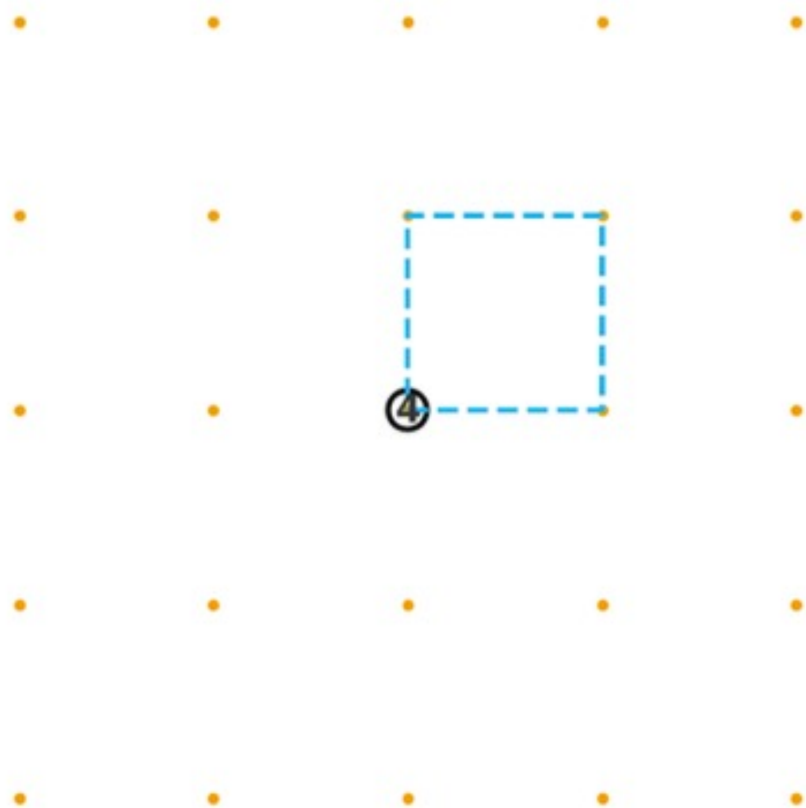
From last time, I want to clarify what 4mm and 6 mm mean.

2-D crystal systems: minimum ↔ maximum point-group symmetry

Crystal system	Unit-cell metric (a,b,γ)	Minimum symmetry (H–M)	Maximum symmetry (H–M)	Intuition for "min → max"
Oblique	$a \neq b,\ \gamma \neq 90^\circ, 60^\circ$	**1** (no symmetry)	**2** (one 180° rotation, C_2)	A generic motif can break C_2; the lattice itself still has a 2-fold (in 2-D this is inversion).
Rectangular	$a \neq b,\ \gamma = 90^\circ$	**m** (one mirror)	**2mm** (C_2 + two perpendicular mirror families)	A motif can keep only one mirror; the lattice has both mirrors and a 2-fold.
Square	$a = b,\ \gamma = 90^\circ$	**4** (four-fold only)	**4mm** (C_4 + mirrors along axes & diagonals)	A motif can remove mirrors but keep C_4; the lattice has the full D_4.
Hexagonal (triangular net)	$a = b,\ \gamma = 60^\circ$	**3** (three-fold only)	**6mm** (C_6 + six mirrors)	A motif can drop to 3-fold; the lattice has the full D_6.

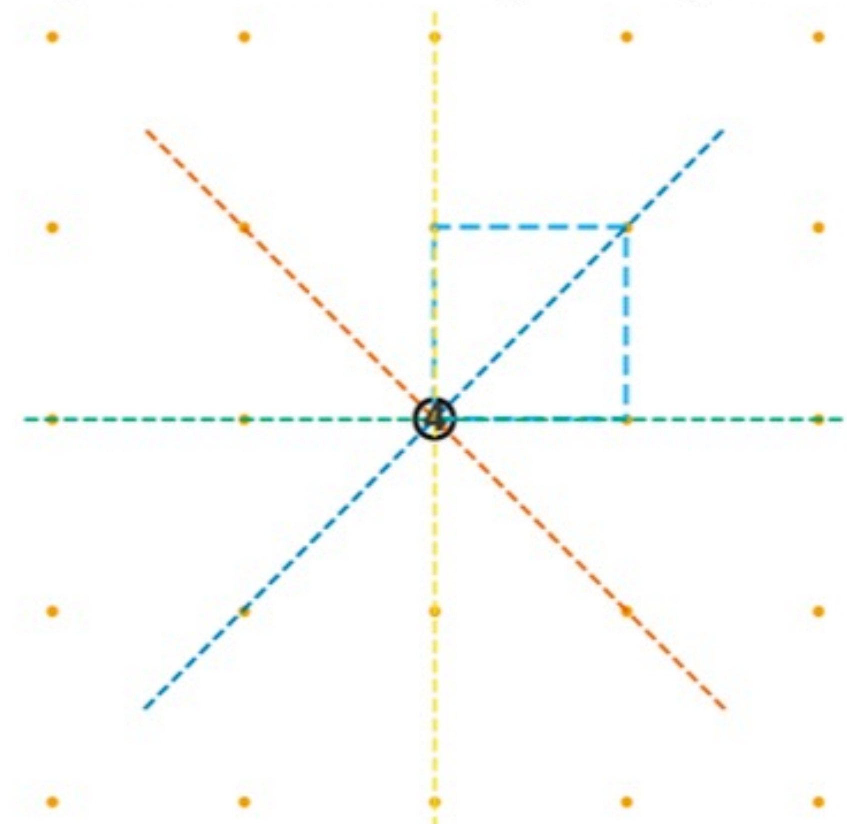
Square — min: 4

Square — minimum symmetry: 4



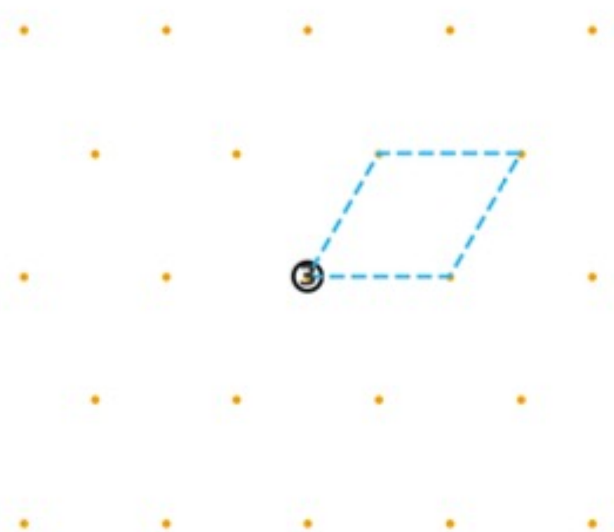
Square — max: 4mm

Square — maximum symmetry: 4mm



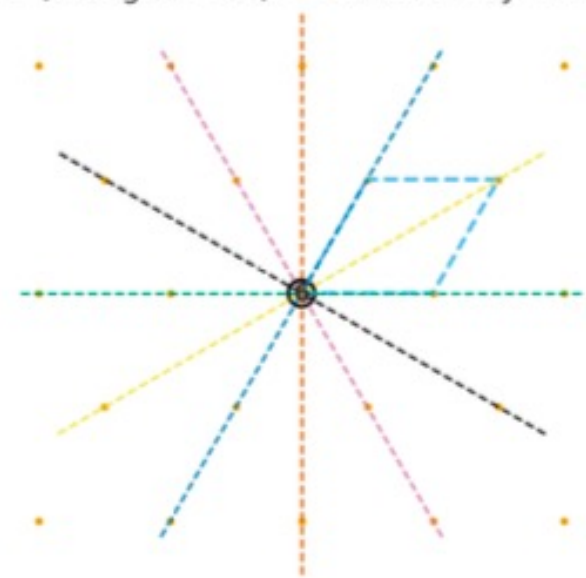
Hexagonal — min: 3

Hexagonal (triangular net) — minimum symmetry: 3



Hexagonal — max: 6mm

Hexagonal (triangular net) — maximum symmetry: 6mm



Homework

- List the five fundamental point-symmetry elements and briefly describe what each does.

- Why are only 2-, 3-, 4-, and 6-fold rotations allowed in crystals?

Homework Question

1.1 Write down the $\langle 111 \rangle$ set of symmetry-equivalent directions in a cubic lattice.

Learning Objectives

By the end of this lecture, students should be able to:

- Explain the relationship between translational symmetry (Bravais lattices) and point symmetry (crystallographic point groups) in defining space groups.
- Identify the seven crystal systems, their characteristic symmetry elements, and the allowed Bravais lattices.
- Distinguish between symmorphic and non-symmorphic space groups.
- Describe the construction of monoclinic space groups and why there are exactly 13 distinct ones.
- Interpret Hermann–Mauguin and Schoenflies notations for space groups.
- Use International Tables for Crystallography to find symmetry elements, Wyckoff positions, and reflection conditions for a given space group.

To describe the symmetry of crystalline solids we use space group symmetry, which combines translational and point symmetry.

14 Bravais Lattices

+

32 Crystallographic Point Groups

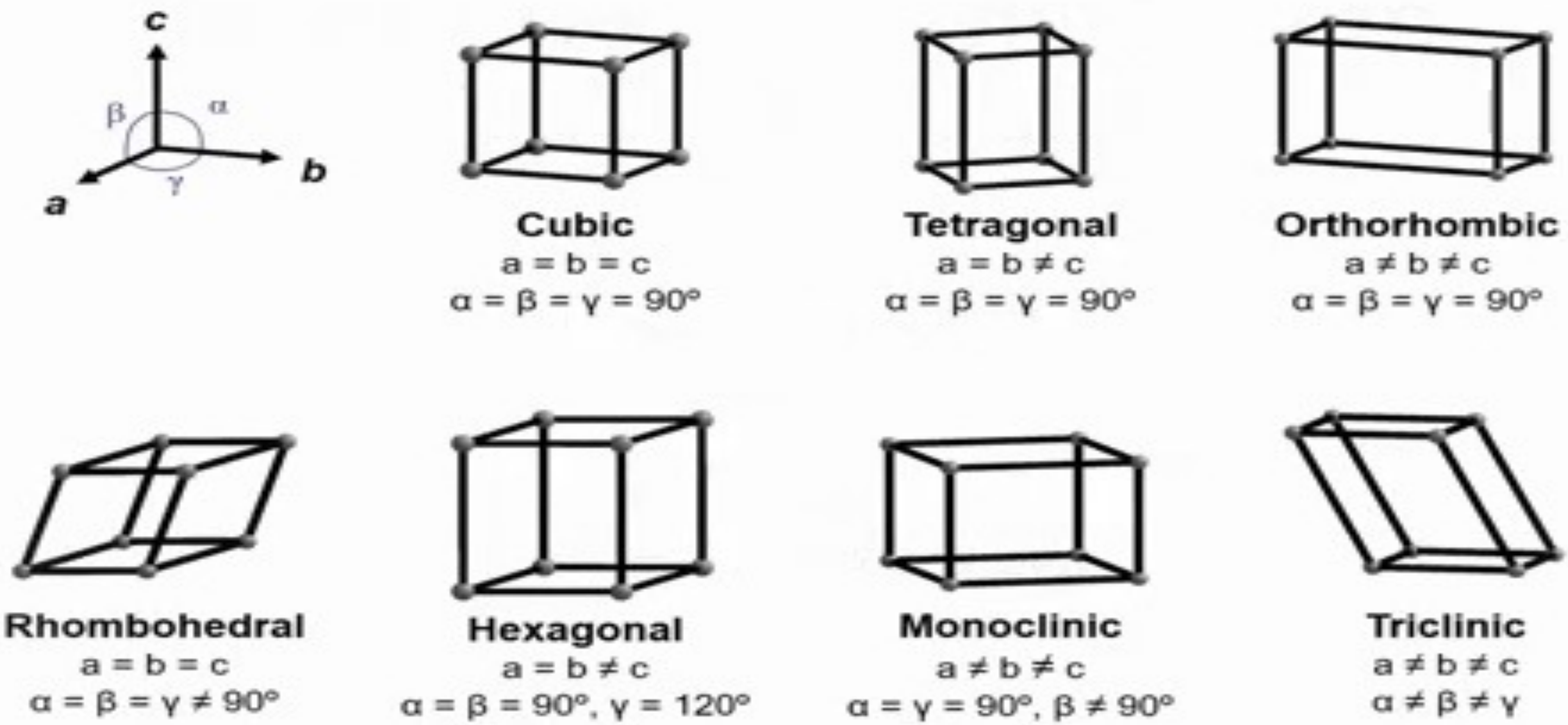
=

230 Space Groups

32 Crystallographic Point Groups

Crystal System	Unit Cell	Required symmetry	Point groups
Cubic	Cubic	3-fold axes along body diagonal	$23, m\bar{3}, \bar{4}3m, 432, m\bar{3}m$
Tetragonal	Tetragonal	4-fold axis	$4, \bar{4}, 4/m, 422, 4mm, \bar{4}m2, 4/mmm$
Hexagonal	Hexagonal	6-fold axis	$6, \bar{6}, 6/m, 622, 6mm, \bar{6}m2, 6/mmm$
Trigonal	Hexagonal or Rhombohedral	3-fold axis	$3, \bar{3}, 32, 3m, \bar{3}m$
Orthorhombic	Orthorhombic	Three mutually perpendicular 2-fold axes or mirror planes	$222, 2mm, mmm$
Monoclinic	Monoclinic	2-fold axis or mirror plane	$2, m, 2/m$
Triclinic	Triclinic	none	$1, \bar{1}$

3D Unit Cells



Fourteen 3D Bravais Lattices

Crystal System	P	C	I	F	Examples
Triclinic ($a \neq b \neq c$; $\alpha \neq \beta \neq \gamma$)	X				Primitive triclinic
Monoclinic ($a \neq b \neq c$; $\alpha = \gamma = 90^\circ$ $\beta \neq 90$)	X	X			Base-centered monoclinic
Orthorhombic ($a \neq b \neq c$; $\alpha = \beta = \gamma = 90^\circ$)	X	X	X	X	Face-centered orthorhombic
Rhombohedral ($a = b = c$; $\alpha = \beta = \gamma \neq 90^\circ$)	X				Primitive rhombohedral
Hexagonal ($a = b \neq c$; $\alpha = \beta = 90^\circ$ $\gamma = 120^\circ$)	X				Primitive hexagonal
Tetragonal ($a = b \neq c$; $\alpha = \beta = \gamma = 90^\circ$)	X		X		Body-centered tetragonal
Cubic ($a = b = c$; $\alpha = \beta = \gamma = 90^\circ$)	X		X	X	Face-centered cubic

Monoclinic Space Groups

2 Bravais Lattices

- Primitive monoclinic (*P*)
- Base-centered monoclinic (*C*)

3 Monoclinic Point groups

- 2 (C_2) [2, 1]
- *m* (C_s) [m, 1]
- 2/*m* (C_{2h}) [2, m, 1, $\bar{1}$]

Monoclinic Space Groups

2 Bravais Lattices

- Primitive monoclinic (*P*)
- Base-centered monoclinic (*C*)

3 Monoclinic Point groups

- 2 (C_2) [2, 1]
- *m* (C_s) [m, 1]
- 2/*m* (C_{2h}) [2, m, 1, $\bar{1}$]

Symmorphic Space Groups

- *P*2
- *Pm*
- *P*2/*m*

Primitive lattice

- *C*2
- *Cm*
- *C*2/*m*

Base-centered lattice

Symmorphic space groups: Possess only the symmetry of the Bravais lattice and the point group (no glide planes or screw axes)

Monoclinic Space Groups

Symmorphic Space Groups

- *P2*
- *Pm*
- *P2/m*

} Primitive lattice

- *C2*
- *Cm*
- *C2/m*

} Base-centered lattice

Monoclinic Space Groups

Symmorphic Space Groups

- $P2$
- Pm
- $P2/m$
- $C2$
- Cm
- $C2/m$

Primitive lattice (P2, Pm, P2/m)

Base-centered lattice (C2, Cm, C2/m)

Nonsymmorphic Space Groups

- $P2_1$
- Pc
- $P2/c$
- $P2_1/m$
- $P2_1/c$
- $C2_1$
- Cc
- $C2/c$
- $C2_1/m$
- $C2_1/c$

Monoclinic Space Groups

Symmorphic Space Groups

- $P2$
- Pm
- $P2/m$

} Primitive lattice

- $C2$
- Cm
- $C2/m$

} Base-centered lattice

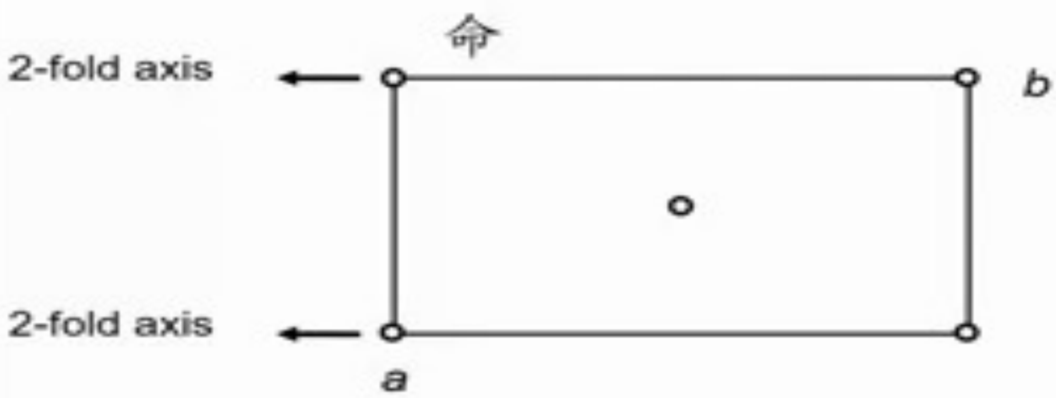
Nonsymmorphic Space Groups

- $P2_1$
- Pc
- $P2/c$
- $P2_1/m$
- $P2_1/c$

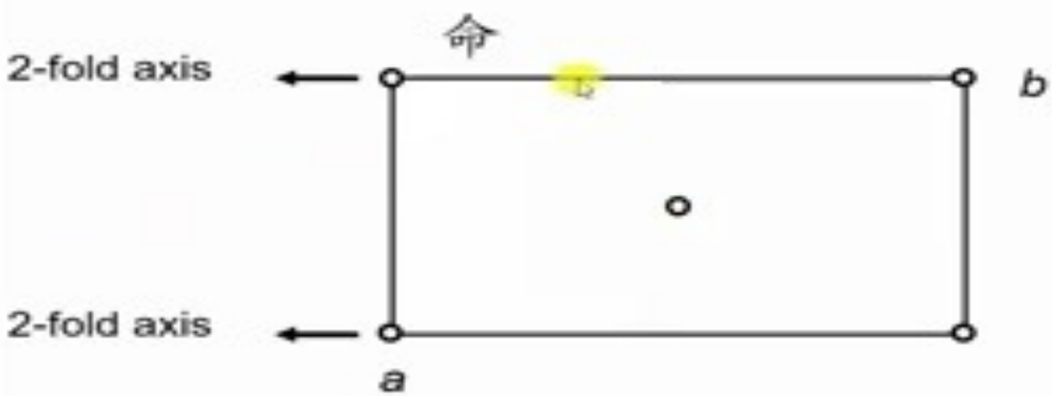
- ~~$C2_1$~~
- Cc
- $C2/c$
- ~~$C2_1/m$~~
- ~~$C2_1/c$~~

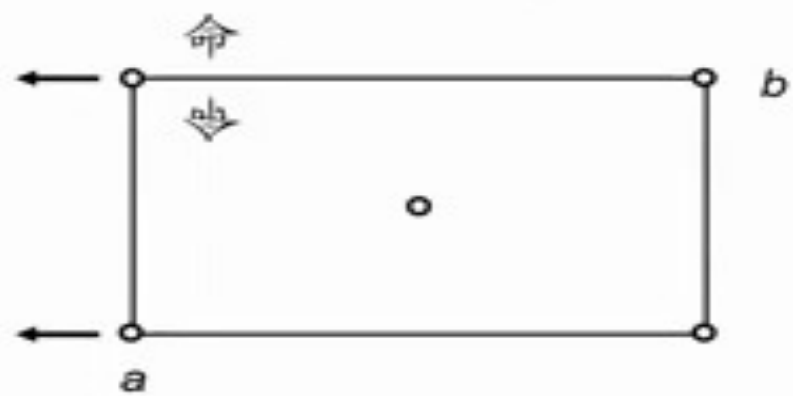
$C2_1 \equiv C2$ $\quad$ $C2_1/m \equiv C2/m$ $\quad$ $C2_1/c \equiv C2/c$

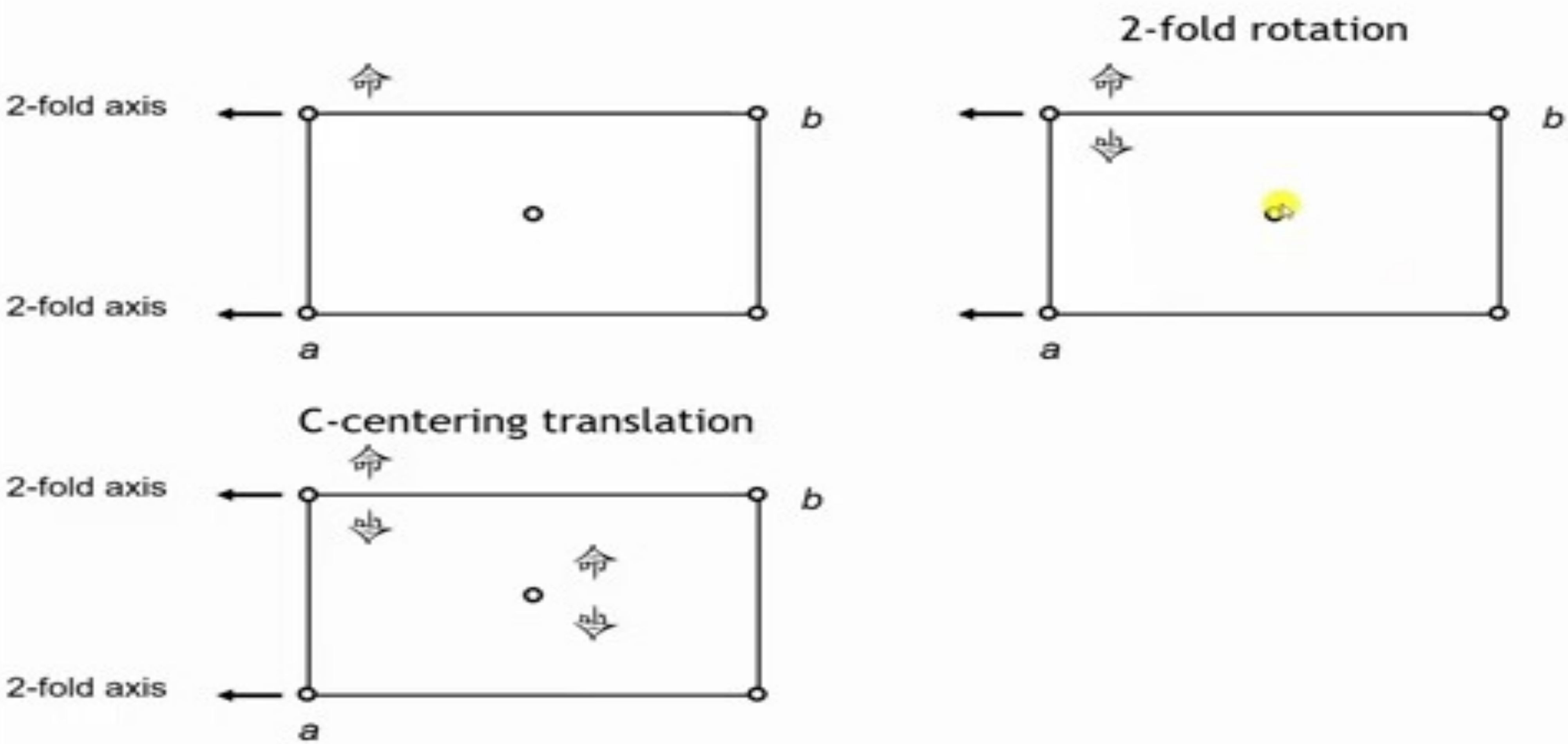
There are a total of 13 monoclinic space groups.

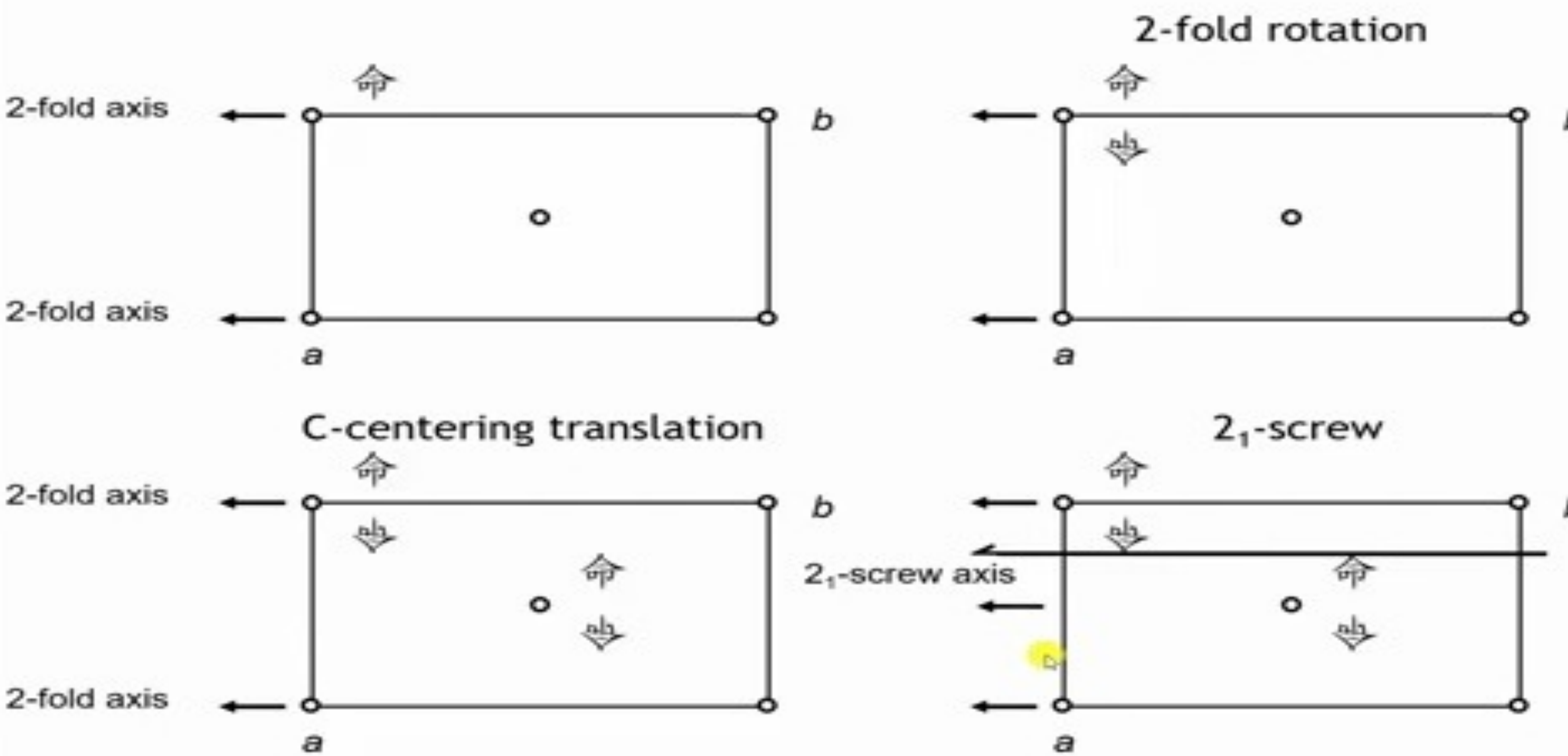

命
2-fold axis
b
2-fold axis
a

2-fold rotation






2-fold rotation
2-fold axis
b
2-fold axis
a
C-centering translation
2-fold axis
b
2-fold axis
a

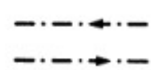


2-fold rotation followed by C-centering translation (½*a* + ½*b*) creates a 2_1 screw axis.
So C2 and $C2_1$ are the same space group (whose name is C2)

International Tables for Crystallography Volume A

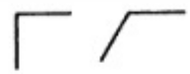
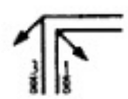
- This reference source contains the symmetry information for all 230 three-dimensional space groups (and more)
- You can access an online version of this reference at https://onlinelibrary.wiley.com/iucr/itc/Ac/

1.4.1. Symmetry planes normal to the plane of projection (three dimensions) and symmetry lines in the plane of the figure (two dimensions)

Symmetry plane or symmetry line	Graphical symbol	Glide vector in units of lattice translation vectors parallel and normal to the projection plane	Printed symbol
Reflection plane, mirror plane Reflection line, mirror line (two dimensions)		None	*m*
'Axial' glide plane Glide line (two dimensions)		$\frac{1}{2}$ lattice vector along line in projection plane $\frac{1}{2}$ lattice vector along line in figure plane	*a*, *b* or *c* *g*
'Axial' glide plane		$\frac{1}{2}$ lattice vector normal to projection plane	*a*, *b* or *c*
'Double' glide plane* (in centred cells only)		*Two* glide vectors: $\frac{1}{2}$ along line parallel to projection plane and $\frac{1}{2}$ normal to projection plane	*e*
'Diagonal' glide plane		*One* glide vector with *two* components: $\frac{1}{2}$ along line parallel to projection plane, $\frac{1}{2}$ normal to projection plane	*n*
'Diamond' glide plane† (pair of planes; in centred cells only)		$\frac{1}{4}$ along line parallel to projection plane, combined with $\frac{1}{4}$ normal to projection plane (arrow indicates direction parallel to the projection plane for which the normal component is positive)	*d*

* For further explanations of the 'double' glide plane *e* see Note (iv) below and Note (x) in Section 1.3.2.
† See footnote § to Section 1.3.1.

1.4.2. Symmetry planes parallel to the plane of projection

Symmetry plane	Graphical symbol*	Glide vector in units of lattice translation vectors parallel to the projection plane	Printed symbol
Reflection plane, mirror plane		None	*m*
'Axial' glide plane		$\frac{1}{2}$ lattice vector in the direction of the arrow	*a*, *b* or *c*
'Double' glide plane† (in centred cells only)		*Two* glide vectors: $\frac{1}{2}$ in either of the directions of the two arrows	*e*
'Diagonal' glide plane		*One* glide vector with *two* components $\frac{1}{2}$ in the direction of the arrow	*n*
'Diamond' glide plane‡ (pair of planes; in centred cells only)		$\frac{1}{4}$ in the direction of the arrow; the glide vector is always half of a centring vector, *i.e.* one quarter of a diagonal of the conventional face-centred cell	*d*

* The symbols are given at the upper left corner of the space-group diagrams. A fraction h attached to a symbol indicates two symmetry planes with 'heights' h and $h + \frac{1}{2}$ above the plane of projection; *e.g.* $\frac{1}{8}$ stands for $h = \frac{1}{8}$ and $\frac{5}{8}$. No fraction means $h = 0$ and $\frac{1}{2}$ (*cf.* Section 2.2.6).

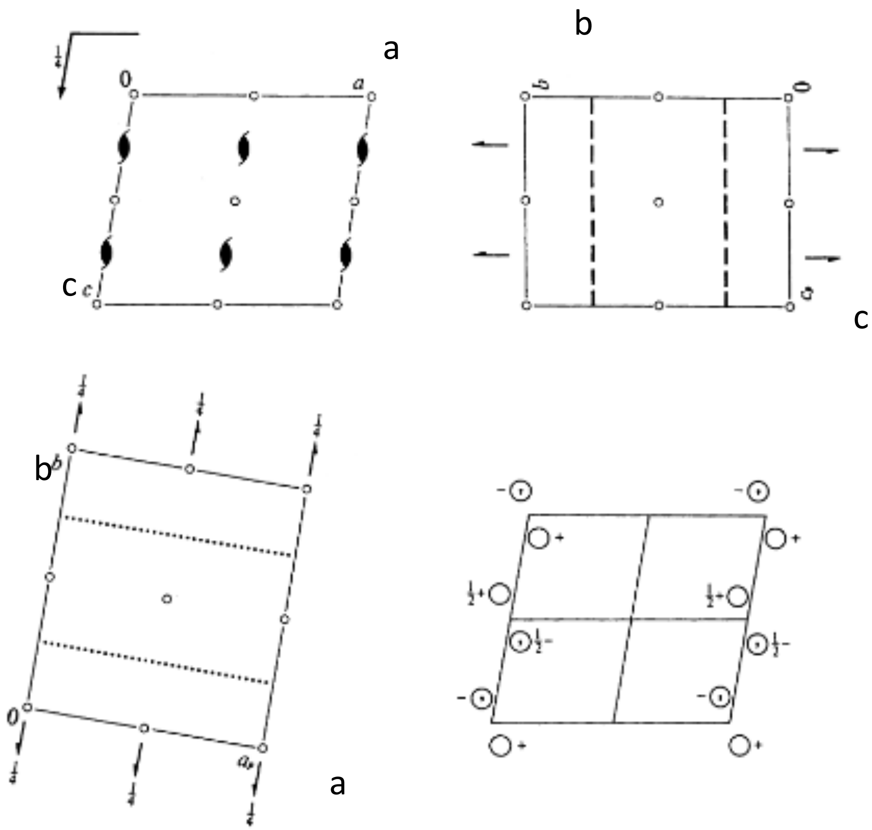
† For further explanations of the 'double' glide plane *e* see Note (iv) below and Note (x) in Section 1.3.2.

‡ See footnote § to Section 1.3.1.

$P2_1/c$ C_{2h}^5 $2/m$ Monoclinic

No. 14 $P12_1/c1$ Patterson symmetry $P12/m1$

UNIQUE AXIS b, CELL CHOICE 1



Origin at $\bar{1}$

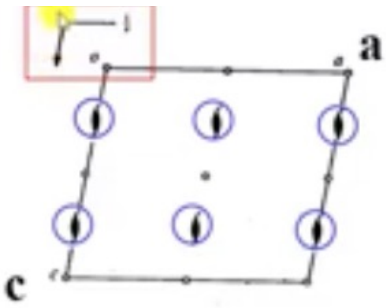
Asymmetric unit $0 \le x \le 1;\quad 0 \le y \le \frac{1}{4};\quad 0 \le z \le 1$

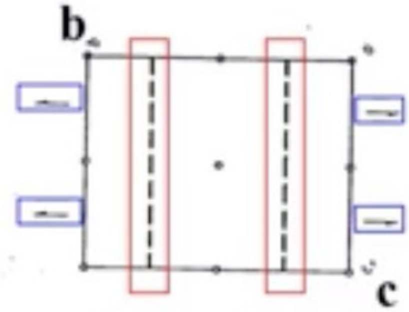
Symmetry operations

(1) 1 (2) $2(0,\frac{1}{2},0)\quad 0,y,\frac{1}{4}$ (3) $\bar{1}\quad 0,0,0$ (4) $c\quad x,\frac{1}{4},z$

$P\ 1\ 2_1/c\ 1$

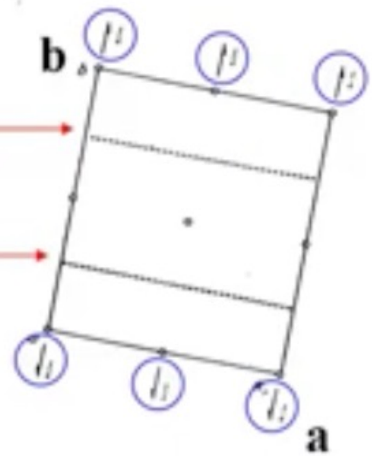
Axes parallel to or planes perpendicular to the b-axis

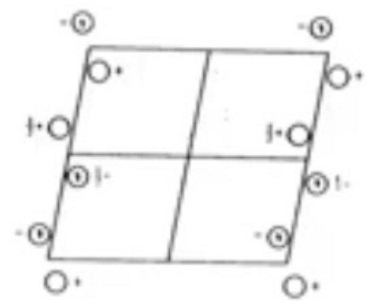




Glide translation in the plane of the projection

Glide translation perpendicular to the plane of the projection





Origin at $\bar{1}$

Asymmetric unit $0 \le x \le 1;\ 0 \le y \le \frac{1}{4};\ 0 \le z \le 1$

Symmetry operations

(1) 1 (2) $2(0,\frac{1}{2},0)\ 0,y,\frac{1}{4}$ (3) $\bar{1}\ 0,0,0$ (4) $c\ x,\frac{1}{4},z$

Inversion Center

c-glide plane

2_1 Screw Axis

Page 2

Generators selected (1); $t(1,0,0)$; $t(0,1,0)$; $t(0,0,1)$; (2); (3)

Positions

Multiplicity, Wyckoff letter, Site symmetry			Coordinates				Reflection conditions
							General:
4	e	1	(1) x,y,z	(2) $\bar{x},y+\frac{1}{2},\bar{z}+\frac{1}{2}$	(3) $\bar{x},\bar{y},\bar{z}$	(4) $x,\bar{y}+\frac{1}{2},z+\frac{1}{2}$	$h0l$: $l=2n$ $0k0$: $k=2n$ $00l$: $l=2n$
							Special: as above, plus
2	d	$\bar{1}$	$\frac{1}{2},0,\frac{1}{2}$	$\frac{1}{2},\frac{1}{2},0$			hkl : $k+l=2n$
2	c	$\bar{1}$	$0,0,\frac{1}{2}$	$0,\frac{1}{2},0$			hkl : $k+l=2n$
2	b	$\bar{1}$	$\frac{1}{2},0,0$	$\frac{1}{2},\frac{1}{2},\frac{1}{2}$			hkl : $k+l=2n$
2	a	$\bar{1}$	$0,0,0$	$0,\frac{1}{2},\frac{1}{2}$			hkl : $k+l=2n$

Symmetry of special projections

Along [001] $p2gm$
$\mathbf{a}'=\mathbf{a}_p$ $\mathbf{b}'=\mathbf{b}$
Origin at $0,0,z$

Along [100] $p2gg$
$\mathbf{a}'=\mathbf{b}$ $\mathbf{b}'=\mathbf{c}_p$
Origin at $x,0,0$

Along [010] $p2$
$\mathbf{a}'=\frac{1}{2}\mathbf{c}$ $\mathbf{b}'=\mathbf{a}$
Origin at $0,y,0$

Maximal non-isomorphic subgroups

I [2] $P1c1$ (Pc, 7) 1; 4
[2] $P12_11$ ($P2_1$, 4) 1; 2
[2] $P\bar{1}$ (2) 1; 3

IIa none

IIb none

Maximal isomorphic subgroups of lowest index

IIc [2] $P12_1/c1$ ($\mathbf{a}'=2\mathbf{a}$ or $\mathbf{a}'=2\mathbf{a},\mathbf{c}'=2\mathbf{a}+\mathbf{c}$) ($P2_1/c$, 14); [3] $P12_1/c1$ ($\mathbf{b}'=3\mathbf{b}$) ($P2_1/c$, 14)

Minimal non-isomorphic supergroups

I [2] $Pnna$ (52); [2] $Pmna$ (53); [2] $Pcca$ (54); [2] $Pbam$ (55); [2] $Pccn$ (56); [2] $Pbcm$ (57); [2] $Pnnm$ (58); [2] $Pbcn$ (60); [2] $Pbca$ (61); [2] $Pnma$ (62); [2] $Cmce$ (64)

II [2] $A12/m1$ ($C2/m$, 12); [2] $C12/c1$ ($C2/c$, 15); [2] $I12/c1$ ($C2/c$, 15); [2] $P12_1/m1$ ($\mathbf{c}'=\frac{1}{2}\mathbf{c}$) ($P2_1/m$, 11); [2] $P12/c1$ ($\mathbf{b}'=\frac{1}{2}\mathbf{b}$) ($P2/c$, 13)

Generators selected (1); $t(1,0,0)$; $t(0,1,0)$; $t(0,0,1)$; (2); (3)

Reflection Conditions/ Systematic Absences

Positions

Multiplicity, Wyckoff letter, Site symmetry			Coordinates			
4	e	1	(1) x,y,z	(2) $\bar{x},y+\frac{1}{2},\bar{z}+\frac{1}{2}$	(3) $\bar{x},\bar{y},\bar{z}$	(4) $x,\bar{y}+\frac{1}{2},z+\frac{1}{2}$
2	d	$\bar{1}$	$\frac{1}{2},0,\frac{1}{2}$	$\frac{1}{2},\frac{1}{2},0$		
2	c	$\bar{1}$	$0,0,\frac{1}{2}$	$0,\frac{1}{2},0$		
2	b	$\bar{1}$	$\frac{1}{2},0,0$	$\frac{1}{2},\frac{1}{2},\frac{1}{2}$		
2	a	$\bar{1}$	$0,0,0$	$0,\frac{1}{2},\frac{1}{2}$		

General position

Wyckoff Sites

Reflection conditions

General:

$h0l$: $l = 2n$
$0k0$: $k = 2n$
$00l$: $l = 2n$

Special: as above, plus

hkl : $k + l = 2n$

hkl : $k + l = 2n$

hkl : $k + l = 2n$

hkl : $k + l = 2n$

Symmetry of special projections

Along [001] $p\,2gm$
$\mathbf{a}' = \mathbf{a}_p$ $\quad \mathbf{b}' = \mathbf{b}$
Origin at $0,0,z$

Along [100] $p\,2gg$
$\mathbf{a}' = \mathbf{b}$ $\quad \mathbf{b}' = \mathbf{c}_p$
Origin at $x,0,0$

Along [010] $p\,2$
$\mathbf{a}' = \frac{1}{2}\mathbf{c}$ $\quad \mathbf{b}' = \mathbf{a}$
Origin at $0,y,0$

Maximal non-isomorphic subgroups

I $\quad$ [2]$P\,1\,2_1\,1\,(P\,2_1)$ $\quad$ 1; 2
[2]$P\,\bar{1}$ $\quad$ 1; 3
[2]$P\,1\,c\,1\,(P\,c)$ $\quad$ 1; 4

IIa none

IIb none

Subgroups = Space group symmetry if certain symmetry operations are eliminated

Supergroups = Space group symmetry if certain symmetry operations are added

Maximal isomorphic subgroups of lowest index

IIc [3]$P\,1\,2_1/c\,1\,(\mathbf{b}' = 3\mathbf{b})(P\,2_1/c)$; [2]$P\,1\,2_1/c\,1\,(\mathbf{a}' = 2\mathbf{a}$ or $\mathbf{a}' = 2\mathbf{a}, \mathbf{c}' = 2\mathbf{a} + \mathbf{c})(P\,2_1/c)$

Minimal non-isomorphic supergroups

I [2]$Pnna$; [2]$Pmna$; [2]$Pcca$; [2]$Pbam$; [2]$Pccn$; [2]$Pbcm$; [2]$Pnnm$; [2]$Pbcn$; [2]$Pbca$; [2]$Pnma$; [2]$Cmca$

II [2]$C\,1\,2/c\,1\,(C\,2/c)$; [2]$A\,1\,2/m\,1\,(C\,2/m)$; [2]$I\,1\,2/c\,1\,(C\,2/c)$; [2]$P\,1\,2_1/m\,1\,(2\mathbf{c}' = \mathbf{c})(P\,2_1/m)$; [2]$P\,1\,2/c\,1\,(2\mathbf{b}' = \mathbf{b})(P\,2/c)$

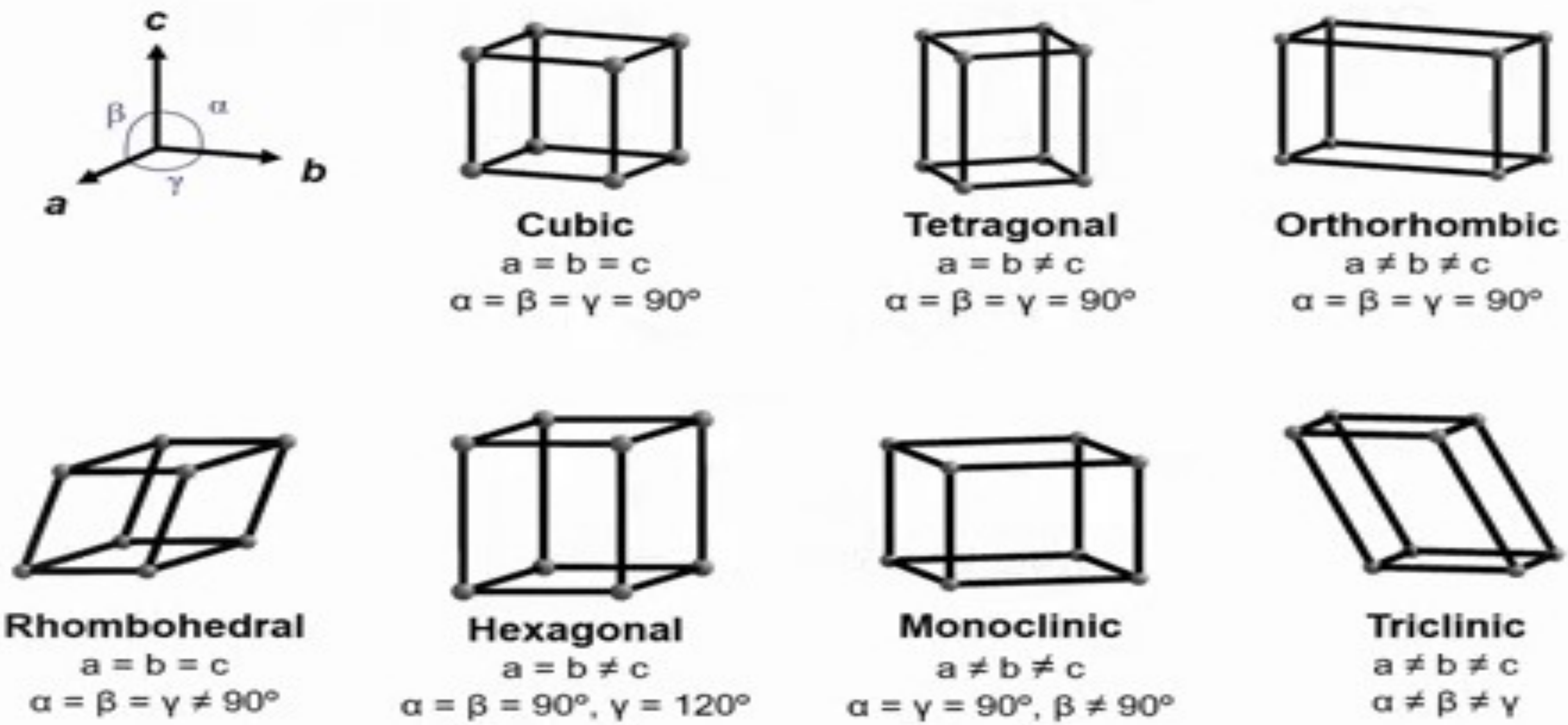
Summary

- Space group symmetry combines **14 Bravais lattices** with **32 crystallographic point groups**, yielding **230 space groups**.
- Only specific point groups are compatible with each crystal system; not all 14 × 32 combinations are valid.
- Symmorphic space groups derive purely from lattice centering + point group, while non-symmorphic groups add screw axes and glide planes.
- The **monoclinic system** illustrates how translational symmetry interacts with point symmetry: it allows 2 Bravais lattices (P, C), 3 point groups (2, m, 2/m), and results in 13 distinct space groups after eliminating redundancies (e.g., C2 ≡ C21).
- Key resources include the **International Tables for Crystallography**, which provide standardized symmetry operations, Wyckoff positions, reflection conditions, and subgroup/supergroup relations.

32 Crystallographic Point Groups

Crystal System	Unit Cell	Required symmetry	Point groups
Cubic	Cubic	3-fold axes along body diagonal	$23, m\bar{3}, \bar{4}3m, 432, m\bar{3}m$
Tetragonal	Tetragonal	4-fold axis	$4, \bar{4}, 4/m, 422, 4mm, \bar{4}m2, 4/mmm$
Hexagonal	Hexagonal	6-fold axis	$6, \bar{6}, 6/m, 622, 6mm, \bar{6}m2, 6/mmm$
Trigonal	Hexagonal or Rhombohedral	3-fold axis	$3, \bar{3}, 32, 3m, \bar{3}m$
Orthorhombic	Orthorhombic	Three mutually perpendicular 2-fold axes or mirror planes	$222, 2mm, mmm$
Monoclinic	Monoclinic	2-fold axis or mirror plane	$2, m, 2/m$
Triclinic	Triclinic	none	$1, \bar{1}$

3D Unit Cells



Directions and Space Group Names

Crystal system	*Post 1*	*Post 2*	*Post 3*
Monoclinic	perpendicular to the plane of the monoclinic angle (standard, ‖ ***b***)		
Orthorhombic	edge ***a***	edge ***b***	edge ***c***
Tetragonal	4(–4) ‖ ***c***	square edges	square diagonals
Trigonal	3(–3) ‖ ***c***	rhombus edges	rhombus diagonal, longer
Hexagonal	6(–6) ‖ ***c***		
Cubic	edges	3(–3) in body diagonals	face diagonals

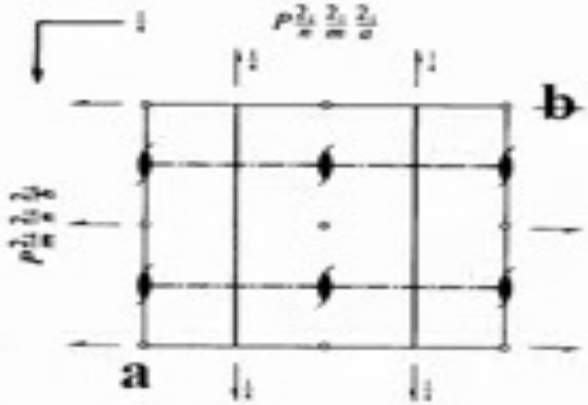
Post = *the conventional direction in a crystal along which the principal symmetry element (rotation axis, mirror, or inversion axis) of the crystal system is oriented.*

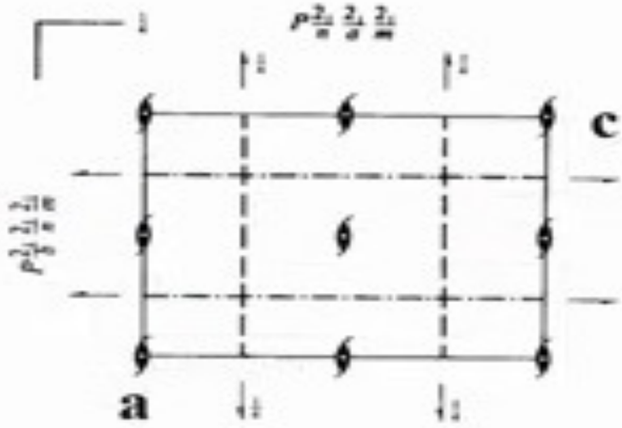
So when the table lists "Post 1, Post 2, Post 3," it is giving the **standard orientation of symmetry axes** for that crystal system.

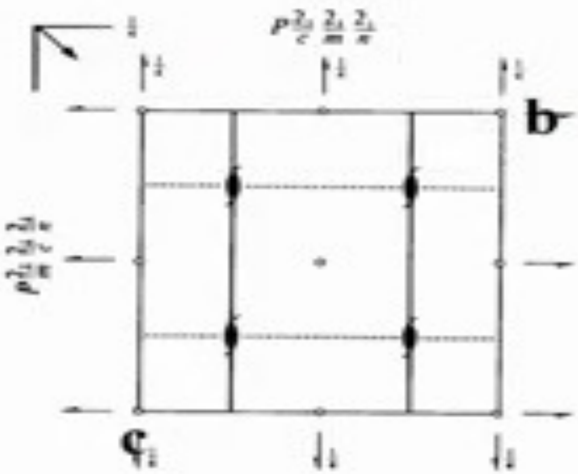
Orthorhombic

Pnma D_{2h}^{16}

No. 62 $P\,2_1/n\,2_1/m\,2_1/a$







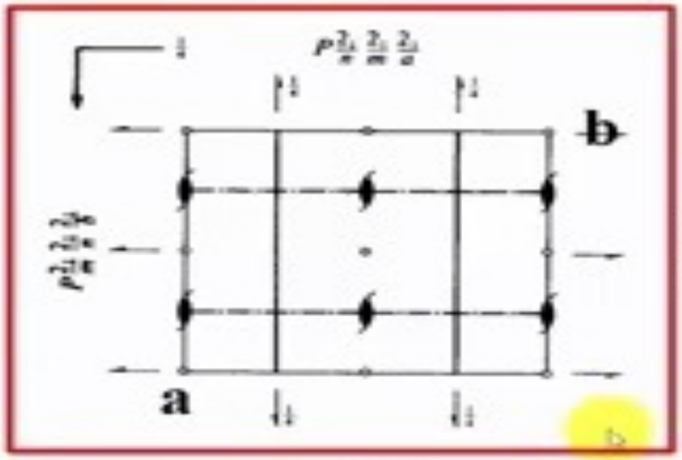
P 2_1/n 2_1/m 2_1/a

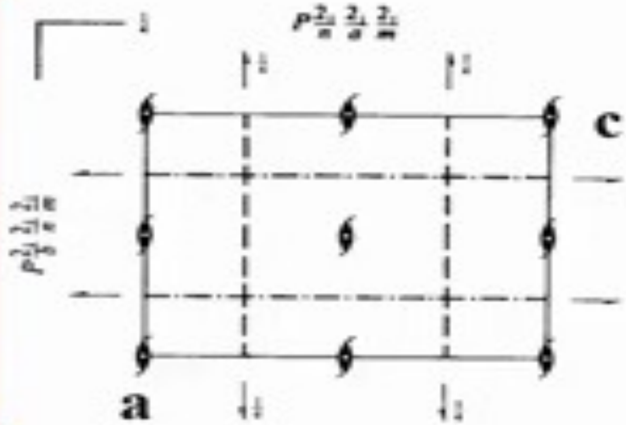
- 2_1 screw axis || to the a-axis + n-glide plane ⊥ to the a-axis
- 2_1 screw axis || to the b-axis + mirror plane ⊥ to the b-axis
- 2_1 screw axis || to the c-axis + a-glide plane ⊥ to the c-axis

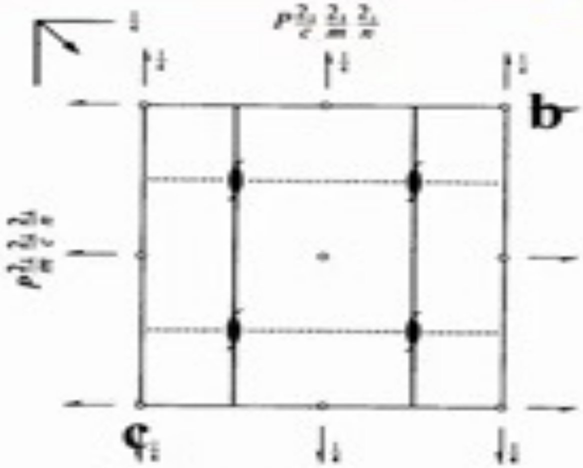
Pnma D_{2h}^{16}

Orthorhombic

No. 62 $P\,2_1/n\;2_1/m\;2_1/a$





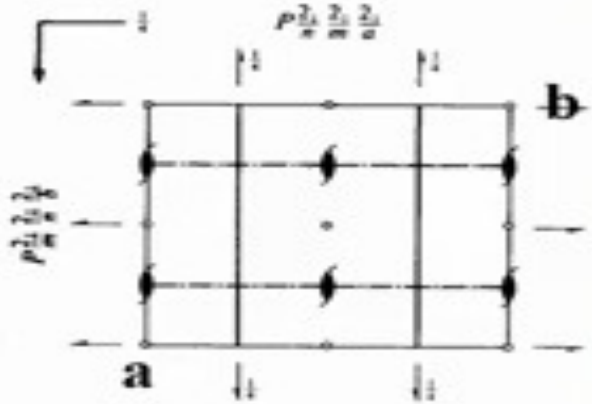


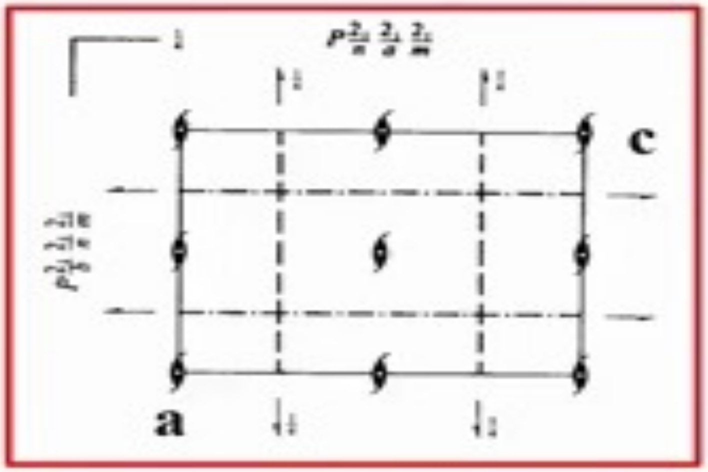
$P\;2_1/n\;2_1/m\;2_1/a$

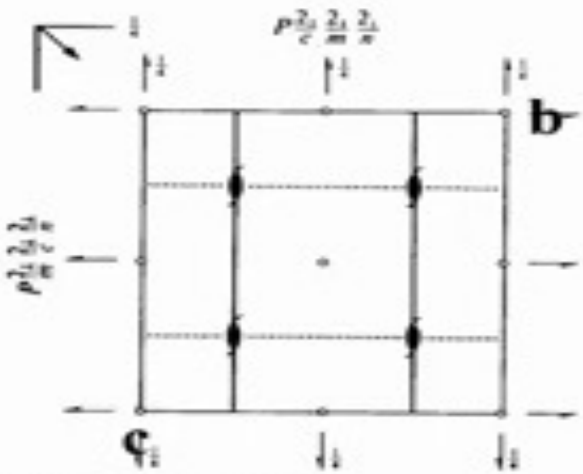
$2_1/n$	$2_1/m$	$2_1/a$
2_1 screw axis‖ to the a-axis + n-glide plane ⊥ to the a-axis	2_1 screw axis‖ to the b-axis + mirror plane ⊥ to the b-axis	2_1 screw axis‖ to the c-axis + a-glide plane ⊥ to the c-axis

Pnma D_{2h}^{16} **Orthorhombic**

No. 62 $P\,2_1/n\,2_1/m\,2_1/a$







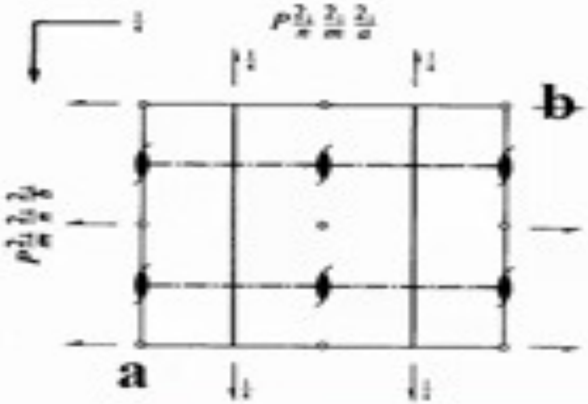
P $2_1/n$ $2_1/m$ $2_1/a$

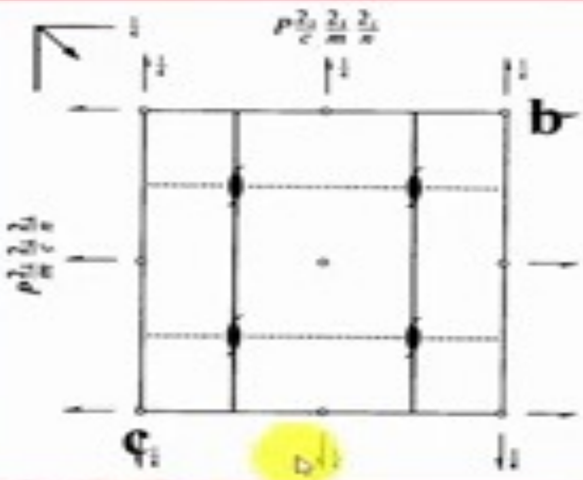
- 2_1 screw axis || to the a-axis + n-glide plane ⊥ to the a-axis
- 2_1 screw axis || to the b-axis + mirror plane ⊥ to the b-axis
- 2_1 screw axis || to the c-axis + a-glide plane ⊥ to the c-axis

P n m a D_{2h}^{16} **Orthorhombic**

No. 62

$P\,2_1/n\,2_1/m\,2_1/a$



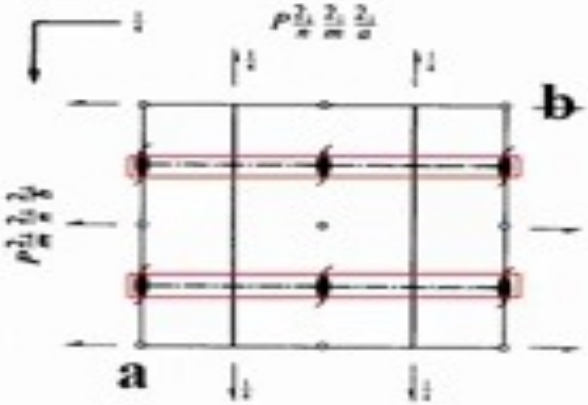


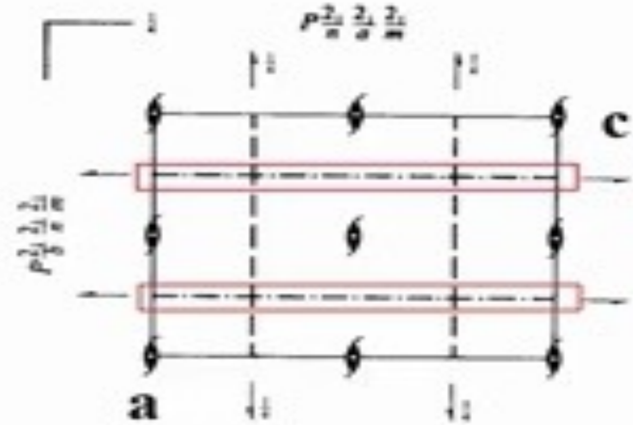
P 2_1/n 2_1/m 2_1/a

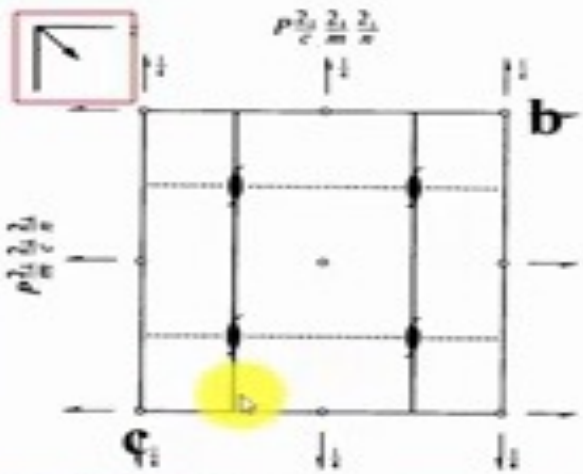
- 2_1 screw axis|| to the a-axis + n-glide plane ⊥ to the a-axis
- 2_1 screw axis|| to the b-axis + mirror plane ⊥ to the b-axis
- 2_1 screw axis|| to the c-axis + a-glide plane ⊥ to the c-axis

Pnma D_{2h}^{16} **Orthorhombic**

No. 62 $P\,2_1/n\;2_1/m\;2_1/a$







$P\;2_1/n\;2_1/m\;2_1/a$

2_1 screw axis || to the a-axis + n-glide plane ⊥ to the a-axis

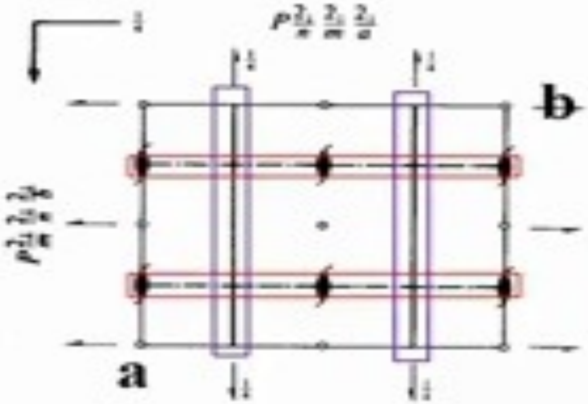
2_1 screw axis || to the b-axis + mirror plane ⊥ to the b-axis

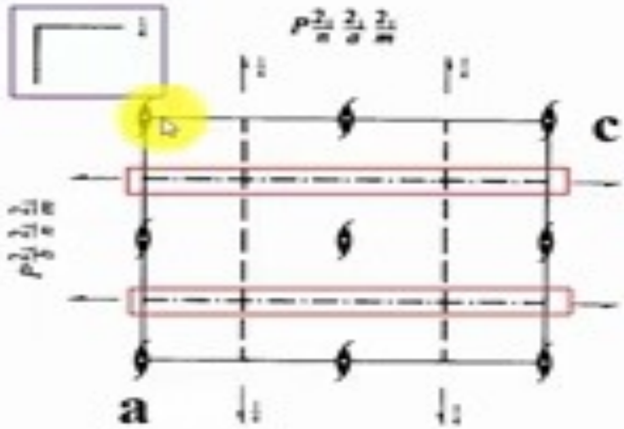
2_1 screw axis || to the c-axis + a-glide plane ⊥ to the c-axis

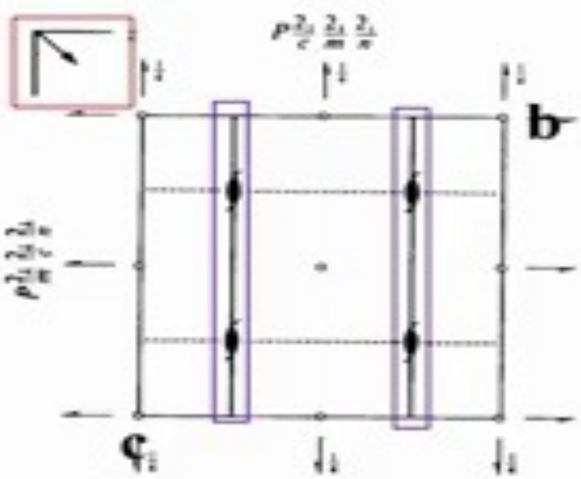
Orthorhombic

Pnma D_{2h}^{16}

No. 62 $P\,2_1/n\,2_1/m\,2_1/a$







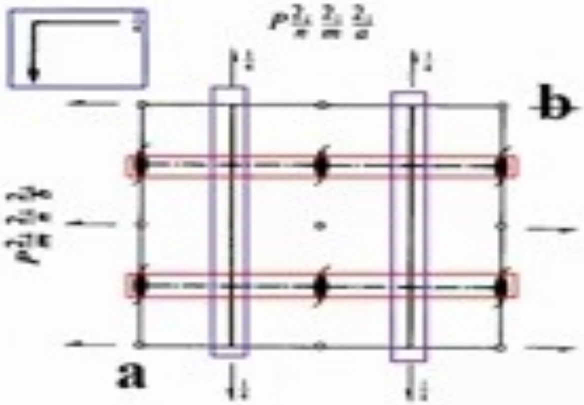
$P\ 2_1/n\ 2_1/m\ 2_1/a$

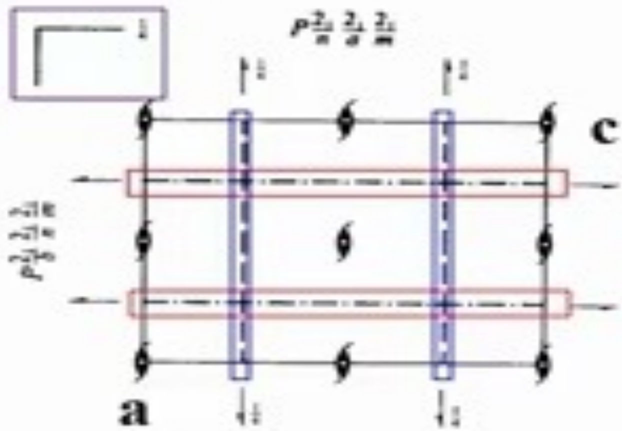
- 2_1 screw axis || to the a-axis + n-glide plane ⊥ to the a-axis
- 2_1 screw axis || to the b-axis + mirror plane ⊥ to the b-axis
- 2_1 screw axis || to the c-axis + a-glide plane ⊥ to the c-axis

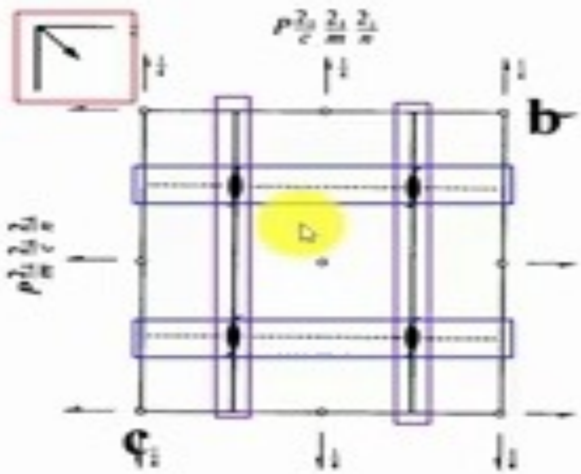
Orthorhombic

Pnma D_{2h}^{16}

No. 62 $P\,2_1/n\,2_1/m\,2_1/a$







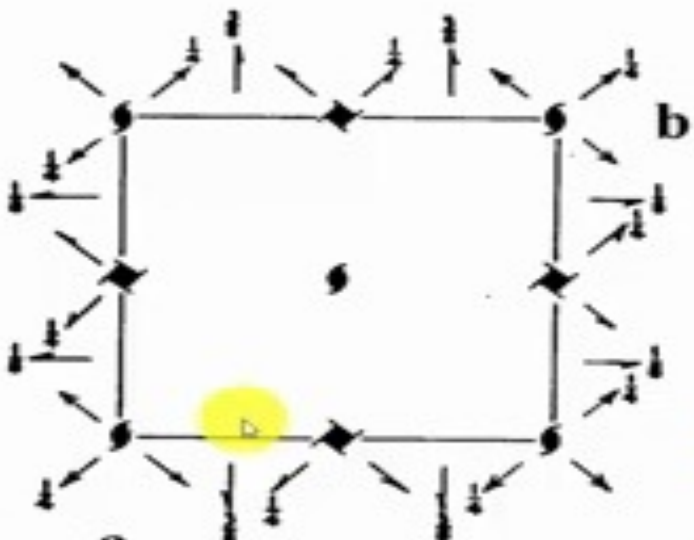
$P\ 2_1/n\ 2_1/m\ 2_1/a$

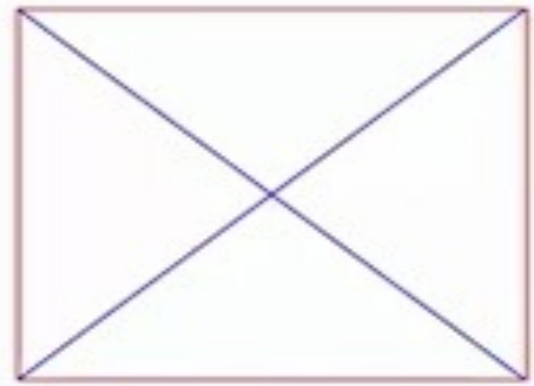
$2_1/n$	$2_1/m$	$2_1/a$
2_1 screw axis‖ to the a-axis + n-glide plane ⊥ to the a-axis	2_1 screw axis‖ to the b-axis + mirror plane ⊥ to the b-axis	2_1 screw axis‖ to the c-axis + a-glide plane ⊥ to the c-axis

Tetragonal

$P\,4_1\,2_1\,2$ D_4^4

No. 92 $P\,4_1\,2_1\,2$





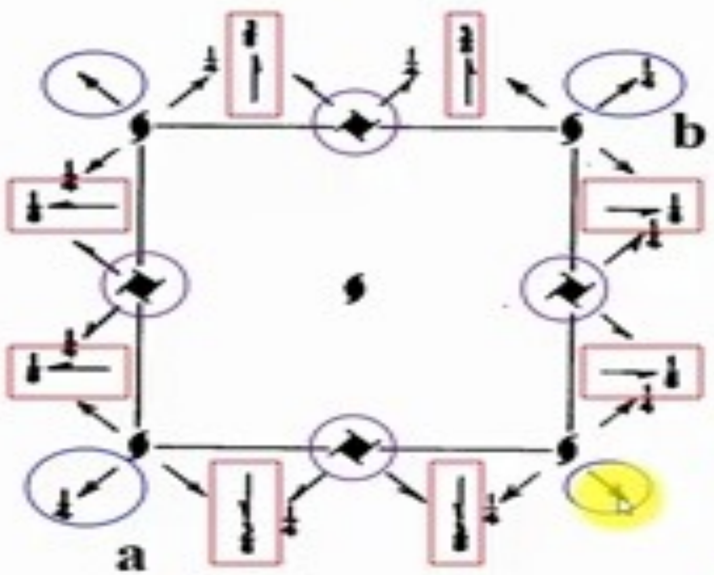
P **4_1** **2_1** **2**

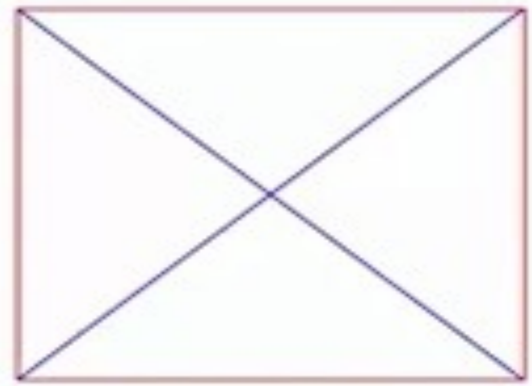
- 4_1 screw axis || to the c-axis, No glides or mirrors ⊥ to the c-axis
- 2_1 screw axis || to the a- & b-axes, No glides or mirrors ⊥ to these axes
- 2-fold axes || to the face diagonals in the ab plane ([110]), No glides or mirrors ⊥ to these axes

Tetragonal

$P\,4_1\,2_1\,2$ D_4^4

No. 92 $P\,4_1\,2_1\,2$





P 4_1 2_1 2

4_1 screw axis || to the c-axis, No glides or mirrors ⊥ to the c-axis

2_1 screw axis || to the a- & b-axes, No glides or mirrors ⊥ to these axes

2-fold axes || to the face diagonals in the ab plane ([110]), No glides or mirrors ⊥ to these axes

Trigonal

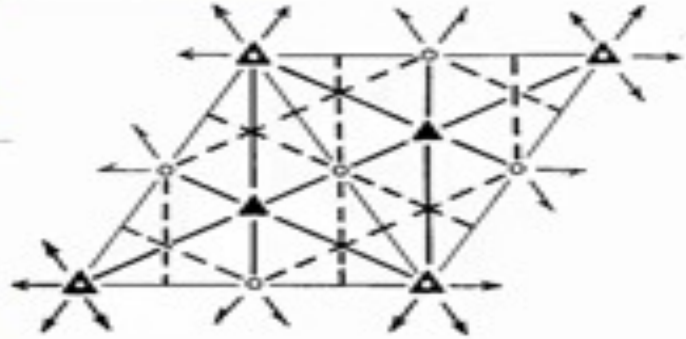
$P\,\bar{3}\,m\,1$ D_{3d}^{3}

No. 164 $P\,\bar{3}\,2/m\,1$

3-fold rotoinversion axis || to the c-axis,

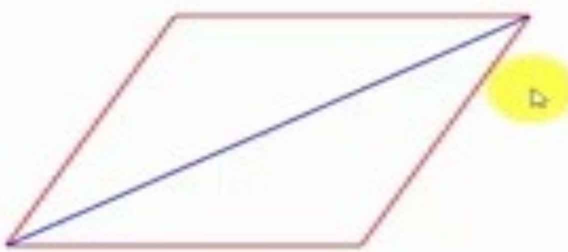
2-fold axis || to the a- & b-axes, Mirror planes ⊥ to these axes

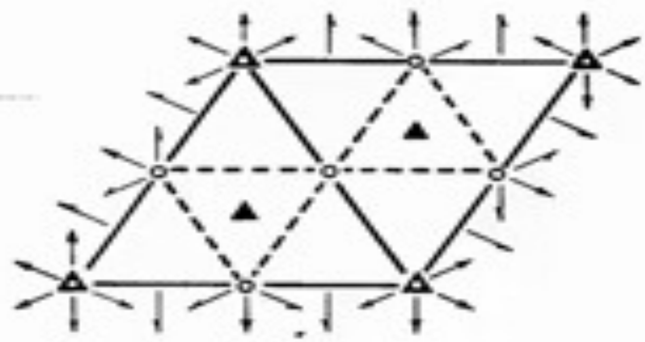
no axes || to the rhombus diagonal in the ab plane ([110]), No glides or mirrors ⊥ to the diagonal



$P\,\bar{3}\,1\,m$ D_{3d}^{1}

No. 162 $P\,\bar{3}\,1\,2/m$





Trigonal

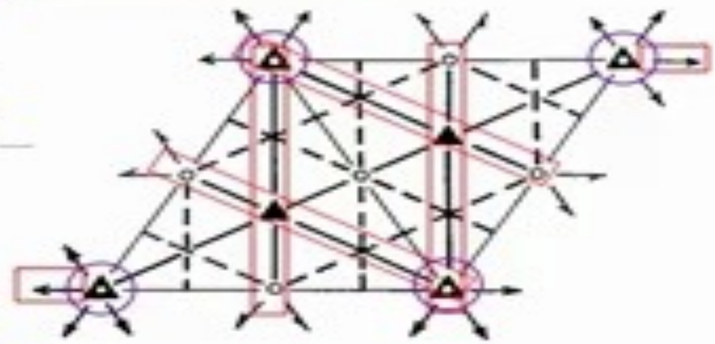
$P\bar{3}m1$ D_{3d}^{3}

No. 164 $P\bar{3}\,2/m\,1$

3-fold rotoinversion axis || to the c-axis,

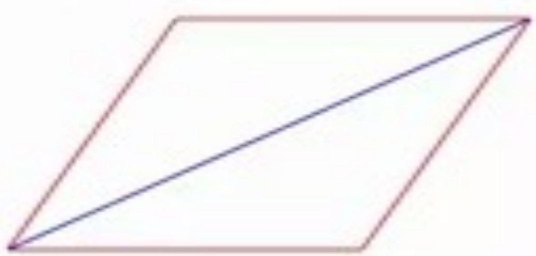
2-fold axis || to the a- & b-axes, Mirror planes ⊥ to these axes

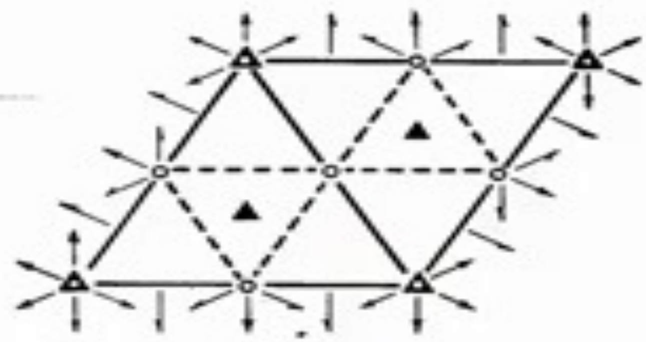
no axes || to the rhombus diagonal in the ab plane ([110]), No glides or mirrors ⊥ to the diagonal



$P\bar{3}1m$ D_{3d}^{1}

No. 162 $P\bar{3}\,1\,2/m$

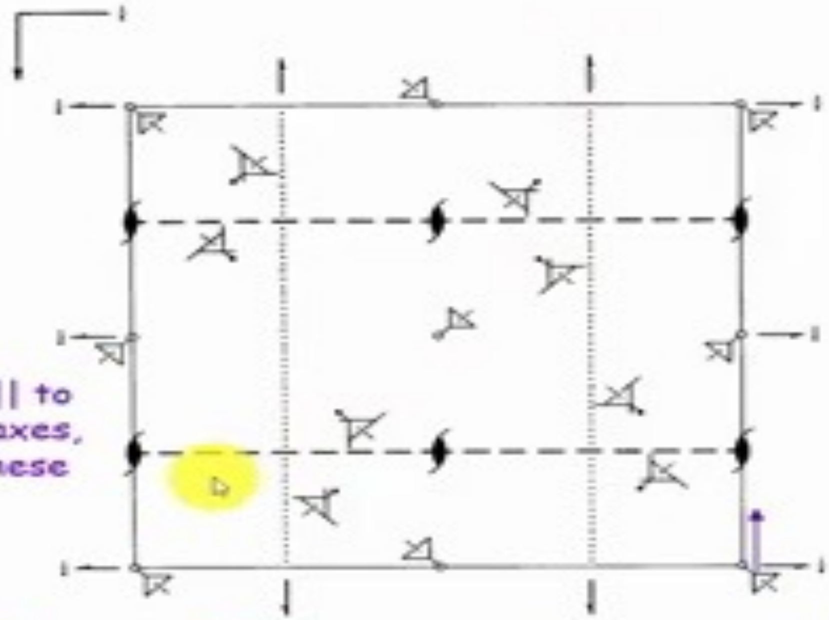


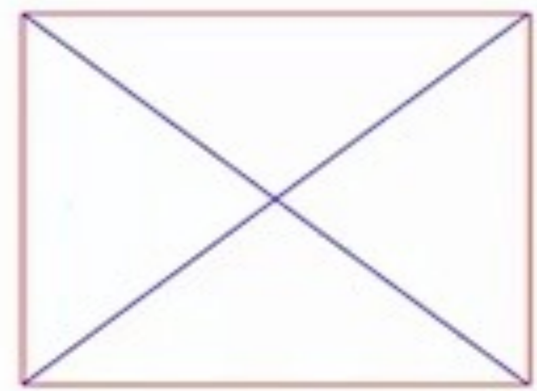


Cubic

$Pa\bar{3}$ T_h^6 $m\bar{3}$ Cubic

No. 205 $P2_1/a\bar{3}$ Patterson symmetry $Pm\bar{3}$





2_1 screw axis || to the a-, b- & c-axes, a-glide ⊥ to these axes

$P\ 2_1/a\ \ \bar{3}\ \ 1$

3-fold rotoinversion axes || to the body diagonals

No axes || to the face diagonals. No glides or mirrors ⊥ to these axes

Name the crystal system, Bravais lattice and point group from the following short Hermann-Mauguin space group symbols.

Pmma

P3m1

Name the crystal system, Bravais lattice and point group from the following short Hermann-Mauguin space group symbols.

Pmma

Crystal system: *orthorhombic*
Bravais lattice: *primitive orthorhombic*
Point group: *mmm* (D_{2h})
nonsymmorphic space group

P3m1

Name the crystal system, Bravais lattice and point group from the following short Hermann-Mauguin space group symbols.

Pmma

Crystal system: *orthorhombic*
Bravais lattice: *primitive orthorhombic*
Point group: *mmm* (D_{2h})
nonsymmorphic space group

P3m1

Crystal system: *trigonal*
Bravais lattice: *primitive hexagonal*
Point group: *3m* (C_{3v})
symmorphic space group

Name the crystal system, Bravais lattice and point group from the following short Hermann-Mauguin space group symbols.

$I4_1/a$

$Fd\bar{3}m$