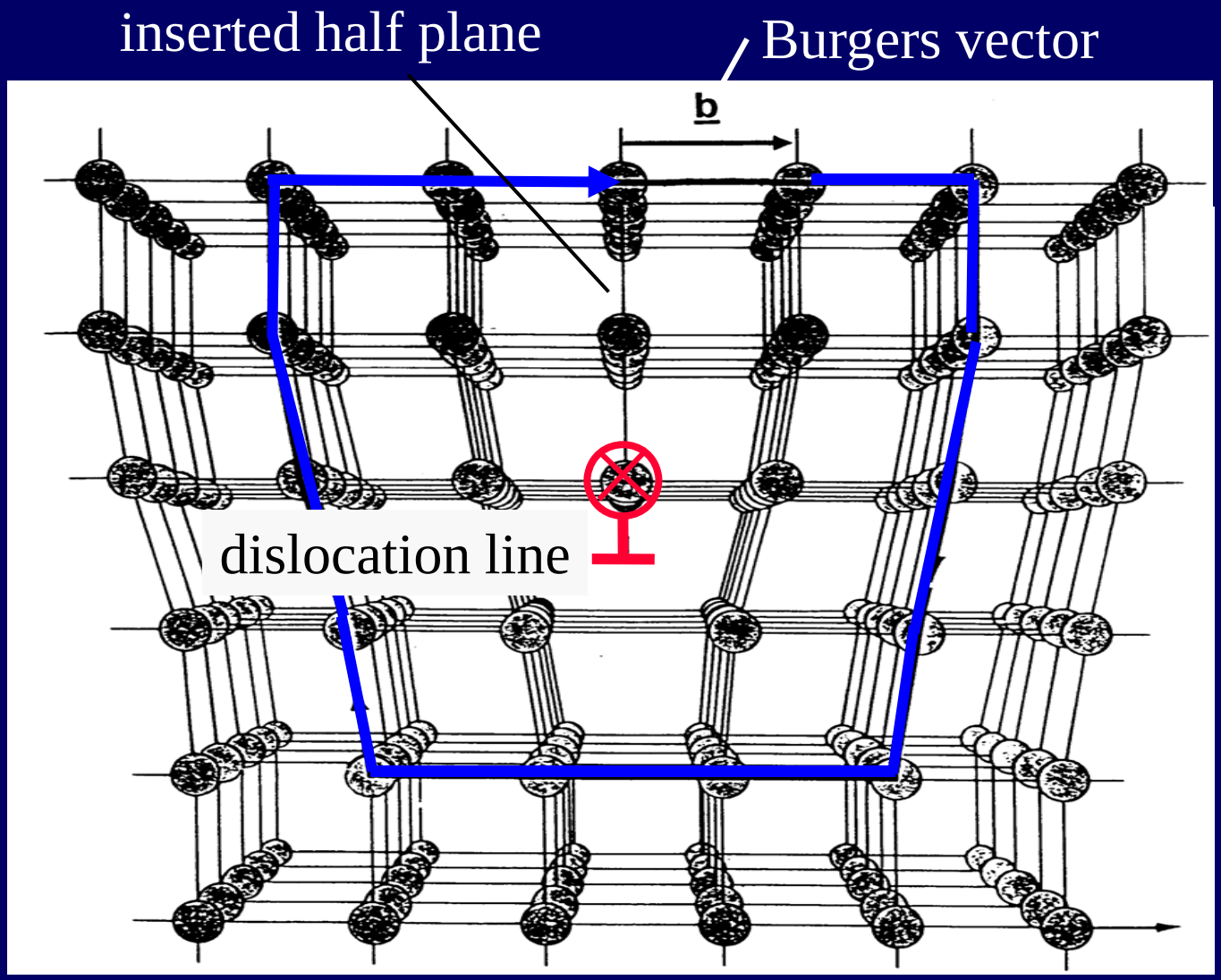
substitutional

interstitial

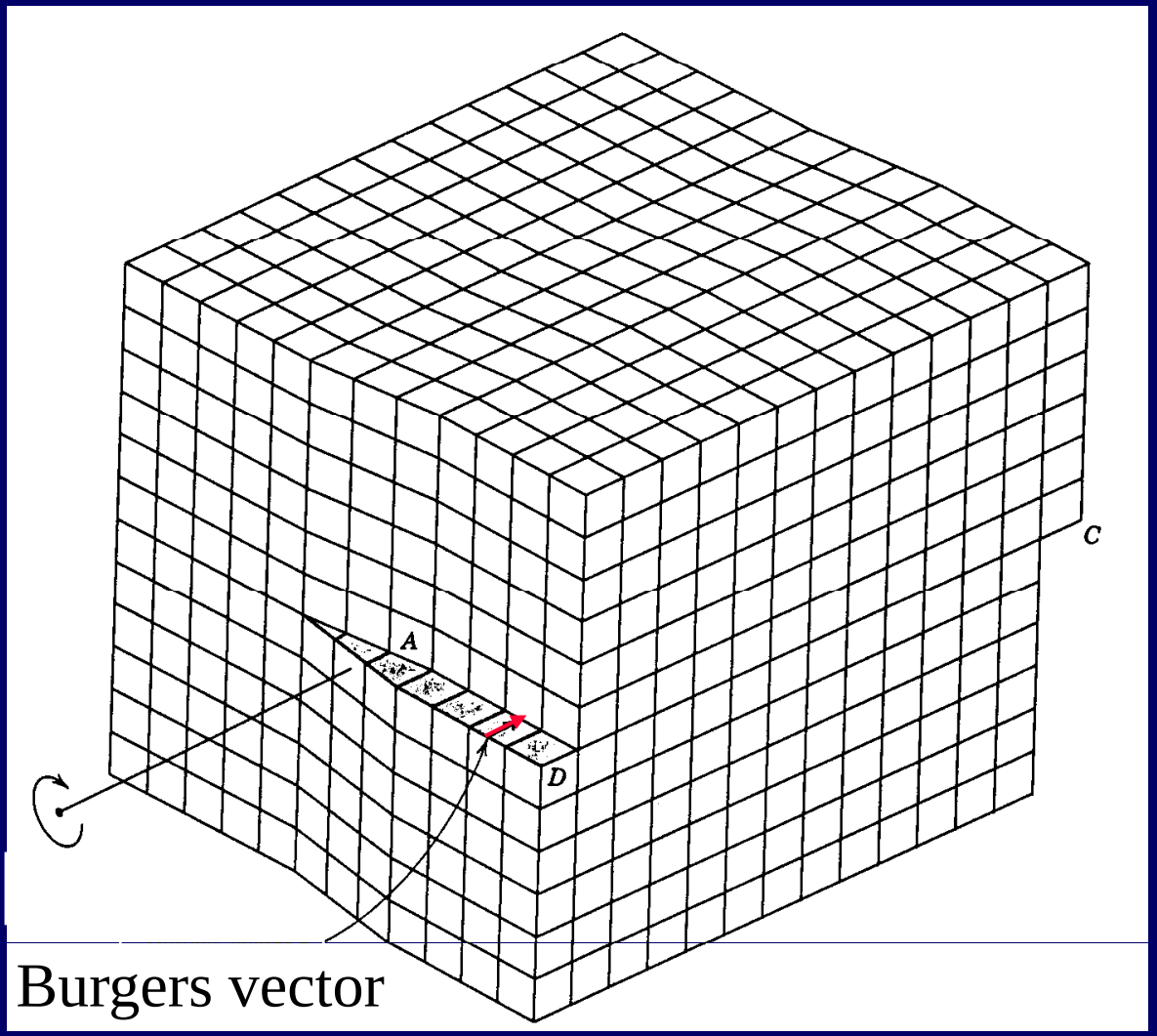




Dislocations: Edge Dislocation

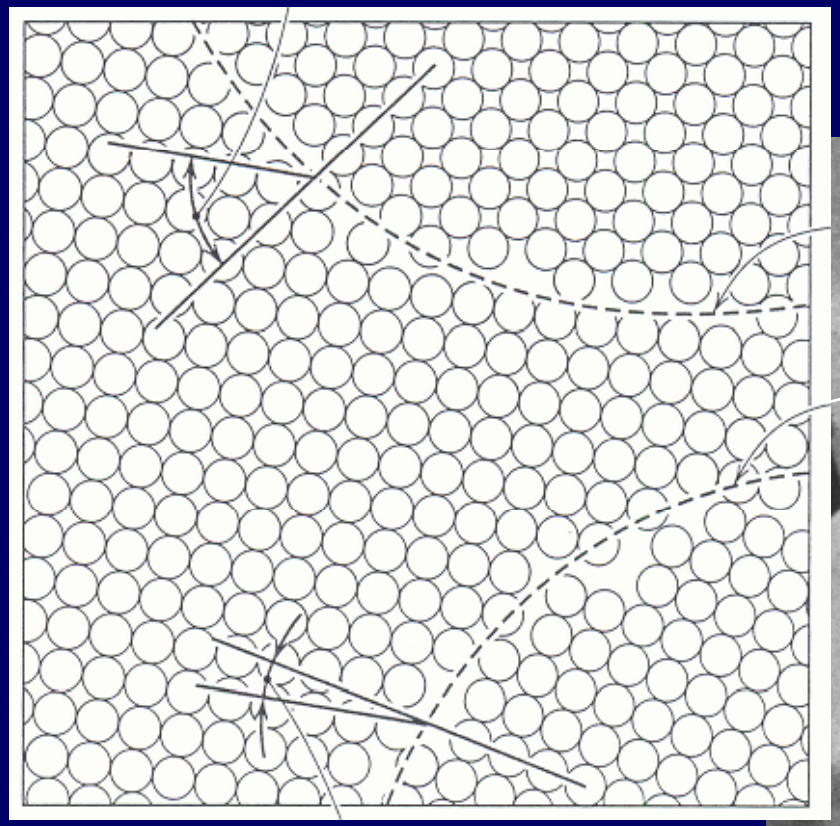


Dislocations: Screw Dislocation



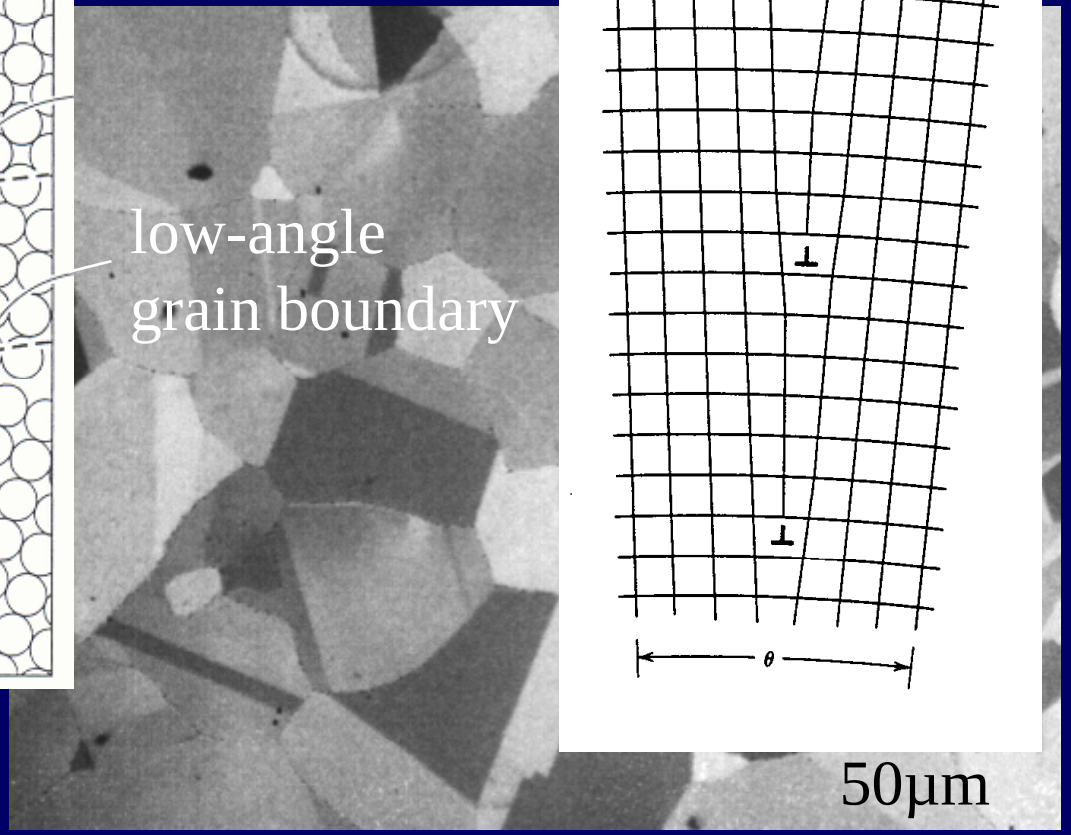
Grain Boundaries

high-angle grain boundary (Θ>15°)



Ni-Base Superallo

low-angle
grain boundary



next

- Properties of materials