Crystal System

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Solid State

Crystalline

- Atoms Stacked in periodic manner
- Repeated pattern unit in 3 dimensions

Polycrystalline

- Periodicity is interrupted at grain boundaries

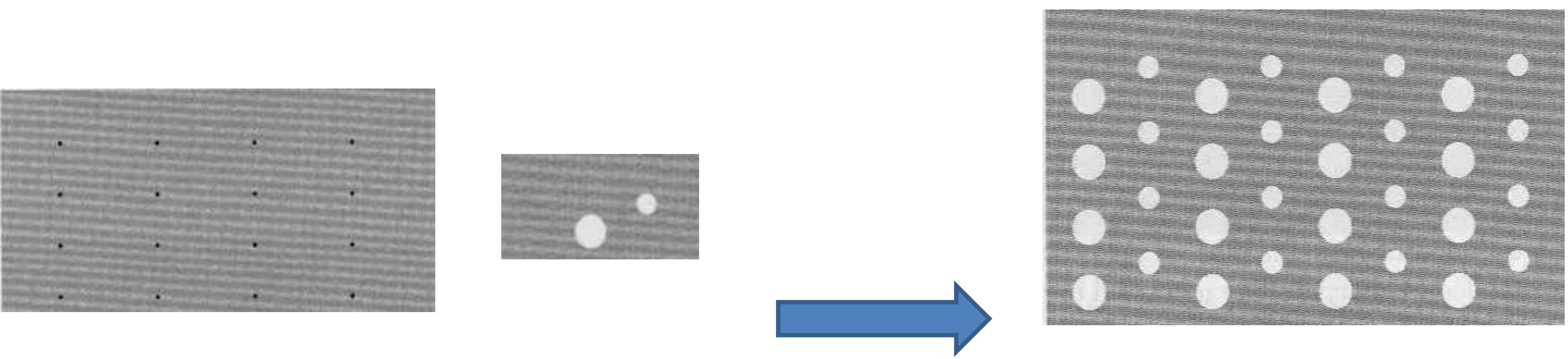
Amorphous

- Size of grains comparable to pattern unit

Crystal Structure

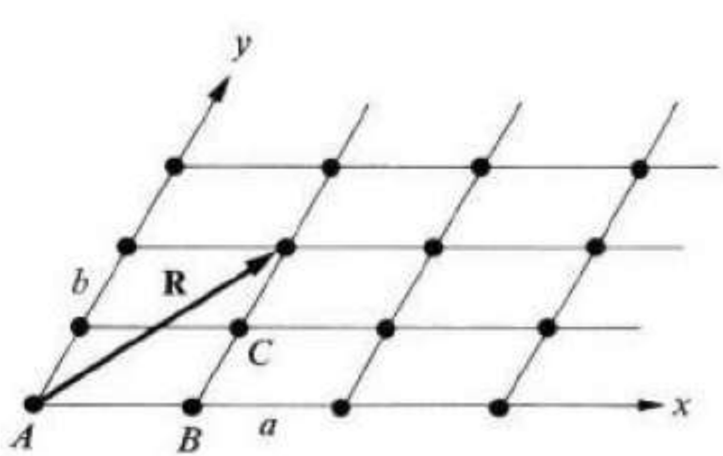
An ideal crystal is formed by infinite repetition of an identical group of atoms.

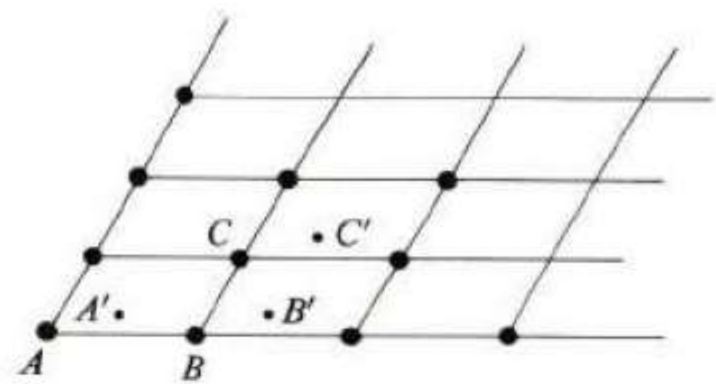
- Three dimensional periodic array of identical building blocks
- Basis:-Atoms, group of atoms
- Lattice:- Set of mathematical points to which basis is attached



Lattice + Basis → Crystal structure

Bravais and Non Bravais Lattice





Bravais Lattice

- All lattice points are equivalent
- All atoms are of the same kind

Non Bravais Lattice

- Some of the lattice points are nonequivalent
- Translation from A to A’ is not equivalent
- Lattice with a basis or interpenetrating bravais lattices

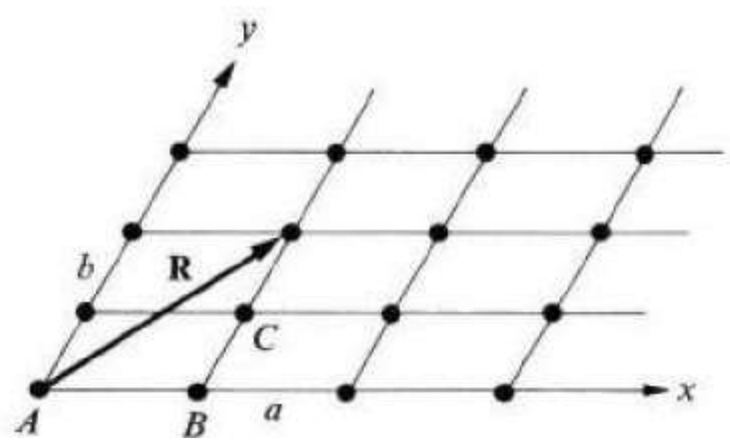
Lattice Translation Vectors

- Lattice is invariant under translation

i.e. lattice as viewed from any lattice point remains invariant, translated by integral multiple of basis vectors **a,b,c**

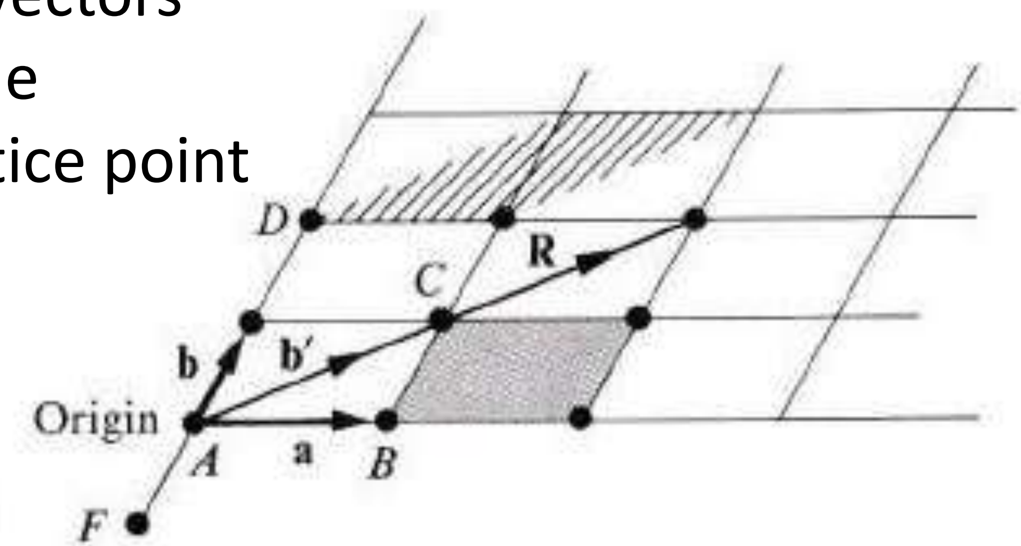
- $\mathbf{R}' = \mathbf{R} + n_1\mathbf{a} + n_2\mathbf{b} + n_3\mathbf{c} = \mathbf{R} + \mathbf{T}$

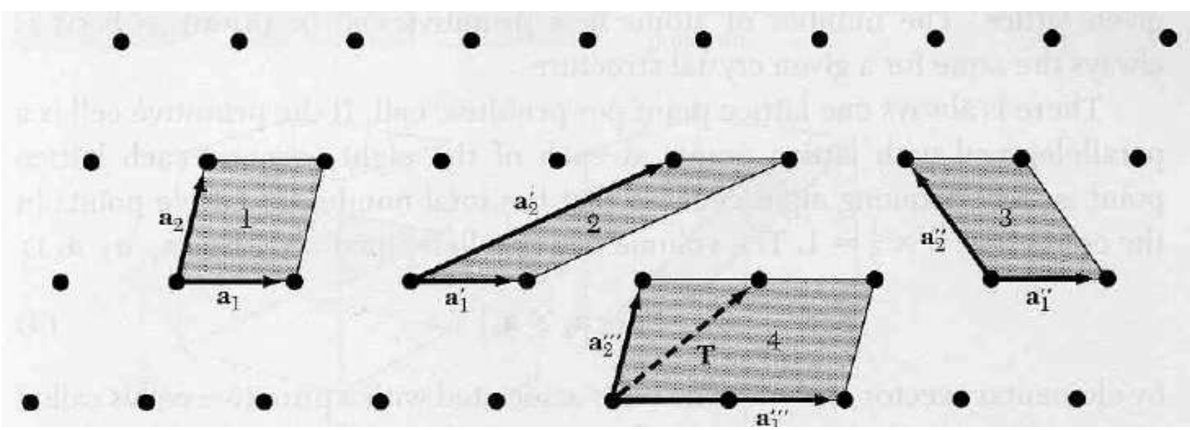
Where n_1, n_2, n_3 are arbitrary integers, **T** is known as translation vector



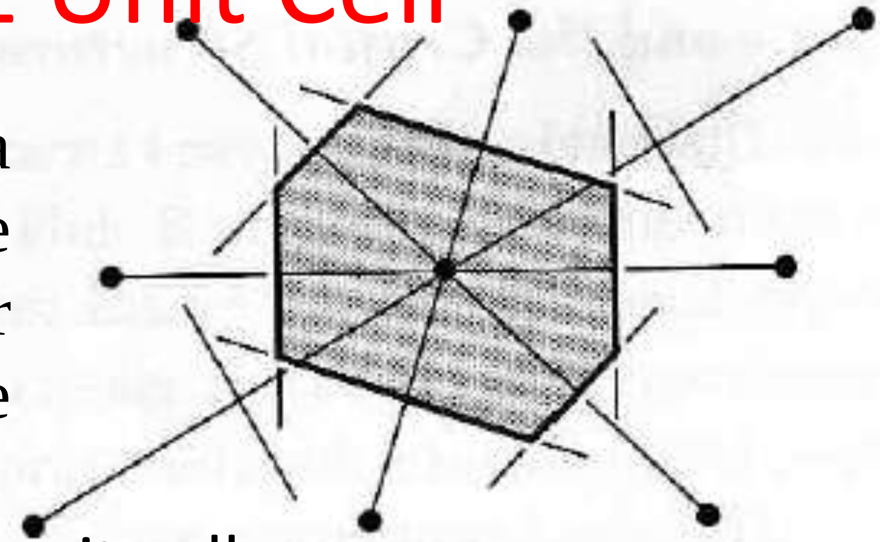
Basis Vectors and Primitive Unit Cells

- Smallest unit which when translated by all lattice vectors covers the lattice once and only once.
- The vectors a and b are basis vectors
- Choice of unit cell is not unique
- Each unit cell has only one lattice point
- All unit cells have same area
- **S=|a×b|**





Wigner Seitz Unit Cell



Weigner Seitz unit cell about a lattice point is the region of space that is closer to that particular point than to any other lattice point.

- Contains only 1 lattice point per unit cell
- Has all the properties of Primitive Unit cell.

Construction

✓Join all lattice points by straight lines

✓Draw normal bisector line/plane to these lines

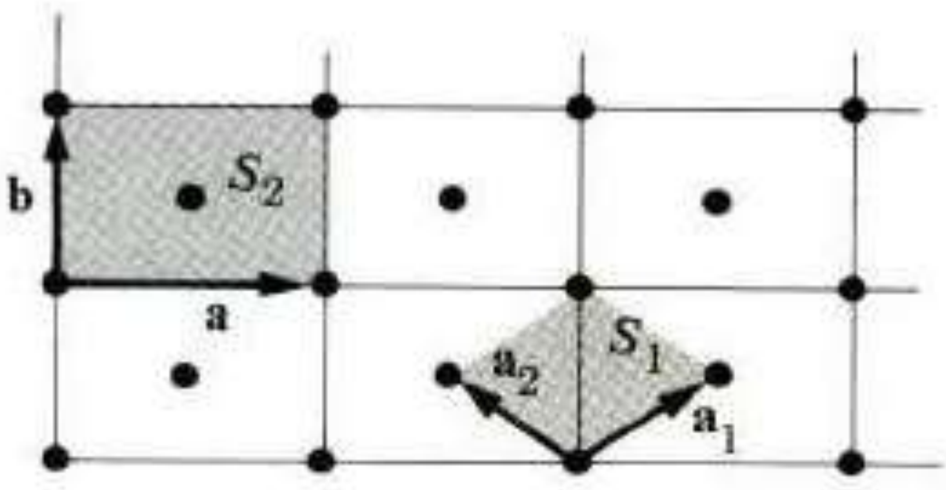
✓The smallest volume enclosed in this way is the Wigner Seitz primitive cell.

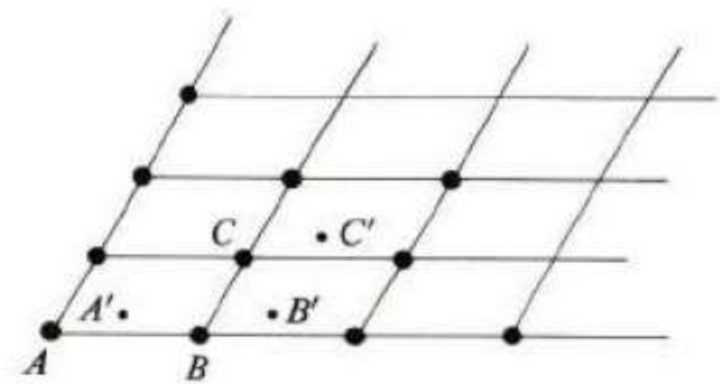
✓When translated by all translation vectors complete lattice can be covered by this cell only once.

Non Primitive Unit Cell

- Unit cell with area larger than primitive unit cell
- More than 1 lattice point per unit cell

Non-primitive cells and non-Bravais lattices have no connection.
Non Primitive Cell refers to the particular (and somewhat arbitrary) choice of basis vectors in a Bravais lattice.
Non Bravais Lattice refers to the physical fact of nonequivalent sites.

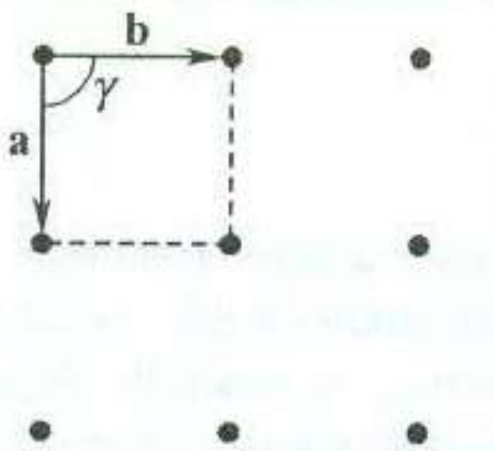




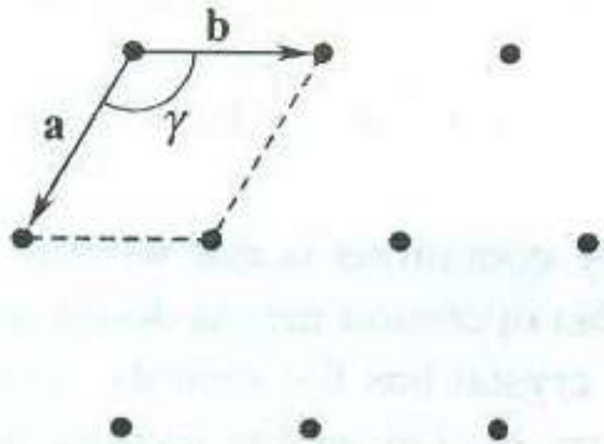
Lattice types in 2 dimensions

Lattice Type	Conventional unit cell	Axes and angles	Point group symmetry about lattice point
Oblique	Parallelogram	a≠b, ø=0°	2
Square	Square	a=b, ø=90°	4 mm
Hexagonal	60° rhombus	a≠b, ø=120°	6 mm
Primitive rectangular	Rectangle	a≠b, ø=90°	2 mm
Centred rectangular	Rectangle	a≠b, ø=90°	2 mm

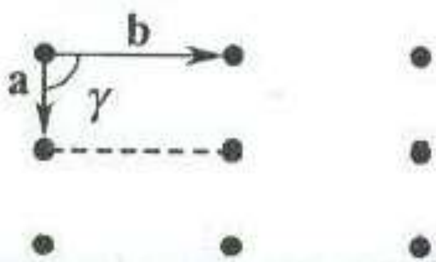
Lattices in 2 D



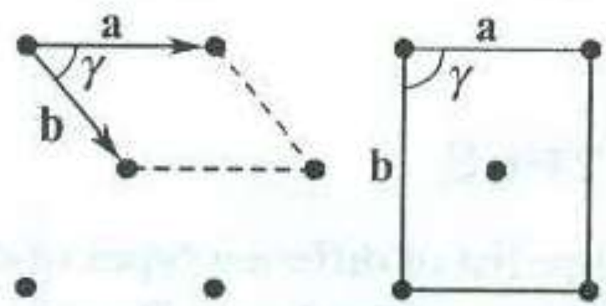
(a) Square lattice
$|\mathbf{a}| = |\mathbf{b}|, \gamma = 90°$



(b) Hexagonal lattice
$|\mathbf{a}| = |\mathbf{b}|, \gamma = 120°$



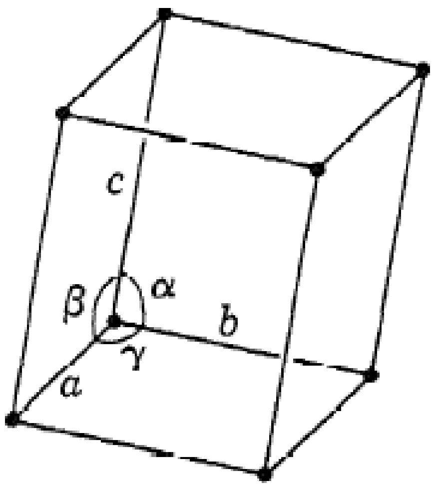
(c) Rectangular lattice
$|\mathbf{a}| \neq |\mathbf{b}|, \gamma = 90°$



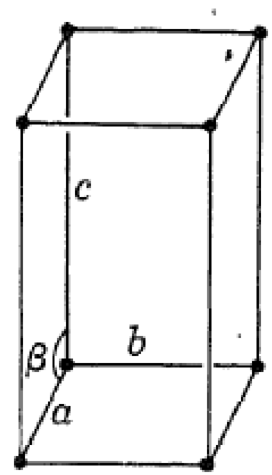
(d) Centred rectangular lattice axes are shown for both the primitive cell and the rectangular unit cell for which $|\mathbf{a}| \neq |\mathbf{b}|, \gamma = 90°$

7 crystal Systems, 14 Bravais Lattices in 3D

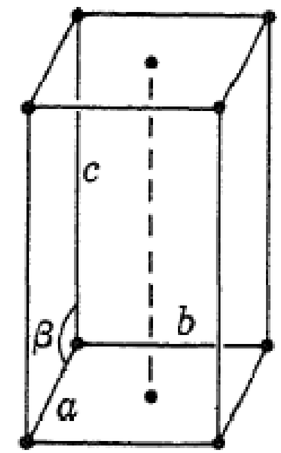
System	Essential Symmetry	Bravais Lattices	Restrictions on conventional cell angles and axes
Triclinic	No Planes, No Axes	Simple	$a \neq b \neq c$ $\alpha \neq \beta \neq \Upsilon$
Monoclinic	One 2-fold axis or one plane	Simple Base centred	$a \neq b \neq c$ $\alpha = \Upsilon = 90° \neq \beta$
Orthorhombic	Three mutually perpendicular 2-fold axis or 2 planes intersecting in a 2-fold axis	Simple Body centred Base centred Face centred	$a \neq b \neq c$ $\alpha = \beta = \Upsilon = 90°$
Tetragonal	One 4-foldaxis or 4-fold inversion axis	Simple Base centred	$a = b \neq c$ $\alpha = \beta = \Upsilon = 90°$
Cubic	Four 3-fold axis	Simple Body centred Face centred	$a = b = c$ $\alpha = \beta = \Upsilon = 90°$
Trigonal	One 3-fold axis	Simple	$a = b = c$ $\alpha = \beta = \Upsilon < 120°, \neq 90°$
Hexagonal	One 6-fold axis	Simple	$a = b \neq c$ $\alpha = \beta = 90°$ $\Upsilon = 120°$



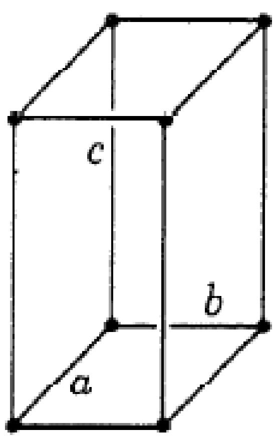
Triclinic



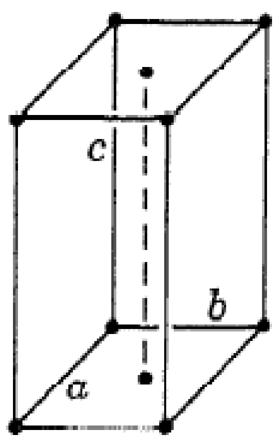
Monoclinic



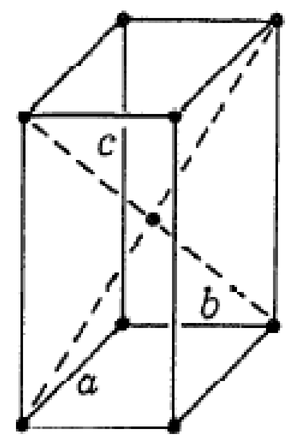
Monoclinic
base centred



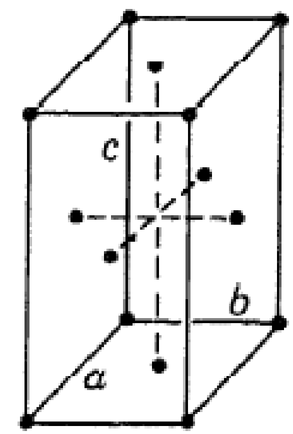
Ortho-rhombic



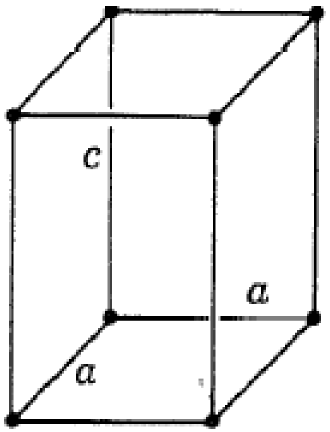
Ortho-rhombic
base centred



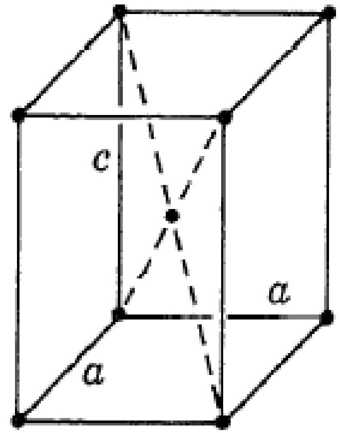
Ortho-rhombic
body centred



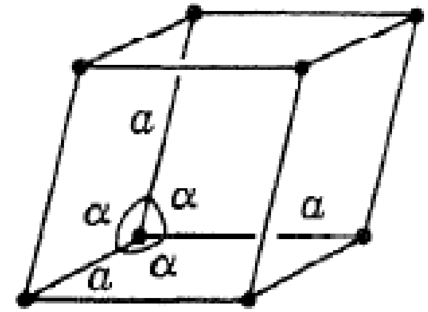
Ortho-rhombic
face centred



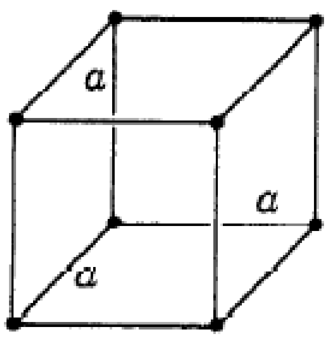
Tetragonal



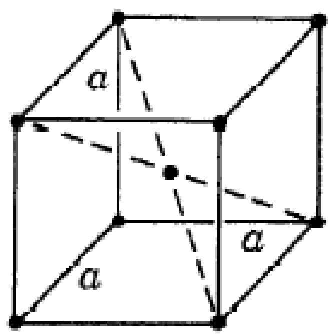
Tetragonal
body centred



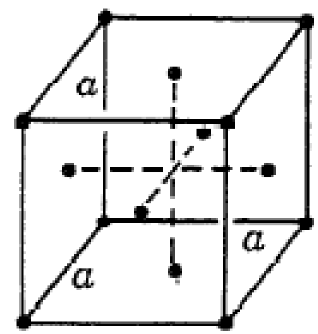
Trigonal



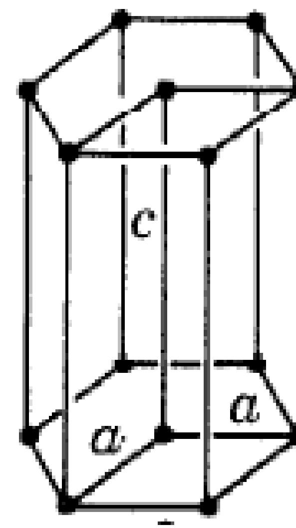
Simple
Cubic



Body centred cubic



Face centred cubic



Hexagonal

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Thank You

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