

O Mundo Mágico de Escher

The Magical World of Escher

percurso sugerido

3º Andar - início da exposição

- Obras originais
- "Periscópio"
- "O poço infinito"
- "Cubo³"
- Cronologia de M. C. Escher

2º Andar

- Obras originais
- "A escada virtual"
- "Metamorfose platônica"
- "A sala impossível"
- "Um passeio pelas ruas de Amsterdã"

1º Andar

- "Um passeio pelas ruas de Amsterdã"
 - "Anamorfoses"
 - "Reflexão sobre Escher"
 - Documentário - "Metamorfose"
 - Filme 3D - "O vale da realidade virtual"
- (Retire sua senha na bilheteria - térreo)

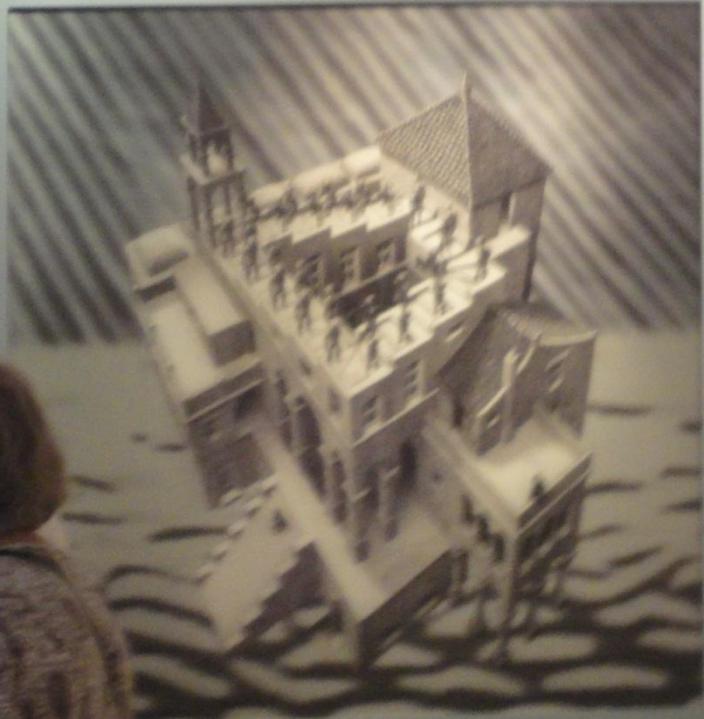
◀ Você está aqui

Térreo

- "O olho mágico"
- "Sala da relatividade"

Subsolo

- Obras originais
- "A casa de Escher"
- Animações



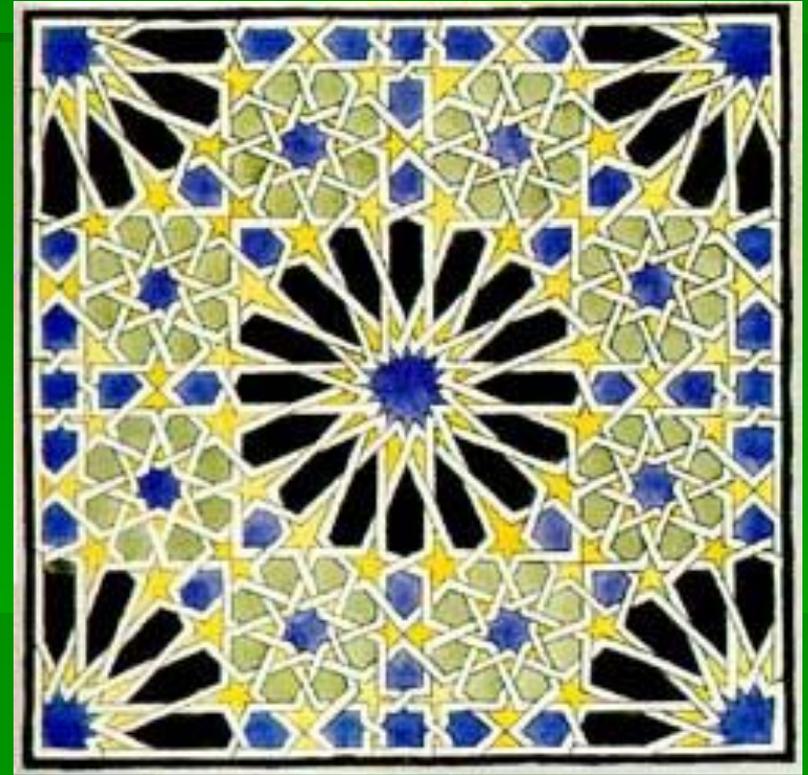
Maurits Cornelis Escher



Self-Portrait

The Beginnings

- The tilings in the Alhambra in Spain were laid out by the Moors in the 14th century.
- Colored tiles forming patterns
- Many truly symmetrical.
- They are not tessellations but they inspired young M.C Escher, who copied them into his notebooks and later converted some into true tessellations.
- These tilings never included animals or plants.
- Escher's tessellations hardly ever left them out!



Escher's drawing of Alhambra tiling.

M. C. Escher

- Escher produced '8 Heads' in 1922 - a hint of things to come. Turn the picture upside-down if all the heads are not apparent.
- He took a boat trip to Spain and went to the Alhambra.
- There, he copied many of the tiling patterns.



'8 Heads' - 1922

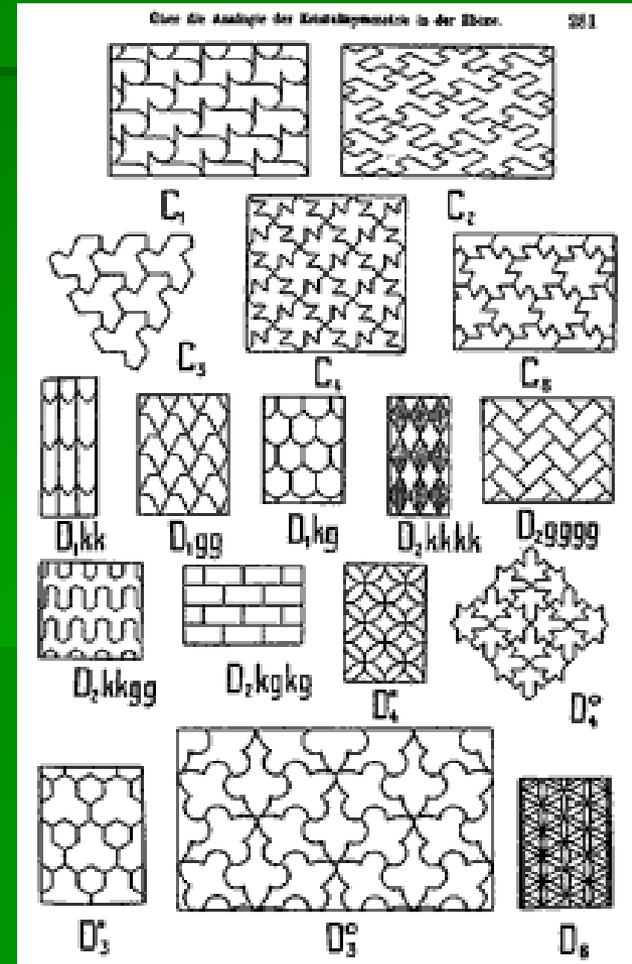
The Alhambra Palace, Granada, Spain, 12th-13th Century



Reflective Symmetry noted in the lower tile patterns

Crystal Structures & Wallpaper

- Escher showed his brother some of his work.
- The brother noted that it was similar to crystal structures he had seen in a paper he read.
- The brother sent Professor George Pólya's wallpaper designs from a Brussels library, saying that an artist could make use of this knowledge.



Pólya 17 Symmetries

ALGEMENE MINERALOGIE
EN KRISTALLOGRAFIE

DOOR

DR B. G. ESCHER
HOGLERAAR TE LEIDEN

TWEDE DRUK

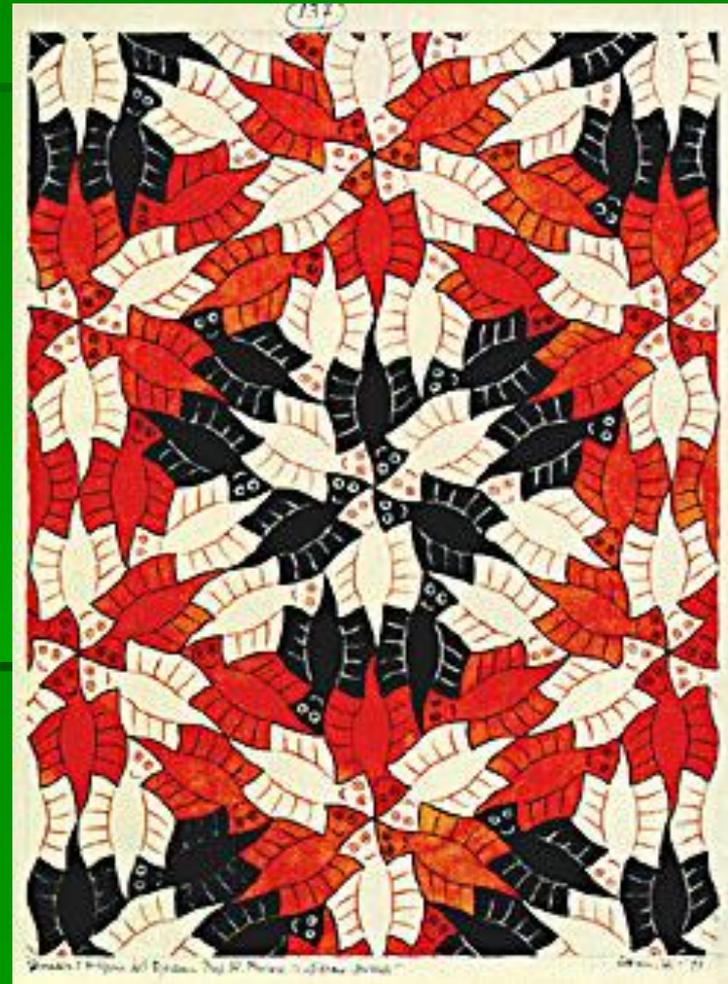


GORINCHEM — J. NOORDUYN EN ZOON — 1950

Berend George Escher

Escher's Last Tessellation

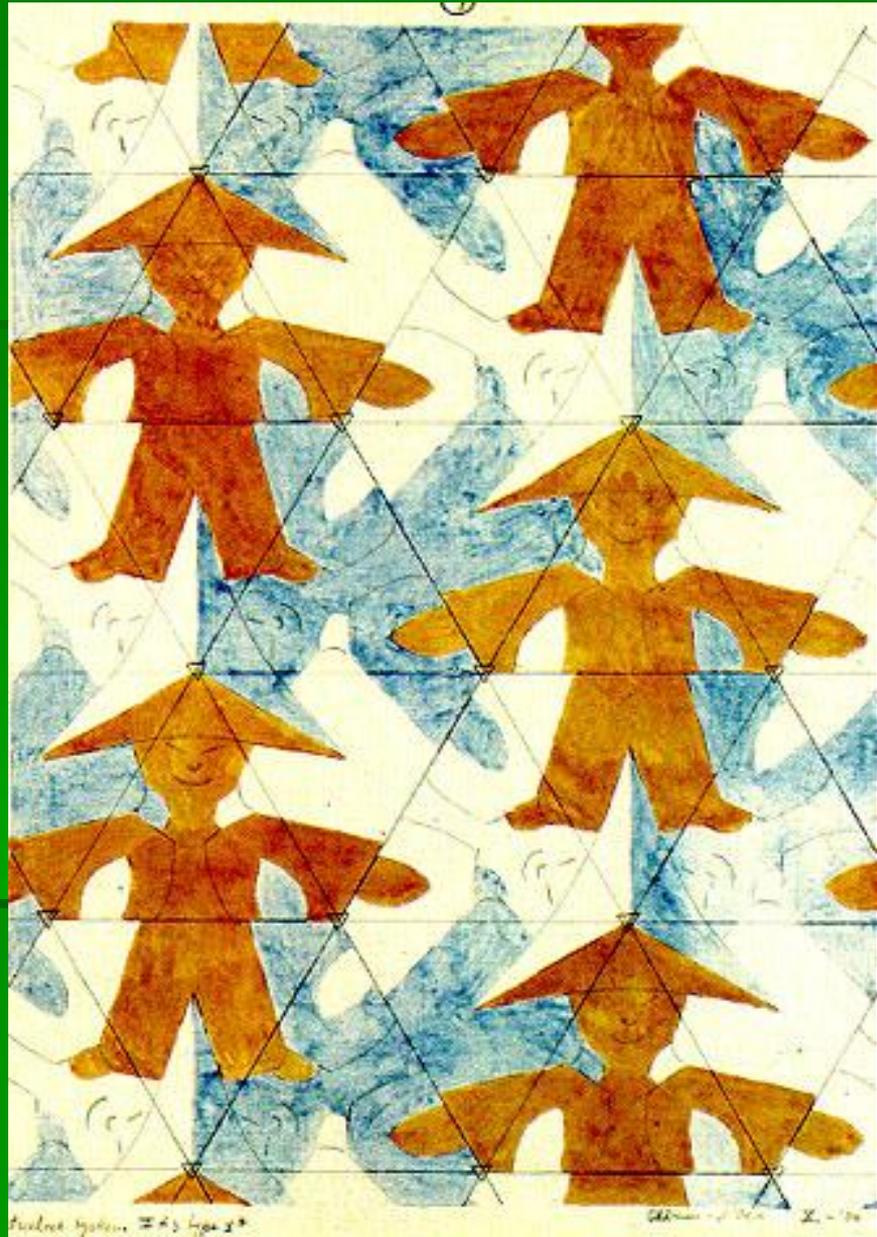
- His last tessellation was a solution to a puzzle sent to him by Roger Penrose, the mathematician. Escher solved it and, true to form, changed the angular wood blocks into rounded 'ghosts'.



Penrose 'Ghosts' - 1971

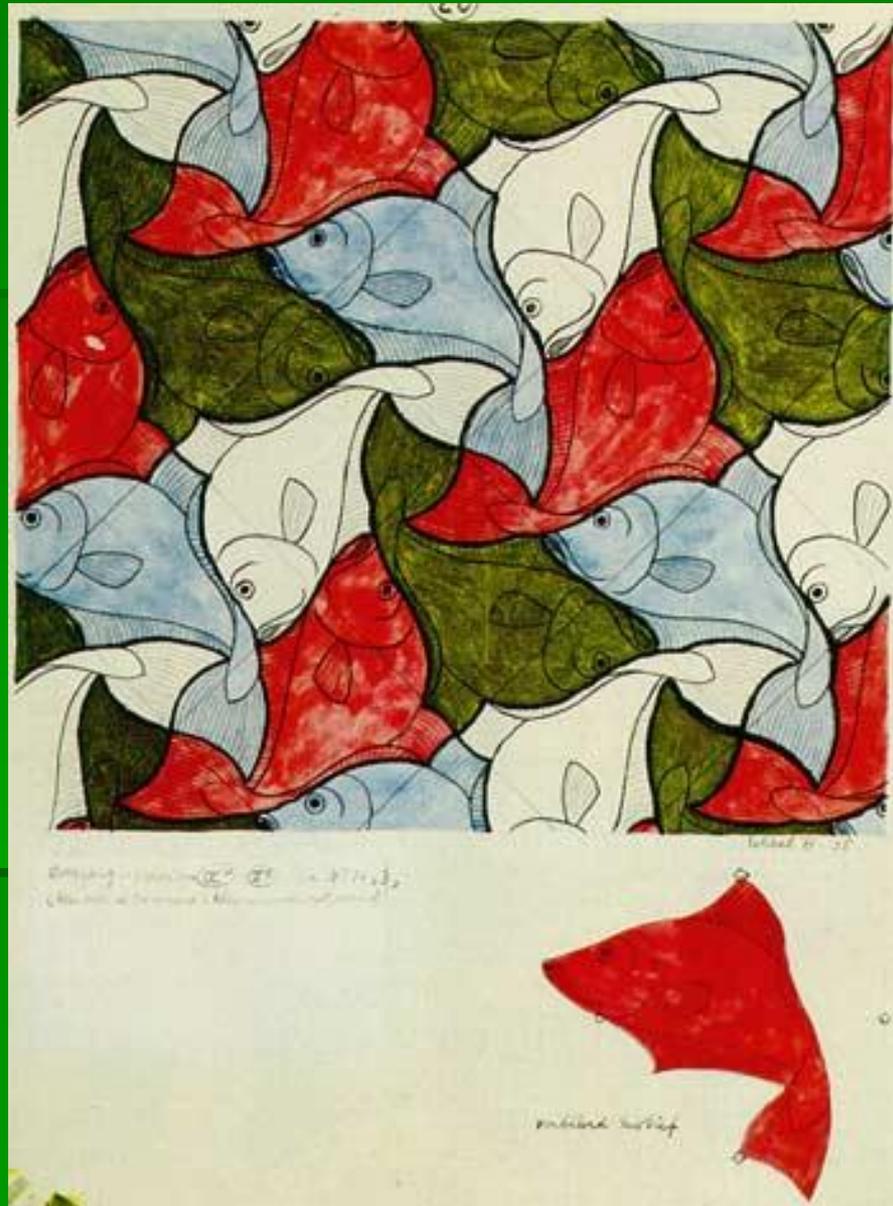
China Boy, 1936

Tessellation by M. C.
Escher



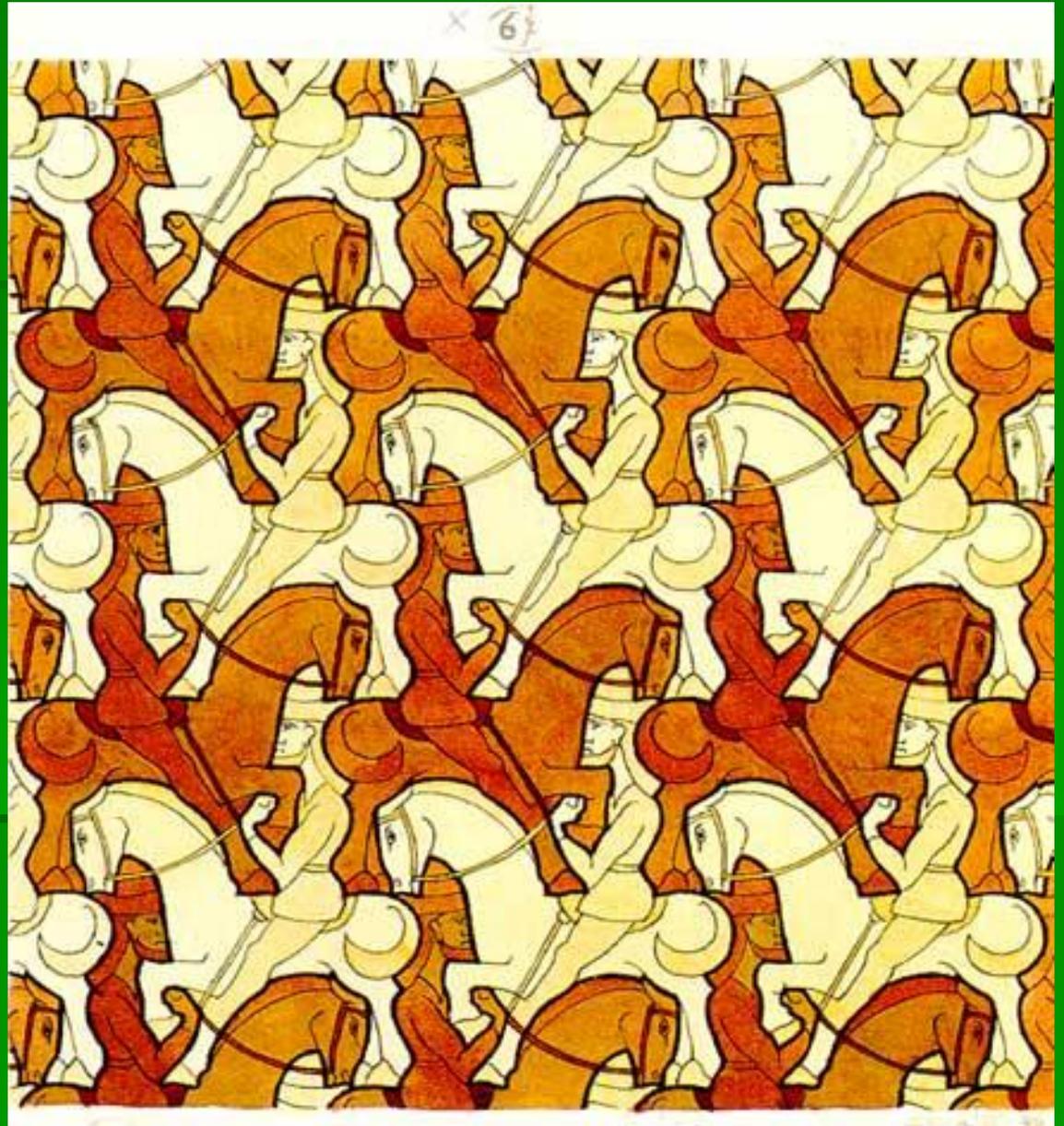
Fish, 1938

Tessellation by M. C.
Escher



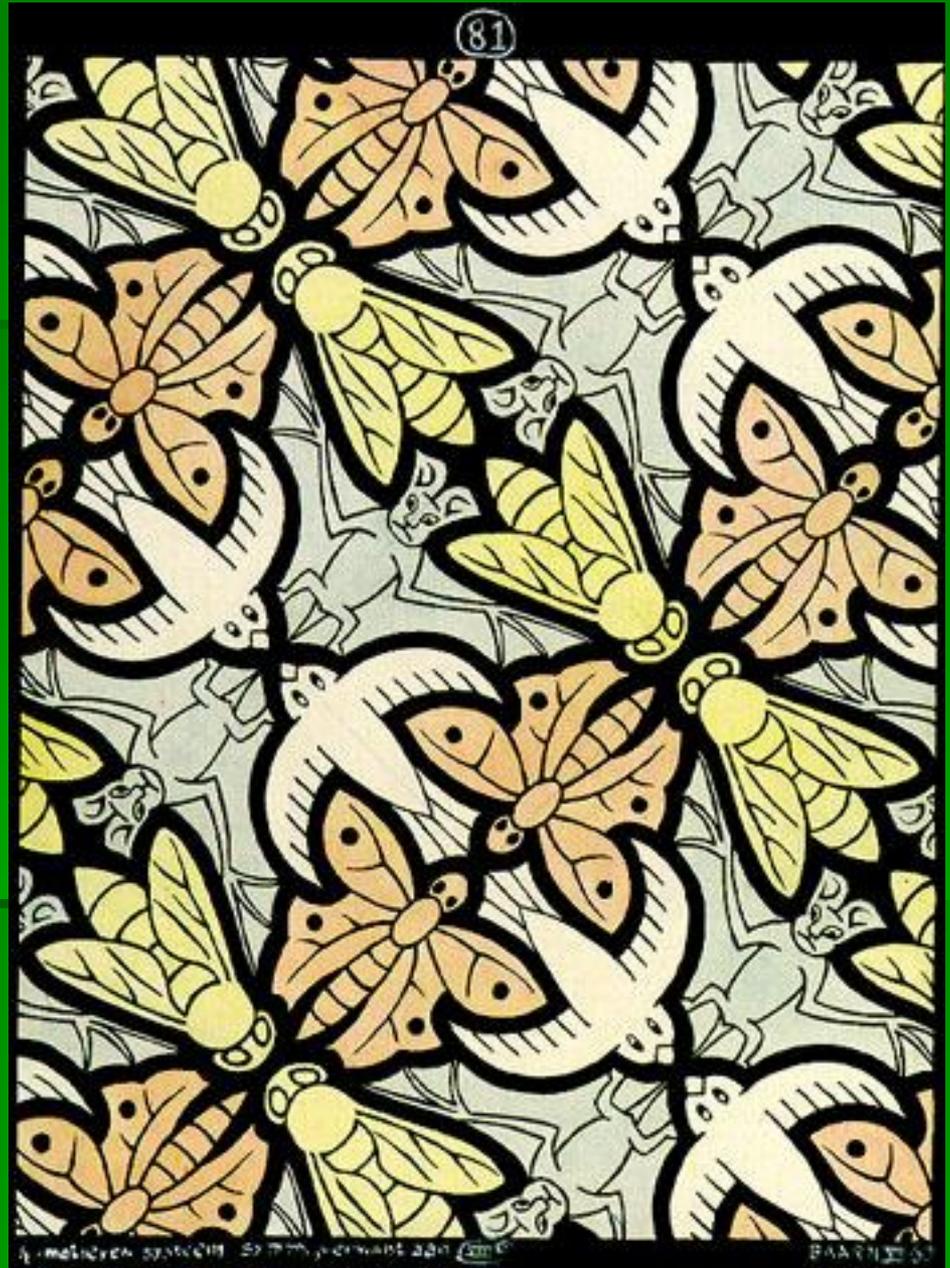
Horsemen n, 1946

Tessellation by M. C.
Escher



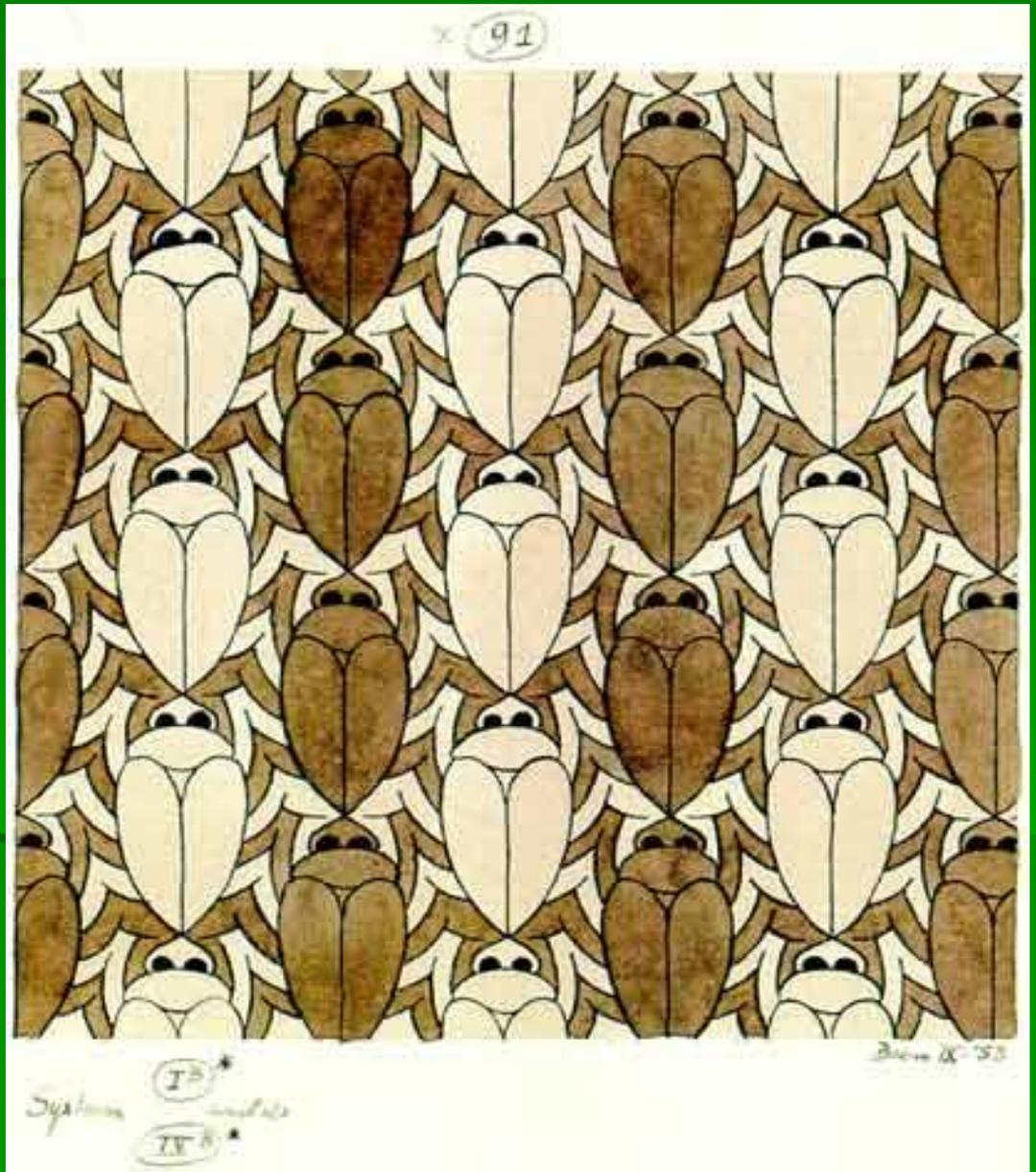
4 Motifs, 1950

Tessellation by M. C.
Escher



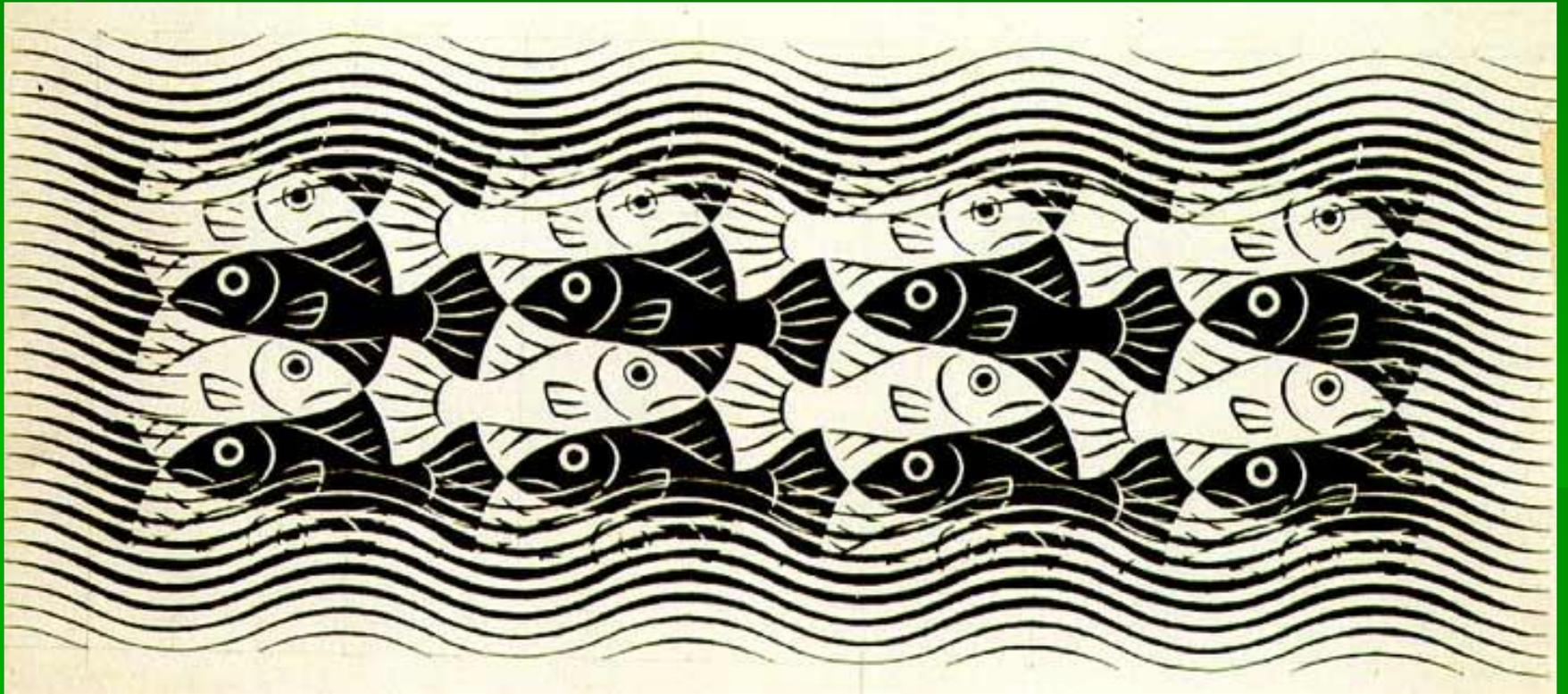
Scarabs, 1953

Tessellation by M. C.
Escher



Fishes, 1958 Mural

Tessellation mural by M. C. Escher



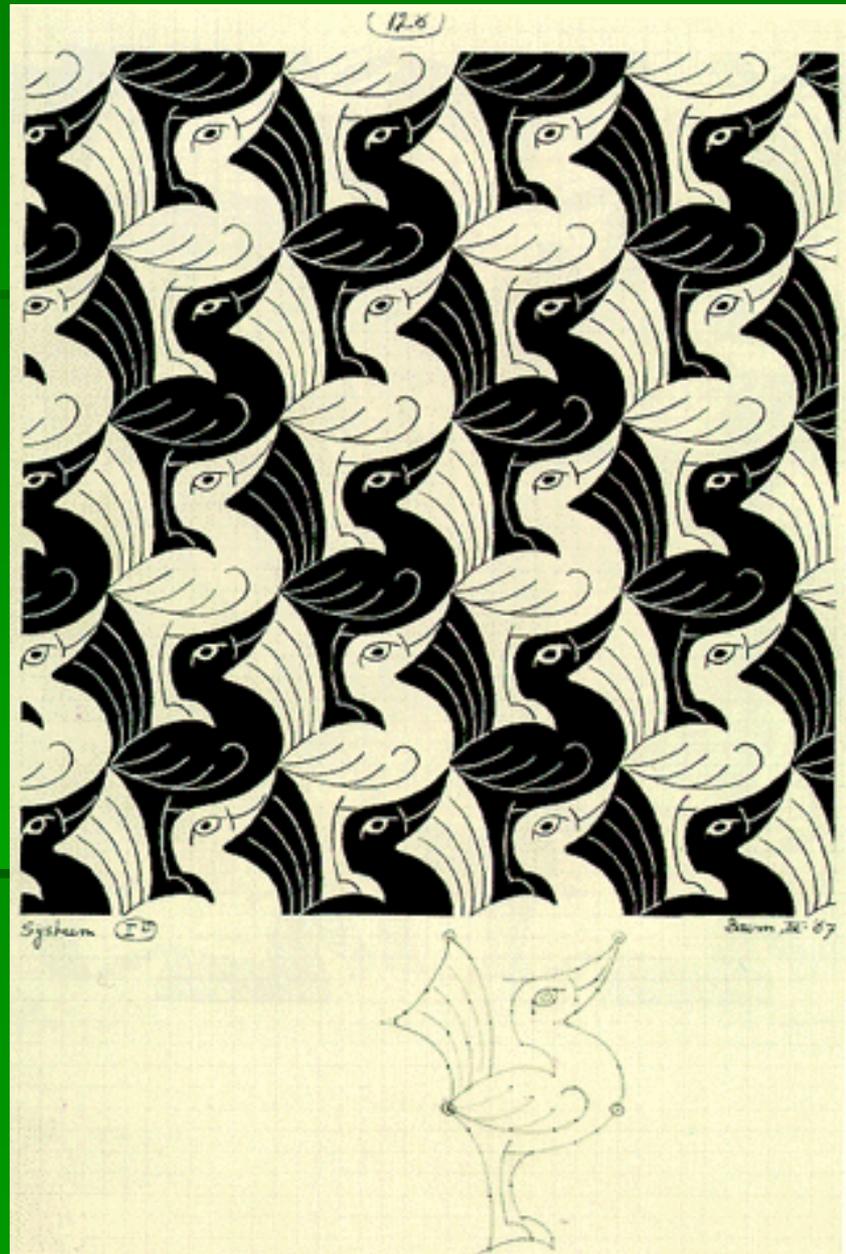
Pegasus, 1959

Tessellation by M. C.
Escher



Birds, 1967

Tessellation by M. C.
Escher



Realism & Tessellations Combined

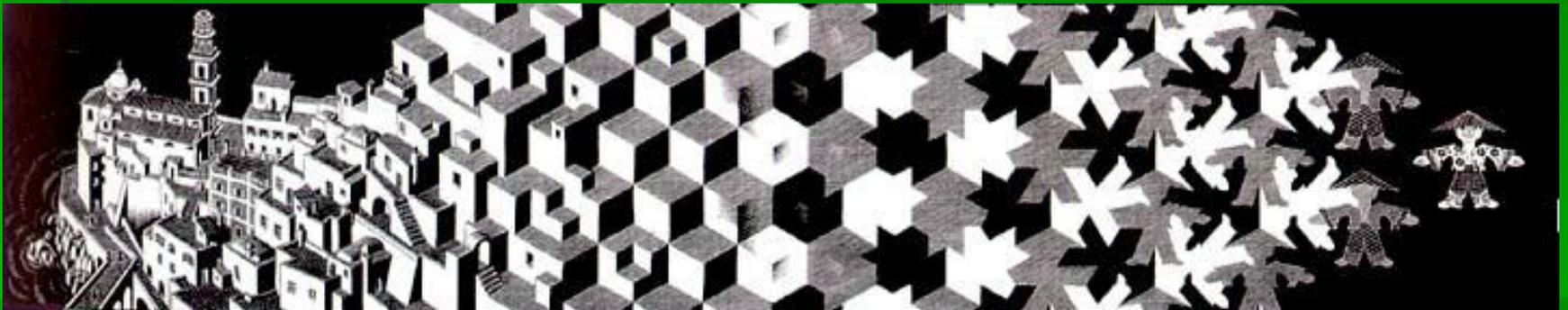
- Sometimes, M. C. Escher would combine realism and tessellations.
- *Reptiles* is an example of this combination.



'Reptiles' - 1943

Metamorphosis I, 1937

by M. C. Escher

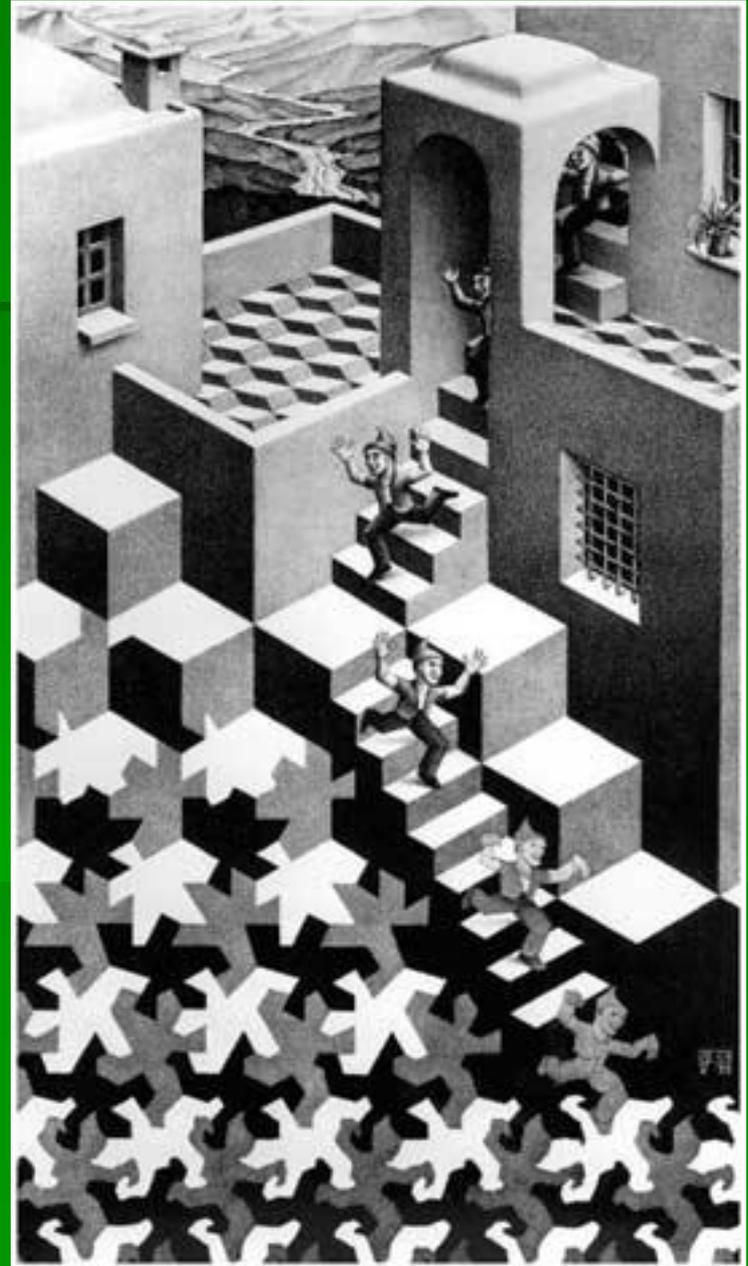


Realism & Tessellation Combined

Cycle, 1938

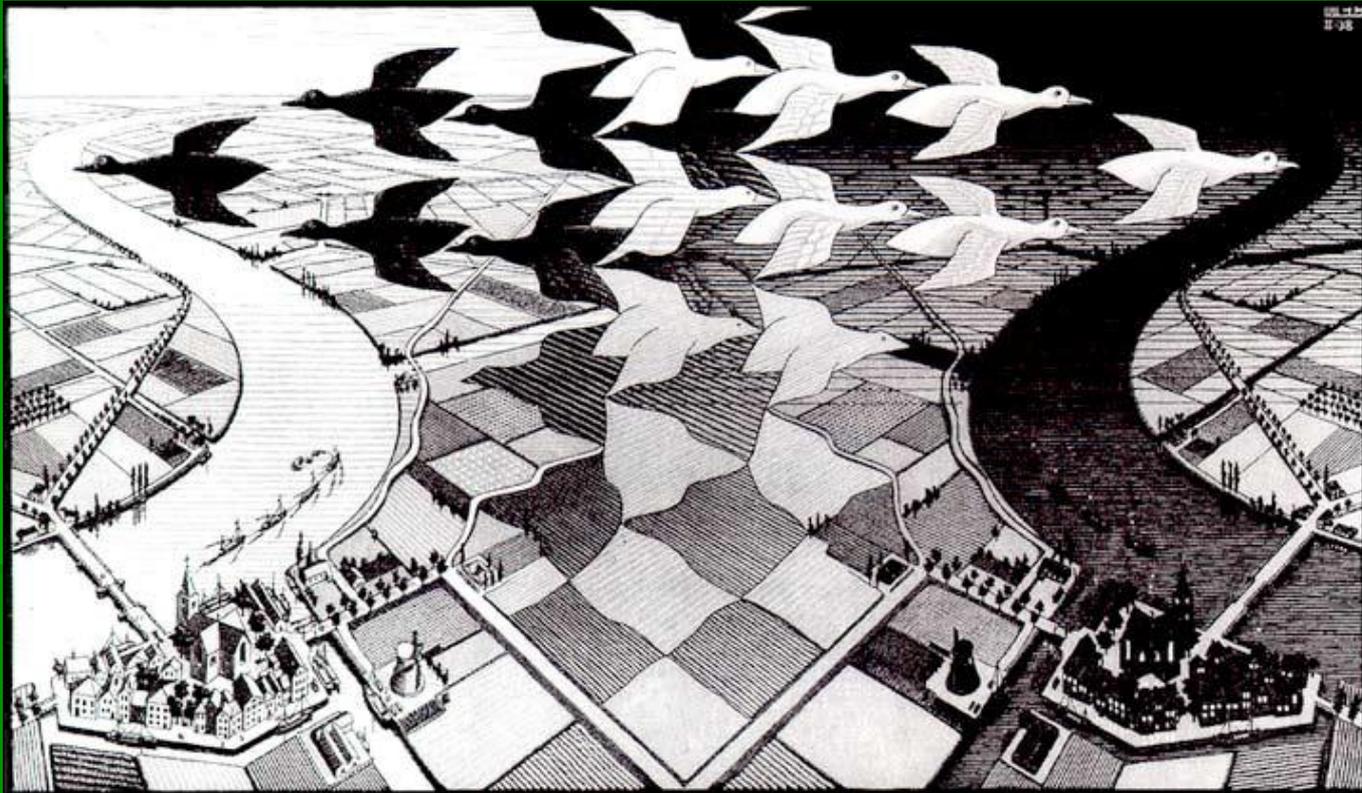
by M. C. Escher

Realism & Tessellation
Combined



Day and Night, 1938

by M. C. Escher



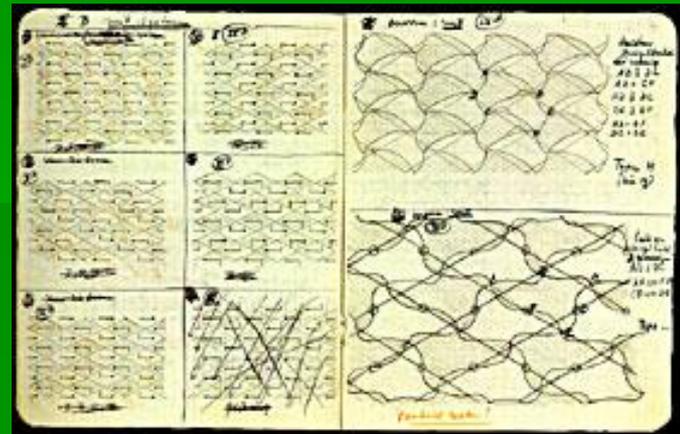
Realism & Tessellation Combined

A Full Life

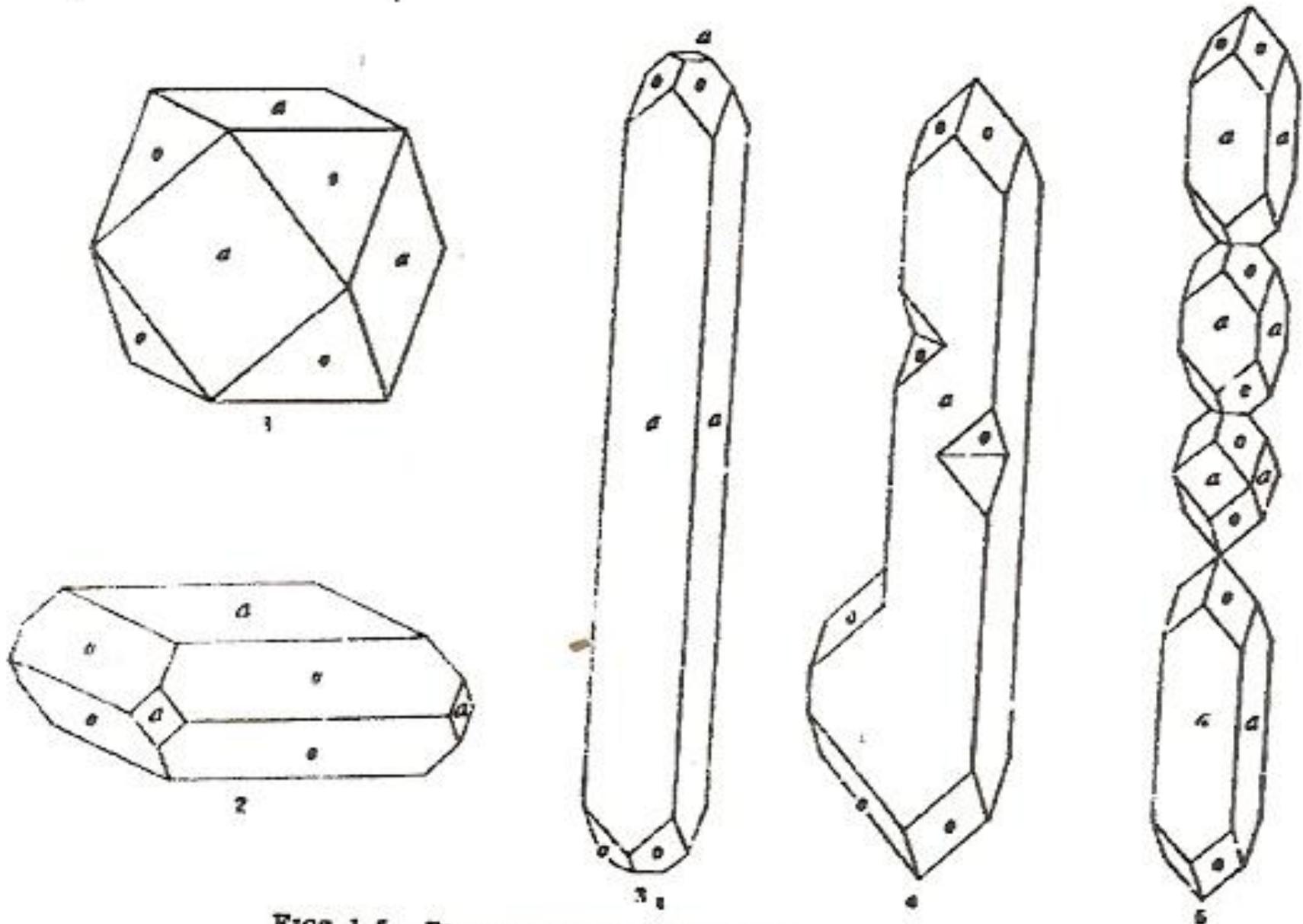
- Escher died on March 27, 1972.
- He had produced
 - 448 woodcuts, linocuts and lithos and
 - over 2,000 drawings.



M. C. Escher



Rhomboid possibilities - 1937 notebook



FIGS. 1-5.—PYRITE CRYSTALS FROM STILLWATER, ARK.

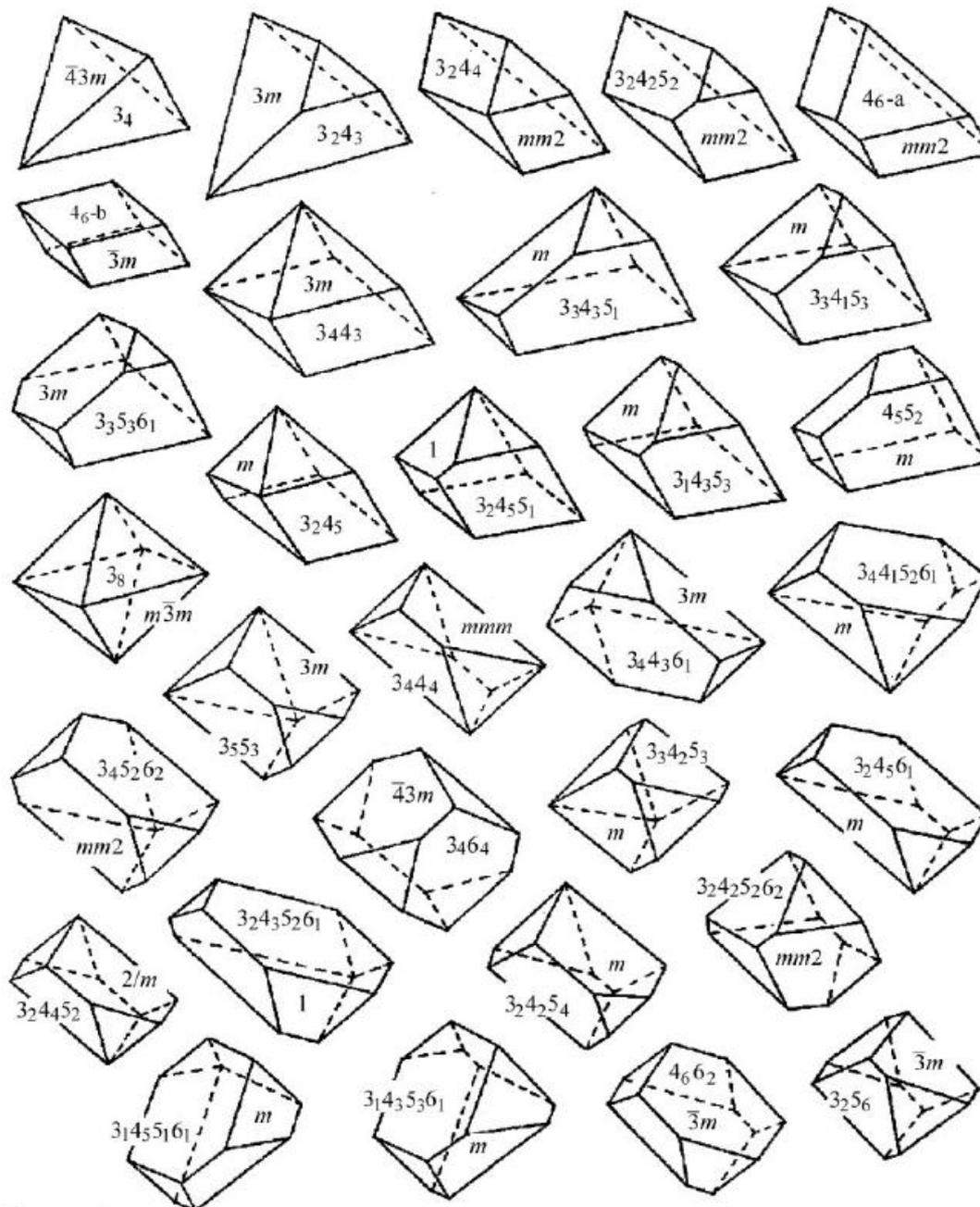


Figure 1
The real crystal octahedra. See text for the symbols.

AS 32 CLASSES CRISTALINAS

Sistema Cristalino	Classe Cristalina	Grau de Simetria	Nome da Classe
Triclínico	1	Sem simetria	Pedial
	$\bar{1}$	i	Pinacoidal
Monoclínico	2	1E2	Esfenoédrica
	m	1m	Domática
	2/m	1E2, 1m, i	Prismática
Ortorrômbo	222	3E2	Biesfenoédrica-rômboica
	mm2	1E2, 2m	Piramidal rômboica
	2/m2/m2/m	3E2, 3m, i	Bipiramidal rômboica
Tetragonal	4	1E4	Piramidal tetragonal
	$\bar{4}$	1E $\bar{4}$	Biesfenoédrica tetragonal
	4/m	1E4, 1m, i	Bipiramidal tetragonal
	422	1E4, 4E2	Trapezoédrica tetragonal
	4mm	1E4, 4m	Piramidal ditetragonal
	$\bar{4}2m$	1E $\bar{4}$, 2E2, 2m	Escalenoédrica tetragonal
	4/m2/m2/m	1E4, 4E2, 5m, i	Bipiramidal ditetragonal
Trigonal (Classe Hexagonal - Divisão Romboédrica)	3	1E3	Piramidal trigonal
	$\bar{3}$	1E $\bar{3}$	Romboédrica
	32	1E3, 3E2	Trapezoédrica trigonal
	3m	1E3, 3m	Piramidal ditrigonal
	$\bar{3}2/m$	1E $\bar{3}$, 3E2, 3m, i	Escalenoédrica hexagonal
Hexagonal (Classe Hexagonal - Divisão Hexagonal)	6	1E6	Piramidal hexagonal
	$\bar{6}$	1E $\bar{6}$	Bipiramidal trigonal
	6/m	1E6, 1m, i	Bipiramidal hexagonal
	622	1E6, 6E2	Trapezoédrica hexagonal
	6mm	1E6, 6m	Piramidal dihexagonal
	$\bar{6}m2$	1E $\bar{6}$, 3E2, 3m	Bipiramidal ditrigonal
	6/m2/m2/m	1E6, 6E2, 7m, i	Bipiramidal dihexagonal
Isométrico (Cúbico)	23	4E3, 3E2	Tetartoédrica
	2/m $\bar{3}$	4E $\bar{3}$, 3E2, 3m, i	Diploédrica
	432	4E3, 3E4, 6E2	Giroédrica
	$\bar{4}3m$	4E3, 3E $\bar{4}$, 6m	Hexatetraédrica
	4/m $\bar{3}2/m$	4E $\bar{3}$, 3E4, 6E2, 9m, i	Hexaoctaédrica

Nicholas Steno (1669):

Lei da Constância dos Ângulos Interfaciais

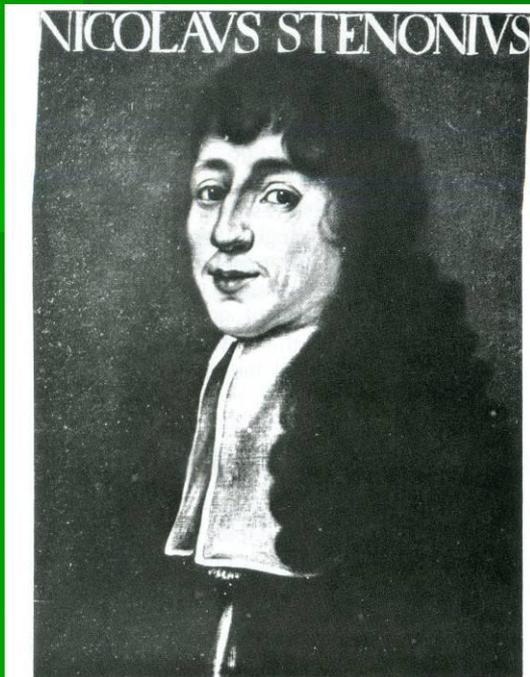
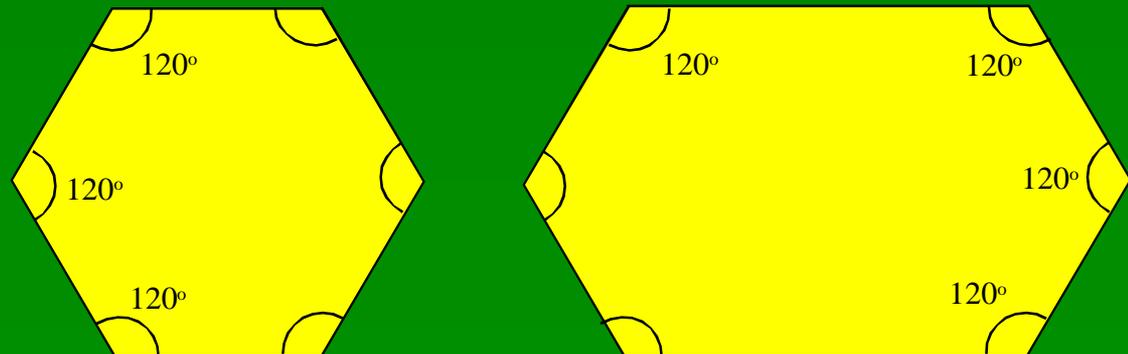
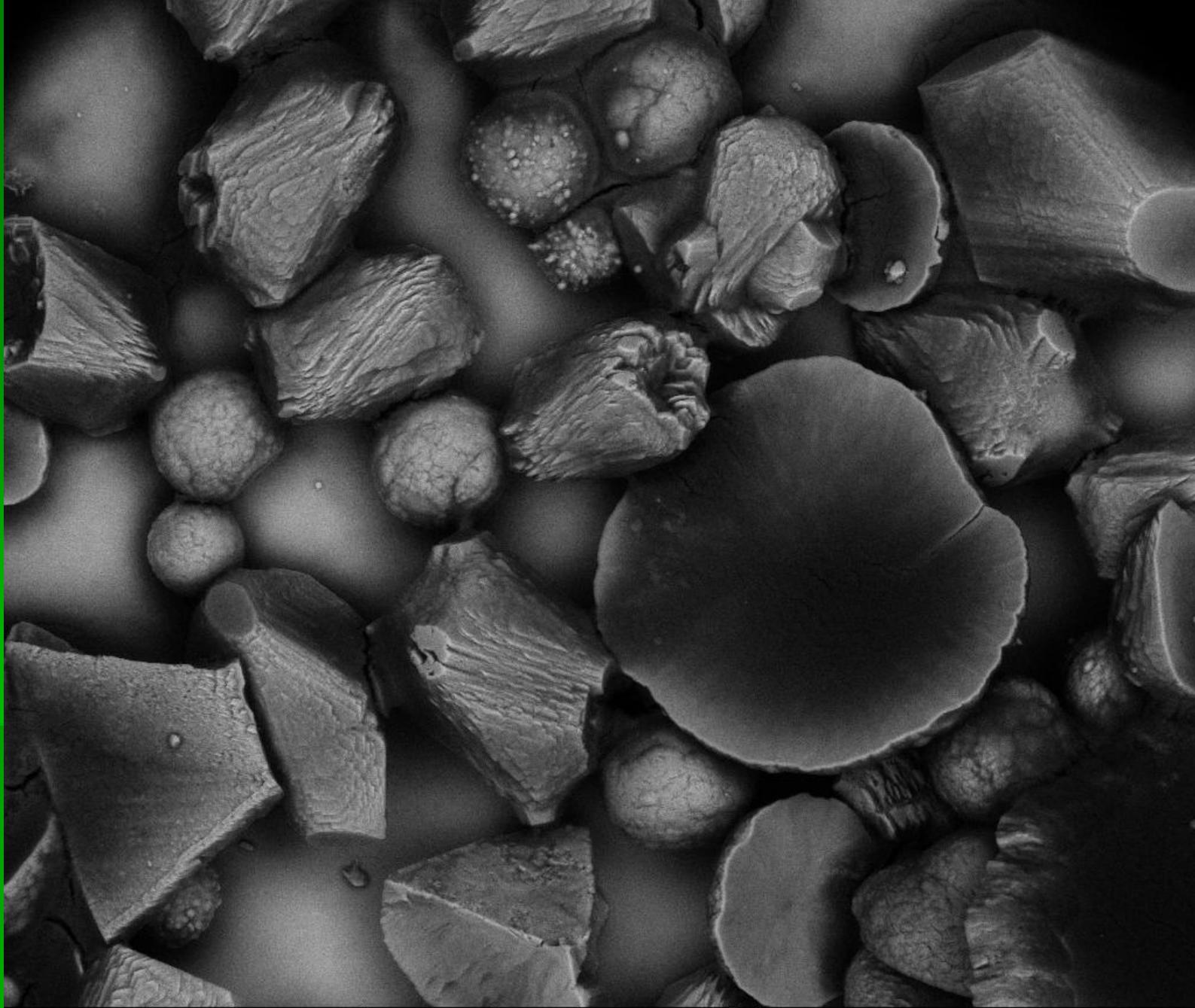


FIG. 1.4. Portrait of Niels Stensen (Latinized to Nicolaus Steno). Steno was born in Copenhagen, Denmark, in 1638 and died in 1686. (From Scherz, G., *Steno, Geological Papers*. Odense University Press, 1969.)





vac mode
ESEM

det
GAD

HV
20.00 kV

WD
15.0 mm

mag
600 x

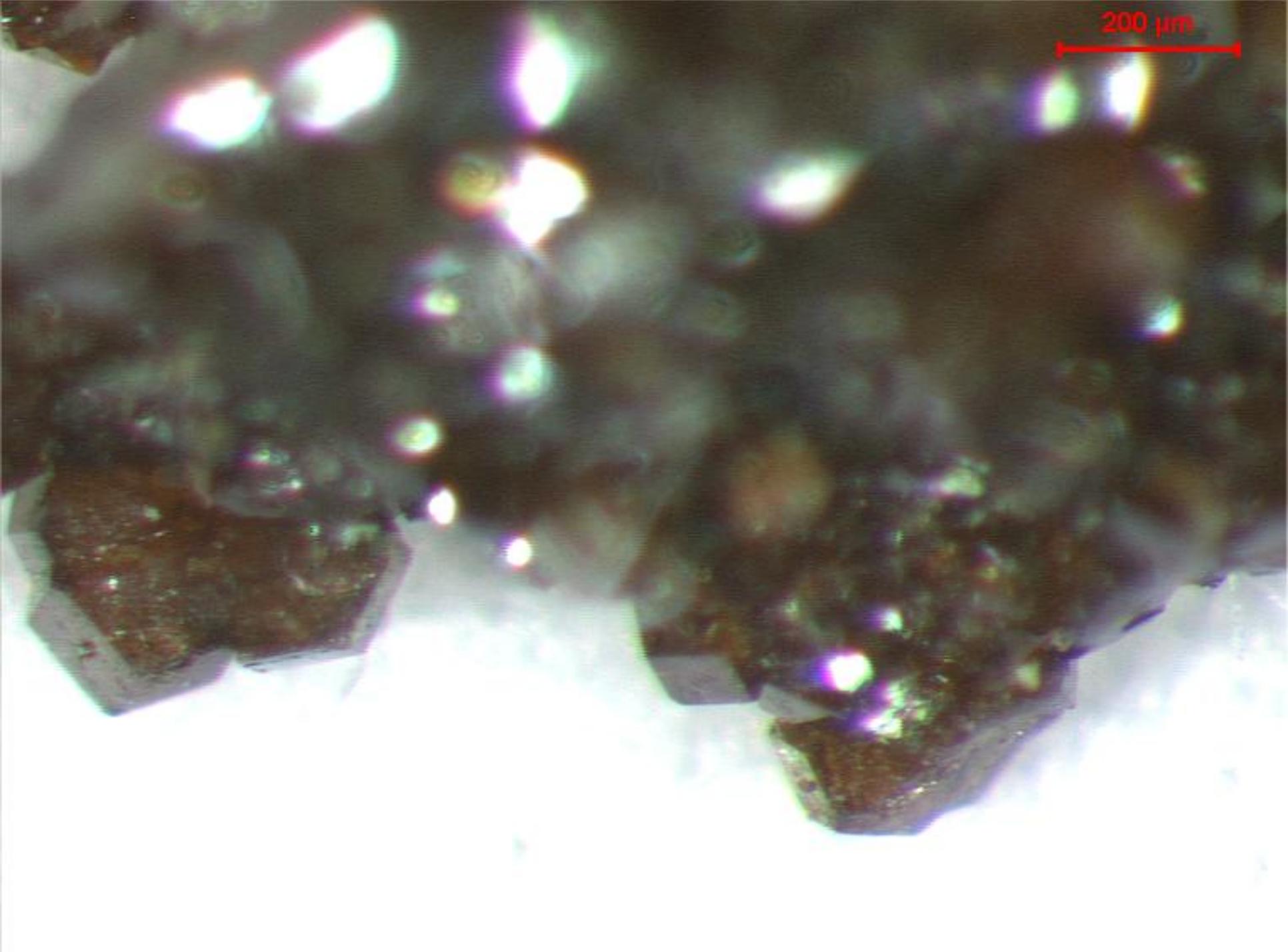
pressure
400 Pa

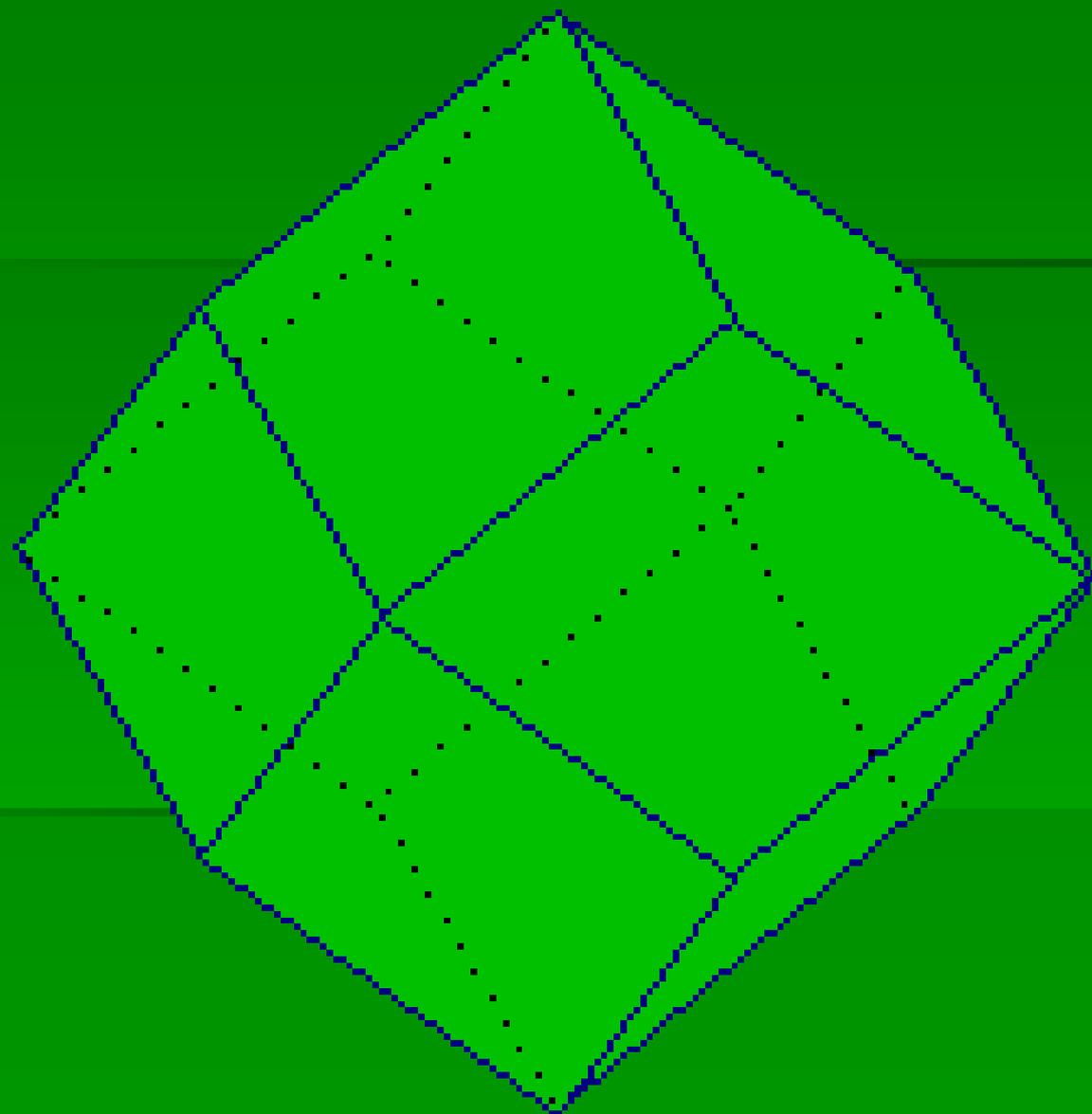


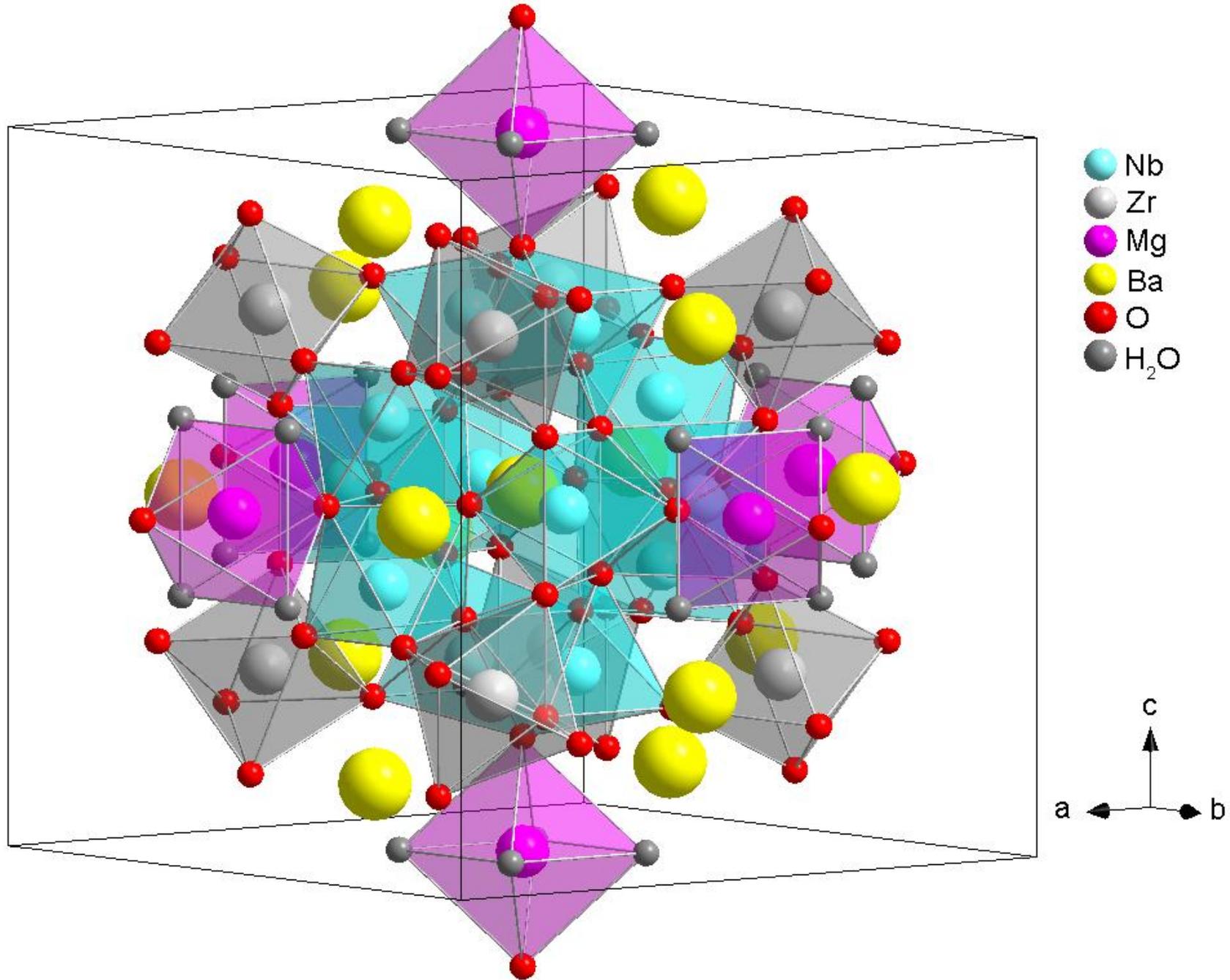
— 100 μ m —
LCT - Quanta 600 FEG

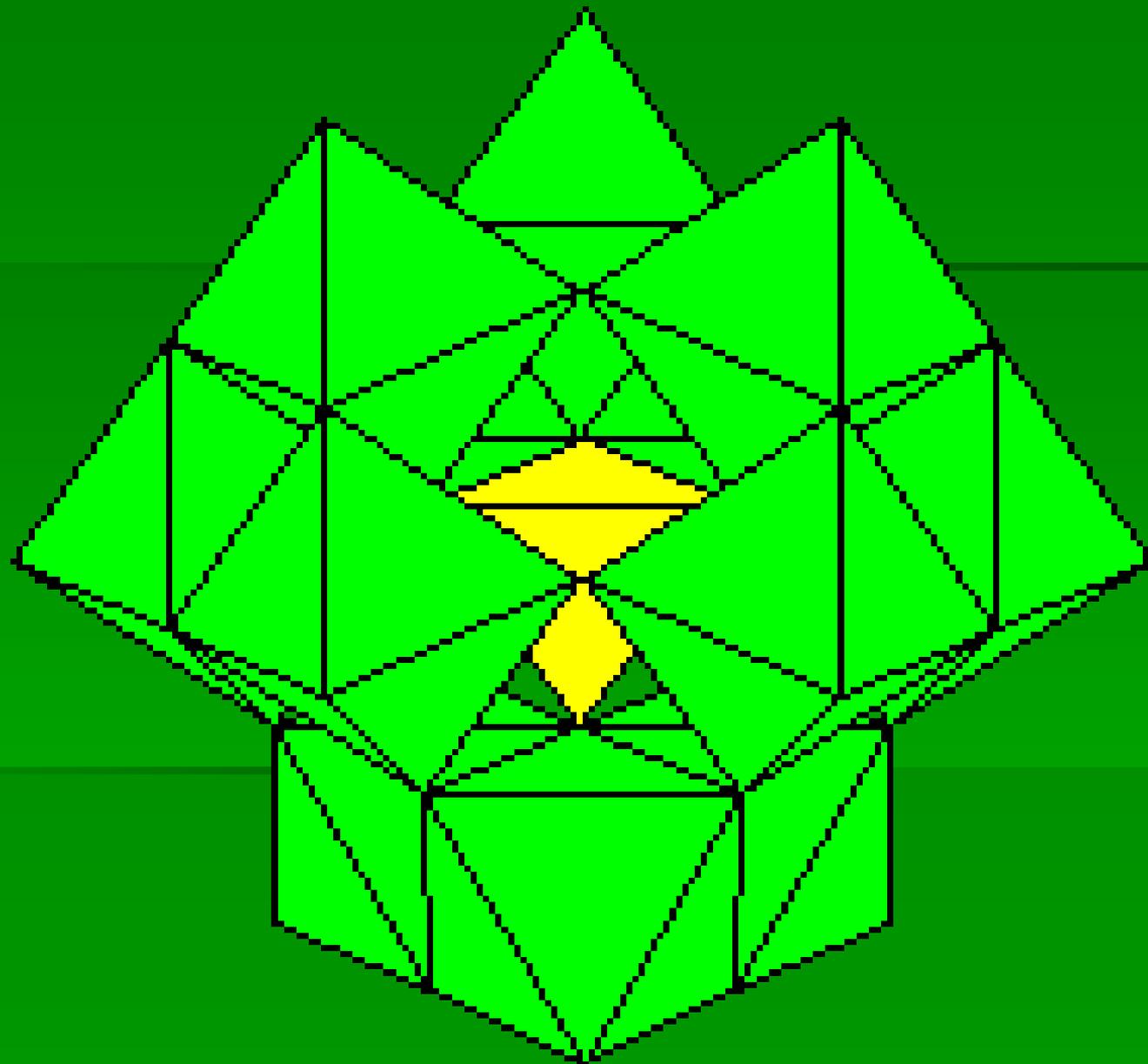


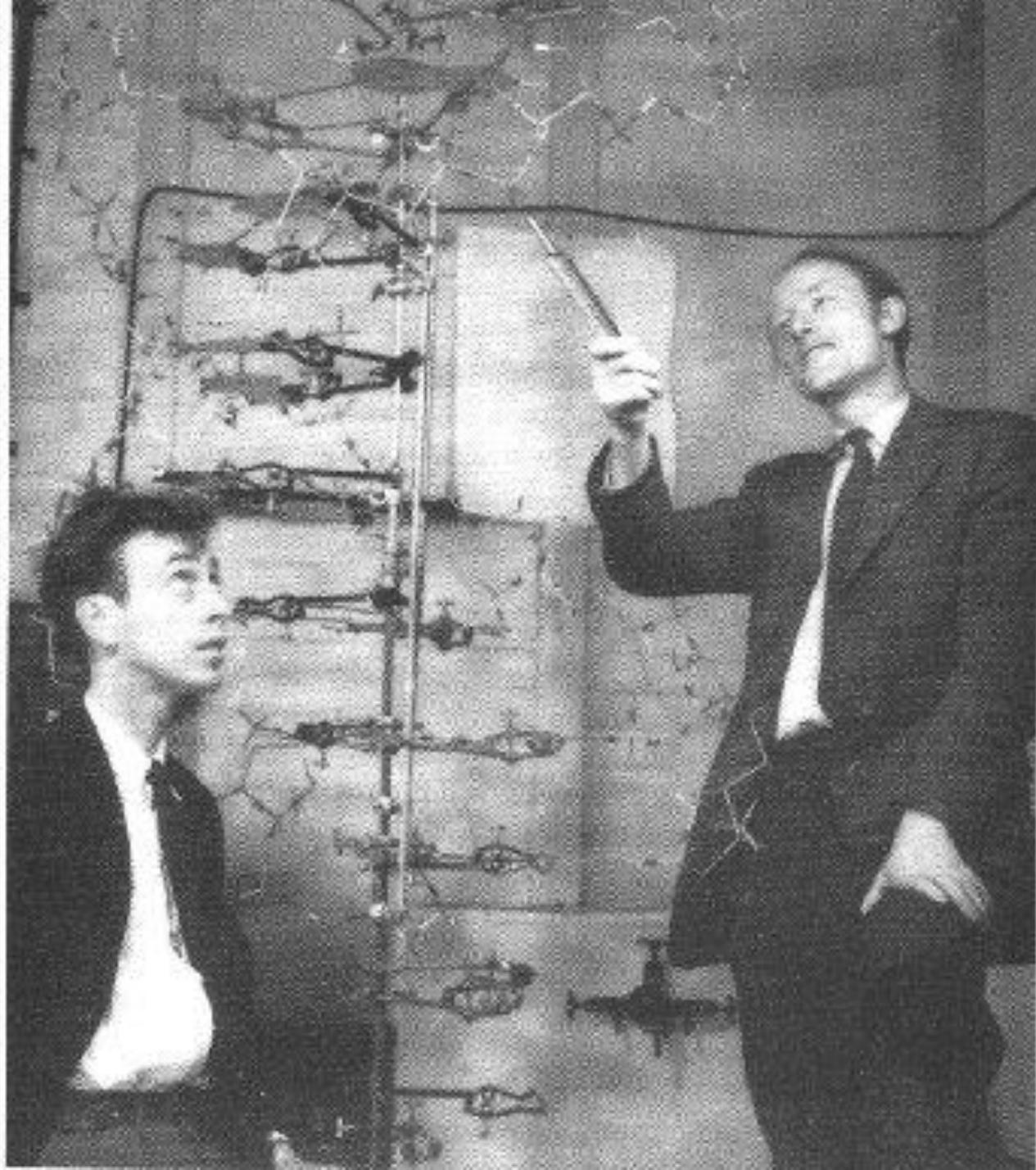
200 μm

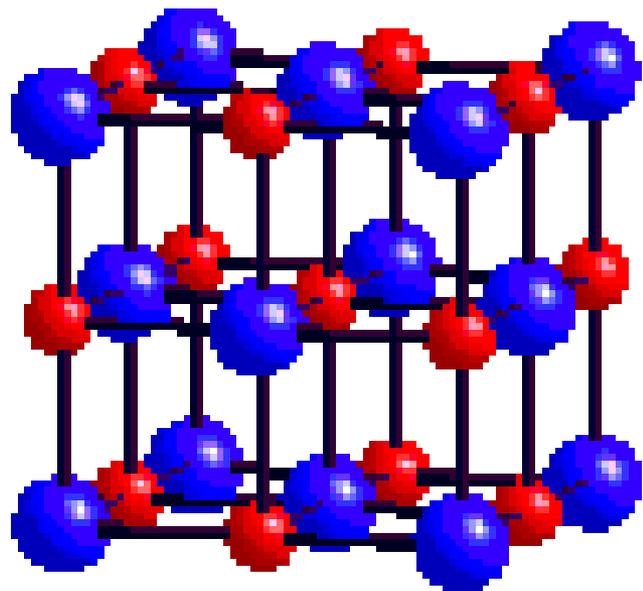


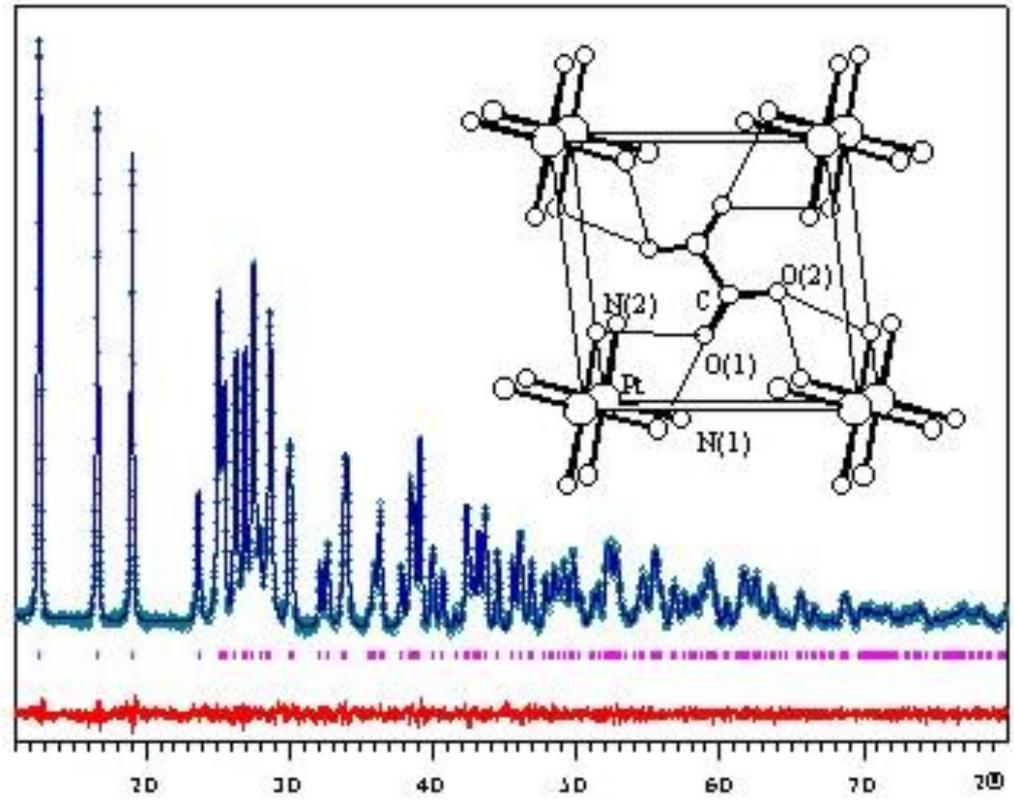
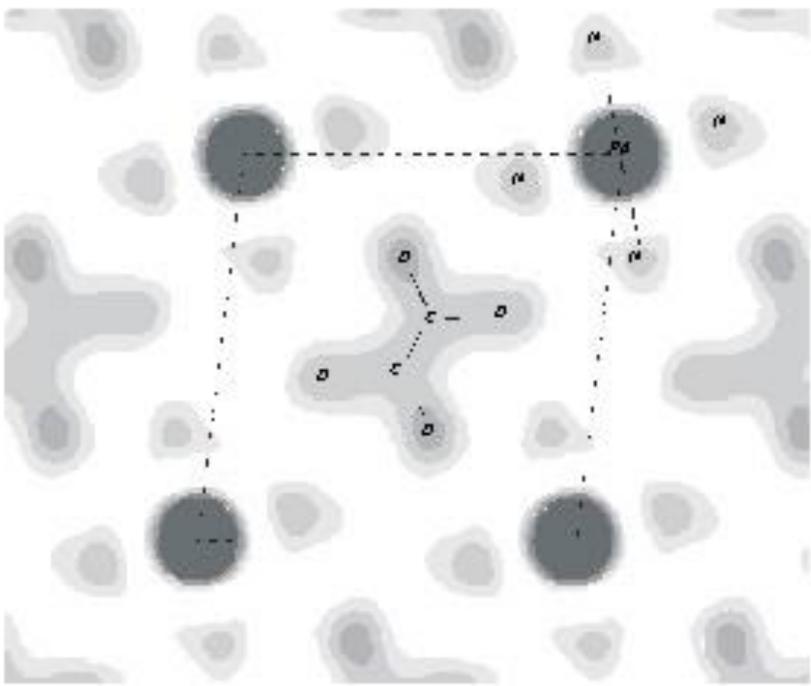






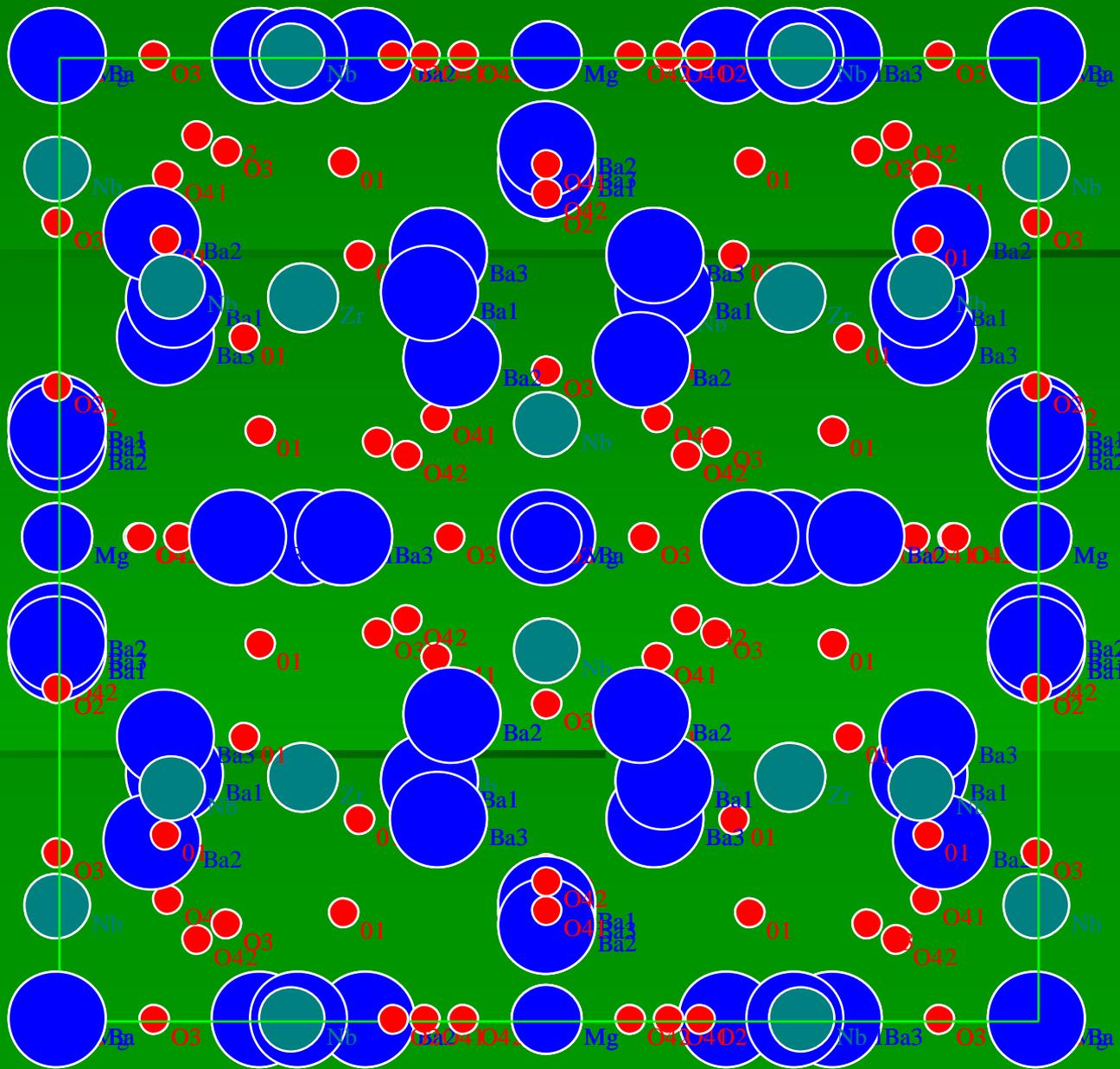


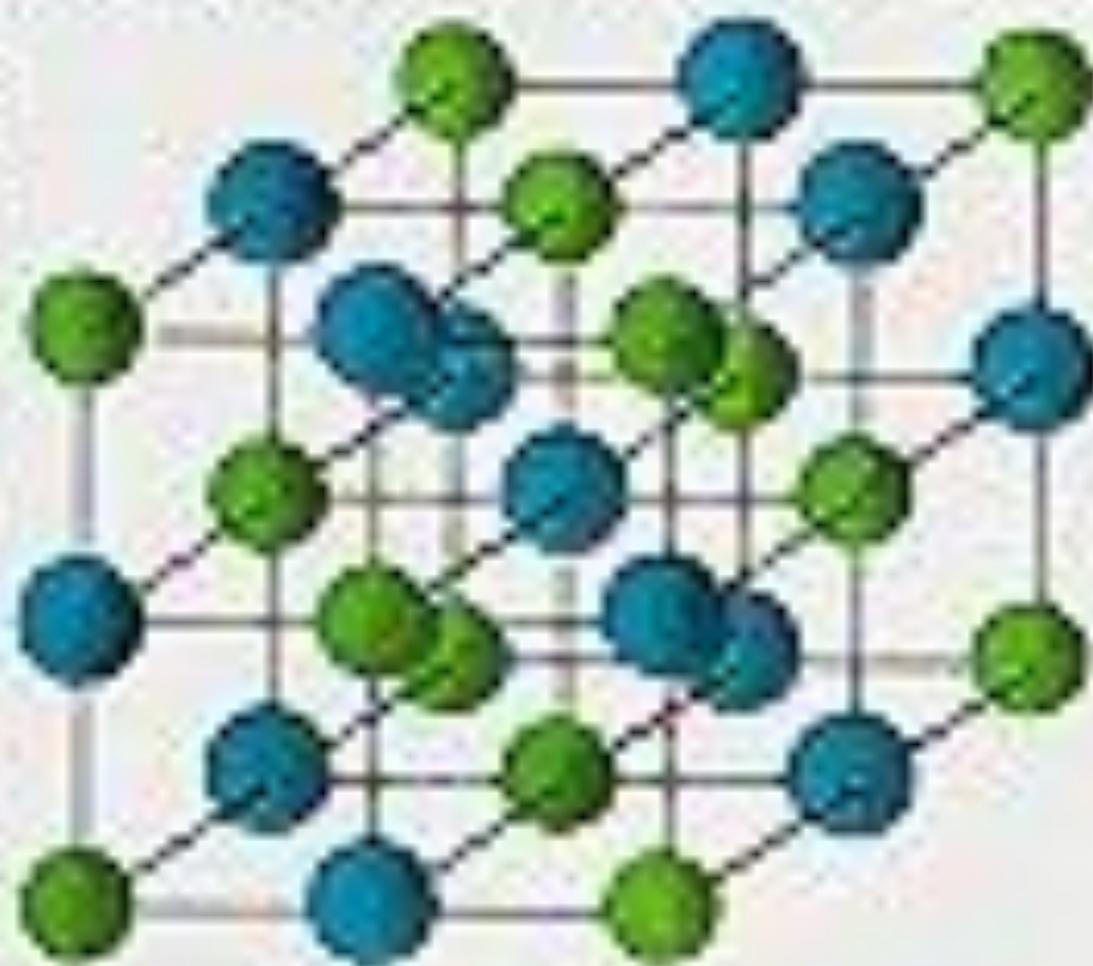




SIMETRIA
INTERNA
DOS
CRISTAIS

Daniel Atencio

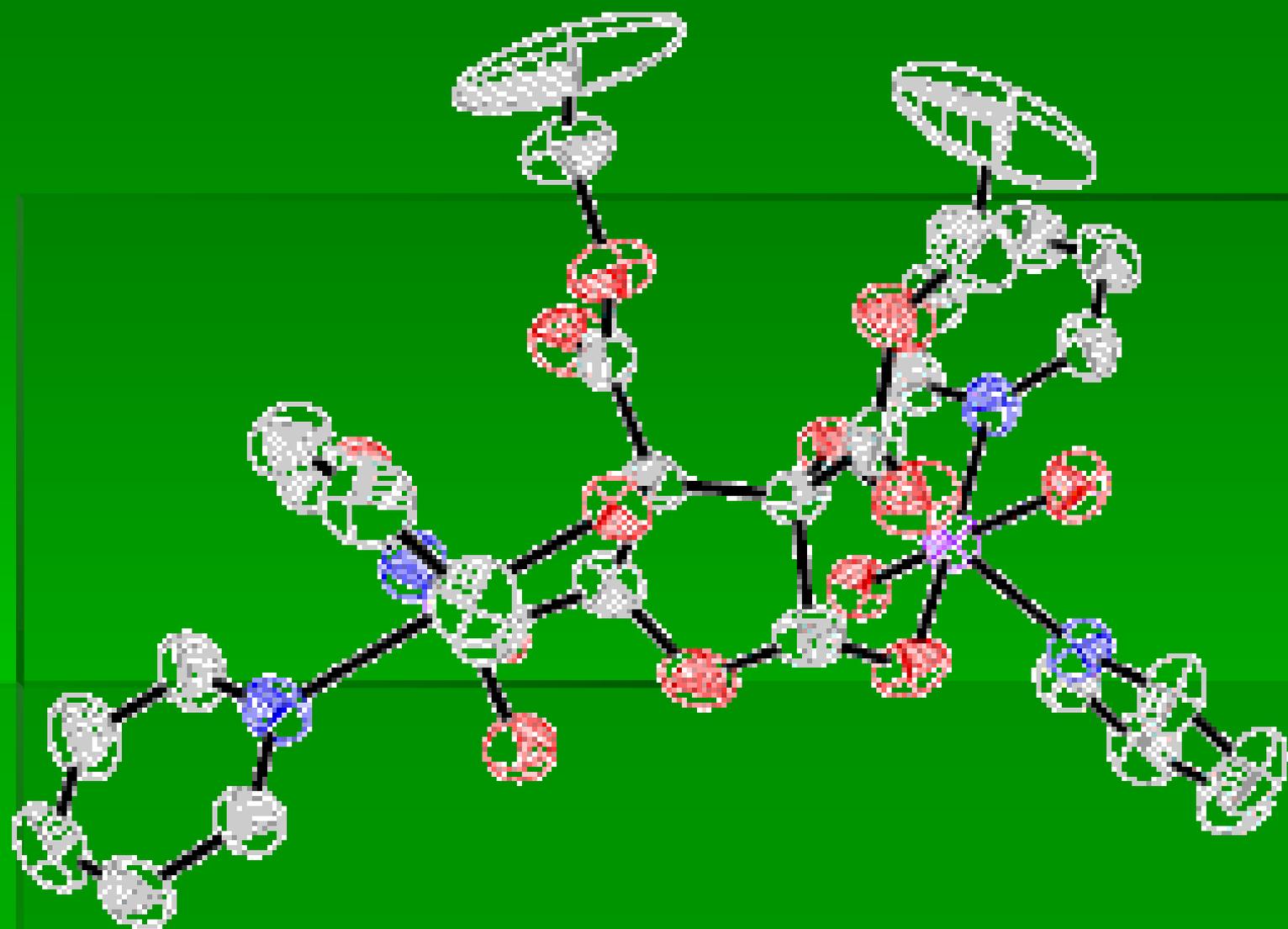


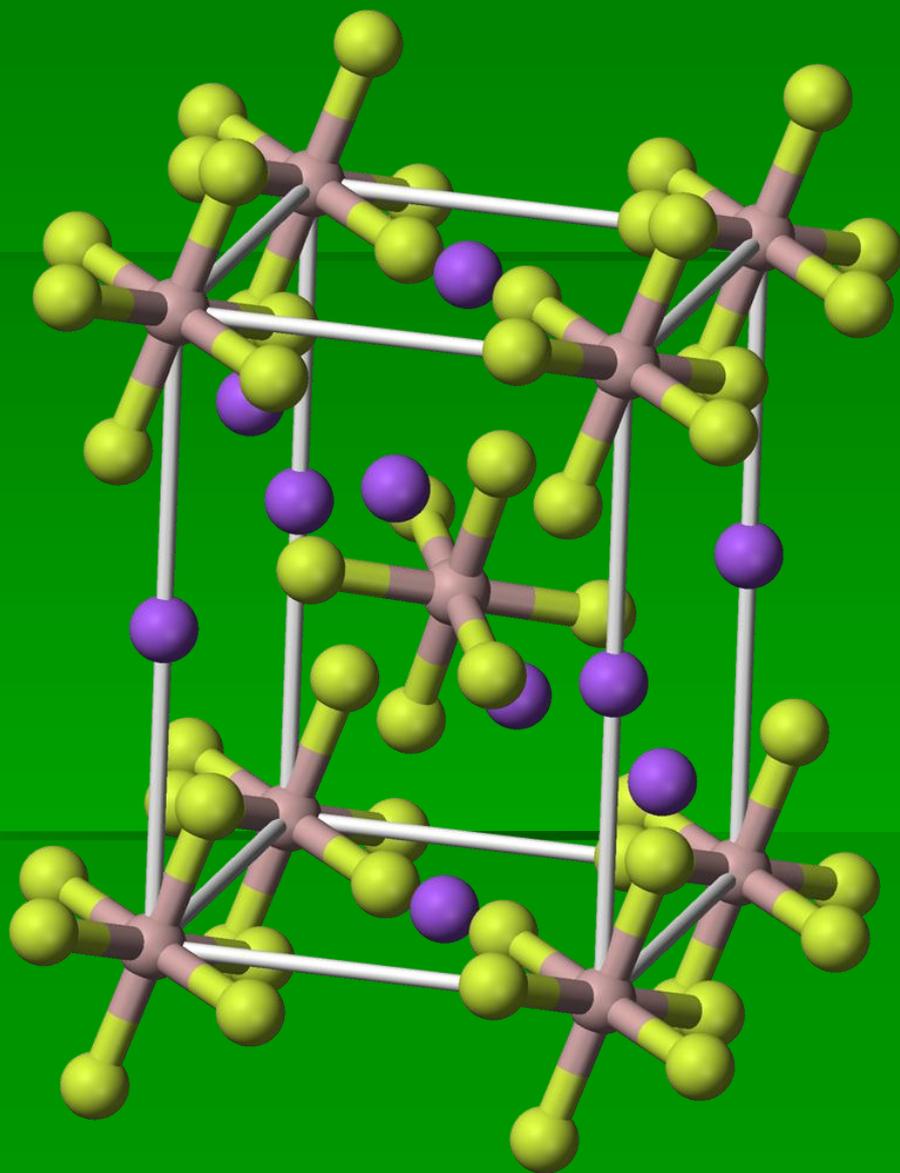


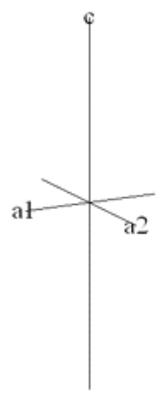
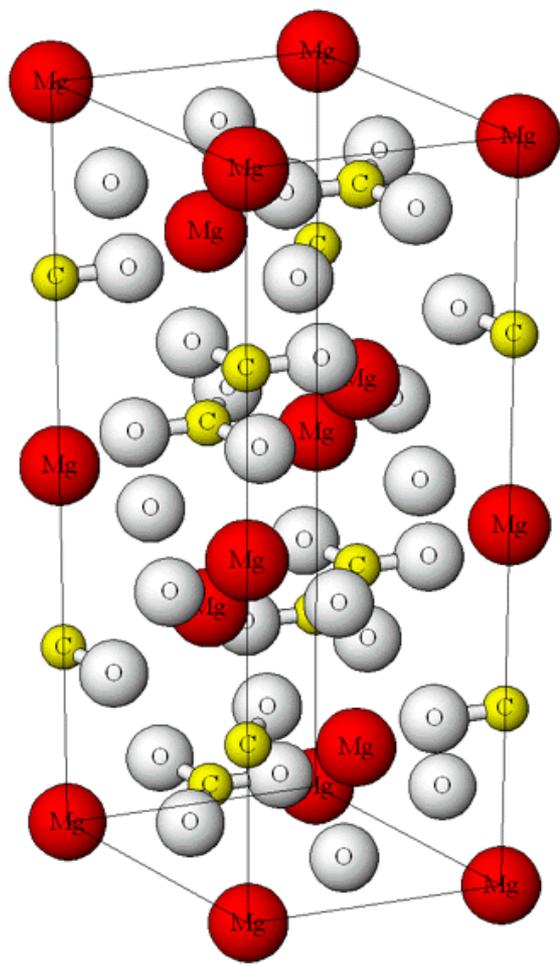
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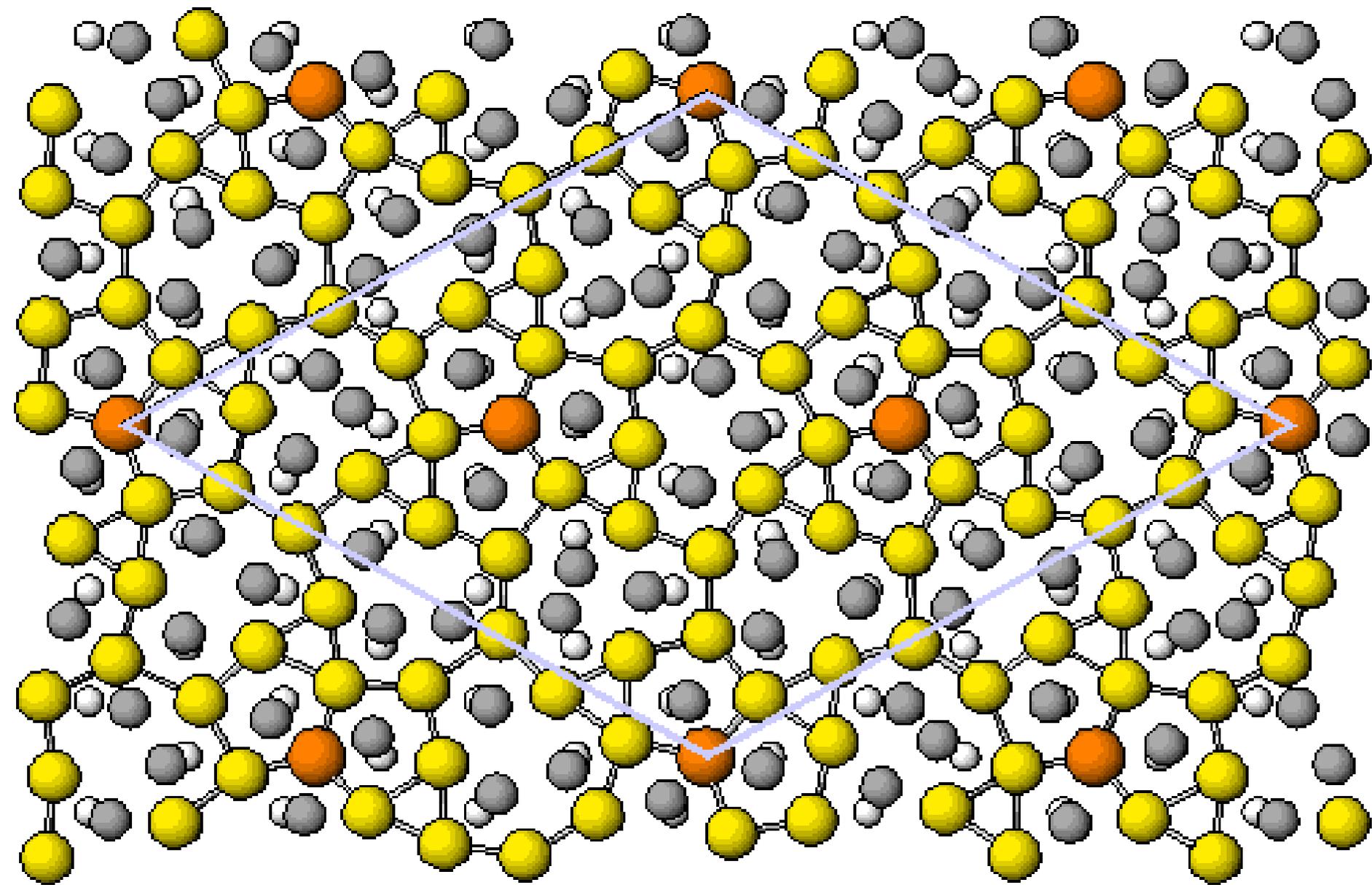
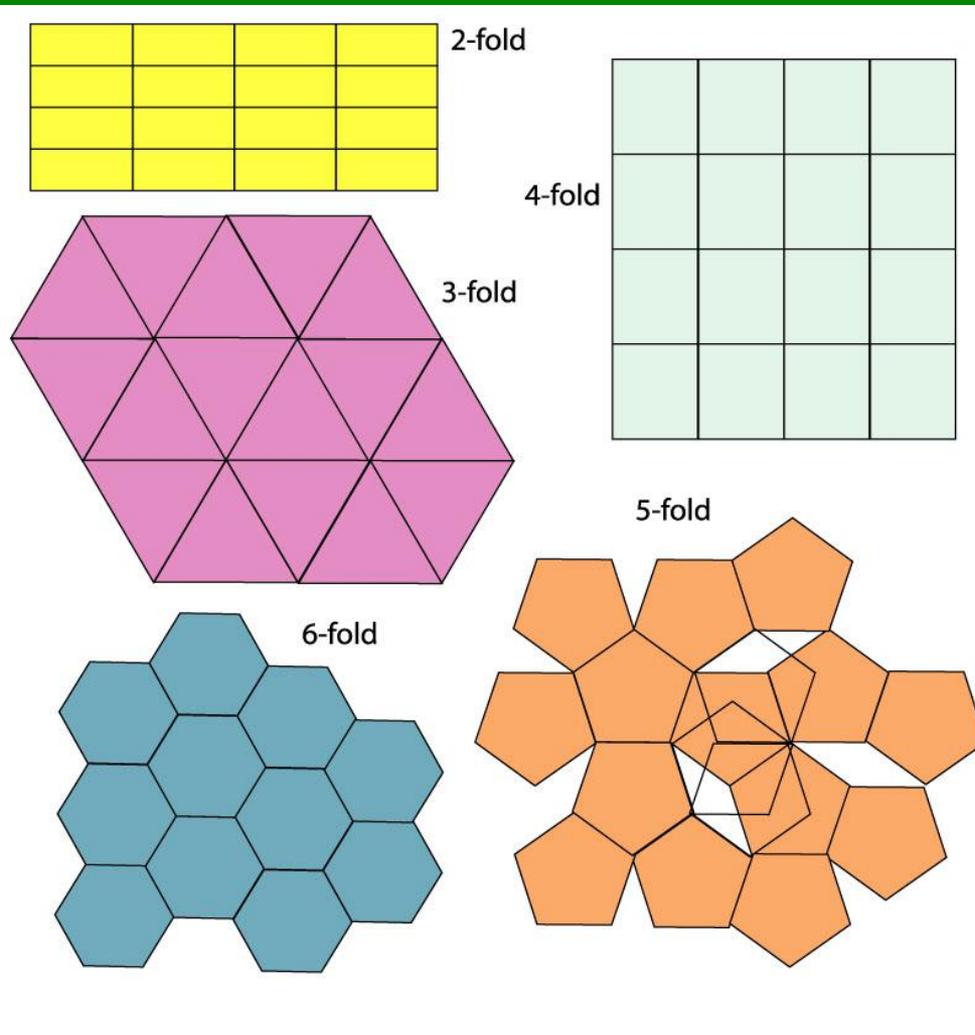


TABLE 12.3 The 230 Space Groups, and the 32 Crystal Classes (Point Groups).
The Space Group Symbols Are, in General, Unabbreviated.

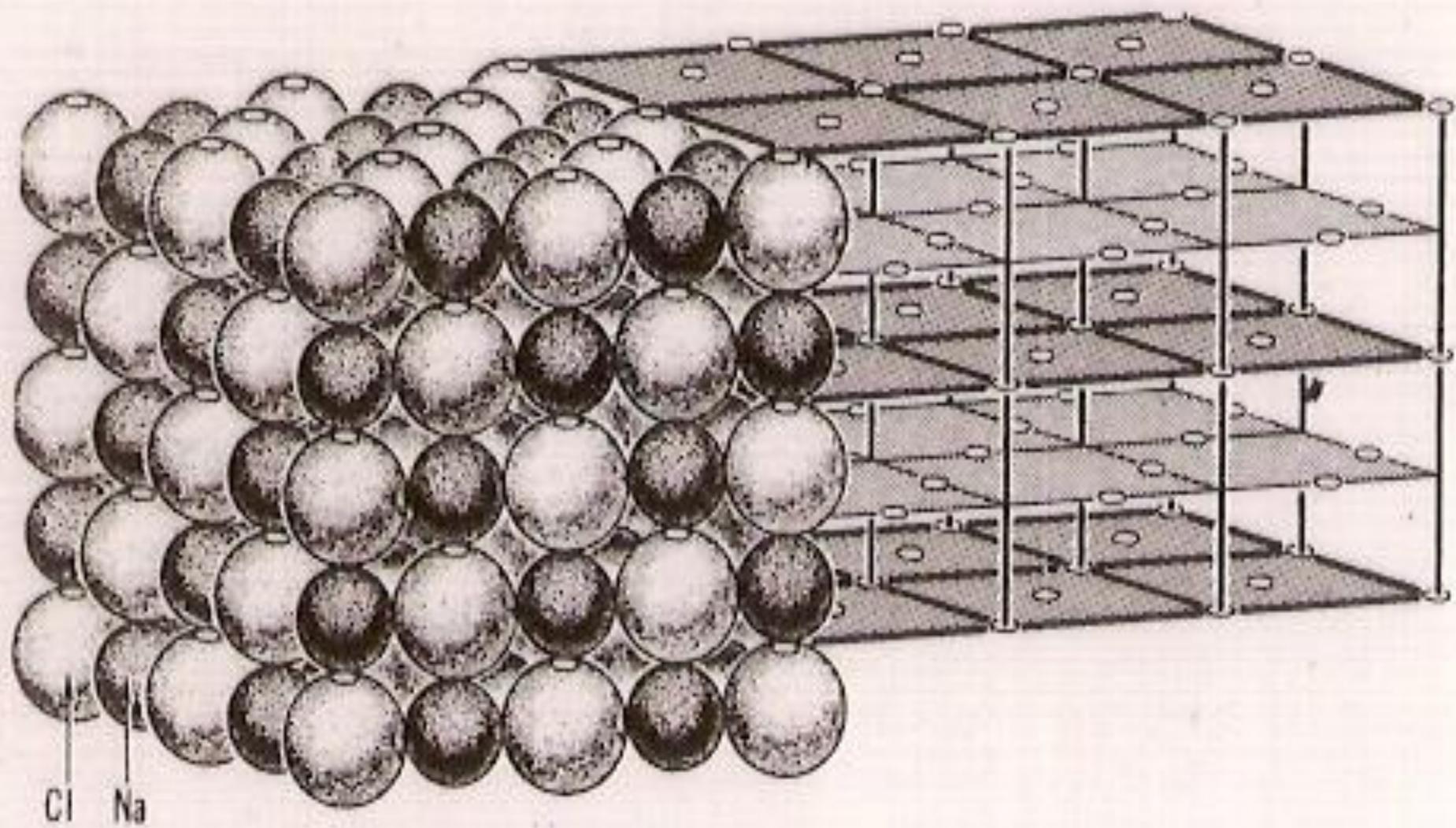
Crystal Class	Space Group
1	$P1$
$\bar{1}$	$P\bar{1}$
2	$P2, P2_1, C2$
m	Pm, Pc, Cm, Cc
$2/m$	$P2/m, P2_1/m, C2/m, P2/c, P2_1/c, C2/c$
222	$P222, P222_1, P2_12_12, P2_12_12_1, C222_1, C222, F222, I222, I2_12_12_1$
$mm2$	$Pmm2, Pmc2_1, Pcc2, Pma2, Pca2_1, Pnc2, Pmn2_1, Pba2, Pna2_1, Pnn2, Cmm2, Cmc2_1, Ccc2, Amm2, Abm2, Ama2, Aba2, Fmmc, Fdd2, Imm2, Iba2, Ima2$
$2/m2/m2/m$	$P2/m2/m2/m, P2/n2/n2/n, P2/c2/c2/m, P2/b2/a2/n, P2_1/m2/m2/a, P2/n2_1/n2/a, P2/m2/n2_1/a, P2_1/c2/c2/a, P2_1/b2_1/a2/m, P2_1/c2_1/c2/n, P2/b2_1/c2/m, P2_1/n2_1/n2/m, P2_1/m2_1/m2/n, P2_1/b2/c2_1/n, P2_1/b2_1/c2_1/a, P2_1/n2_1/m2_1/a, C2/m2/c2/m, C2/m2/c2_1/a, C2/m2/m2/m, C2/c2/c2/m, C2/m2/m2/a, C2/c2/c2/a, F2/m2/m2/m, F2/d2/d2/d, I2/m2/m2/m, I2/b2/a2/m, I2/b2/c2/a, I2/m2/m2/a,$
4	$P4, P4_1, P4_2, P4_3, I4, I4_1$
$\bar{4}$	$P\bar{4}, I\bar{4}$
$4/m$	$P4/m, P4_2/m, P4/n, P4_2/n, I4/m, I4_1/a$
422	$P422, P4_22, P4_122, P4_22_1, P4_22_2, P4_322, P4_22_2, P4_322, P4_22_2, I422, I4_122$
$4mm$	$P4mm, P4bm, P4_1cm, P4_2nm, P4cc, P4nc, P4_1mc, P4_2bc, I4mm, I4cm, I4_1md, I4_1cd$
$\bar{4}2m$	$P\bar{4}2m, P\bar{4}2c, P\bar{4}2_1m, P\bar{4}2_1c, P\bar{4}m2, P\bar{4}c2, P\bar{4}b2, P\bar{4}n2, I\bar{4}m2, I\bar{4}c2, I\bar{4}2m, I\bar{4}2d$
$4/m2/m2/m$	$P4/m2/m2/m, P4/m2/c2/c, P4/n^2/b^2/m, P4/n2/n2/c, P4/m2_1/b2/m, P4/m2_1/n2/c, P4/n2_1/m2/m, P4/n2_1/c2/c, P4_1/m2/m2/c, P4_2/m2/c2/m, P4_2/n2/b2/c, P4_2/n2/n2/m, P4_2/m2_1/b2/c, P4_2/m2_1/n2/m, P4_1/n2_1/m2/c, P4_2/n2_1/c2/m, I4/m2/m2/m, I4/n^2/c^2/m, I4_1/a2/m2/d, I4_1/a2/c2/d$
3	$P3, P3_1, P3_2, R3$
$\bar{3}$	$P\bar{3}, R\bar{3}$
32	$P312, P321, P3_112, P3_121, P3_212, P3_221, R32$
$3m$	$P\bar{3}m1, P\bar{3}1m, P\bar{3}c1, P\bar{3}1c, R\bar{3}m, R\bar{3}c$
$\bar{3}2/m$	$P31m, P31c, P3m1, P3c1, R3m, R3c$
6	$P6, P6_1, P6_2, P6_3, P6_4, P6_5$
$\bar{6}$	$P\bar{6}$
$6/m$	$P6/m, P6_3/m$
622	$P622, P6_122, P6_222, P6_322, P6_422, P6_522$
$6mm$	$P6mm, P6cc, P6_3cm, P6_3mc$
$\bar{6}m2$	$P\bar{6}m2, P\bar{6}c2, P\bar{6}2m, P\bar{6}2c$
$6/m2/m2/m$	$P6/m2/m2/m, P6/m2/c2/c, P6_3/m2/c2/m, P6_2/m2/m2/c$
23	$P23, F23, I23, P2_13, I2_13$
$2/m\bar{3}$	$P2/m\bar{3}, P2/n\bar{3}, F2/m\bar{3}, F2/d\bar{3}, I2/m\bar{3}, P2_1/a\bar{3}, I2/a\bar{3}$
432	$P432, P4_232, F432, F4_132, I432, P4_332, P4_132, I4_332$
$\bar{4}3m$	$P\bar{4}3m, F\bar{4}3m, I\bar{4}3m, P\bar{4}3n, F\bar{4}3c, I\bar{4}3d$
$4/m\bar{3}2/m$	$P4/m\bar{3}2/m, P4/n\bar{3}2/n, P4_2/m\bar{3}2/n, P4_2/n\bar{3}2/m, F4/m\bar{3}2/m, F4/m\bar{3}2/c, P4_1/d\bar{3}2/m, F4_1/d\bar{3}2/c, I4/m\bar{3}2/m, I4_1/a\bar{3}2/d$

Translações



A simetria do retículo e a simetria do grupo pontual se **inter-relacionam**, porque ambas são propriedades do padrão de simetria global

Este é o motivo pelo qual eixos de simetria rotacional de ordem 5 e > 6 não funcionam em cristais



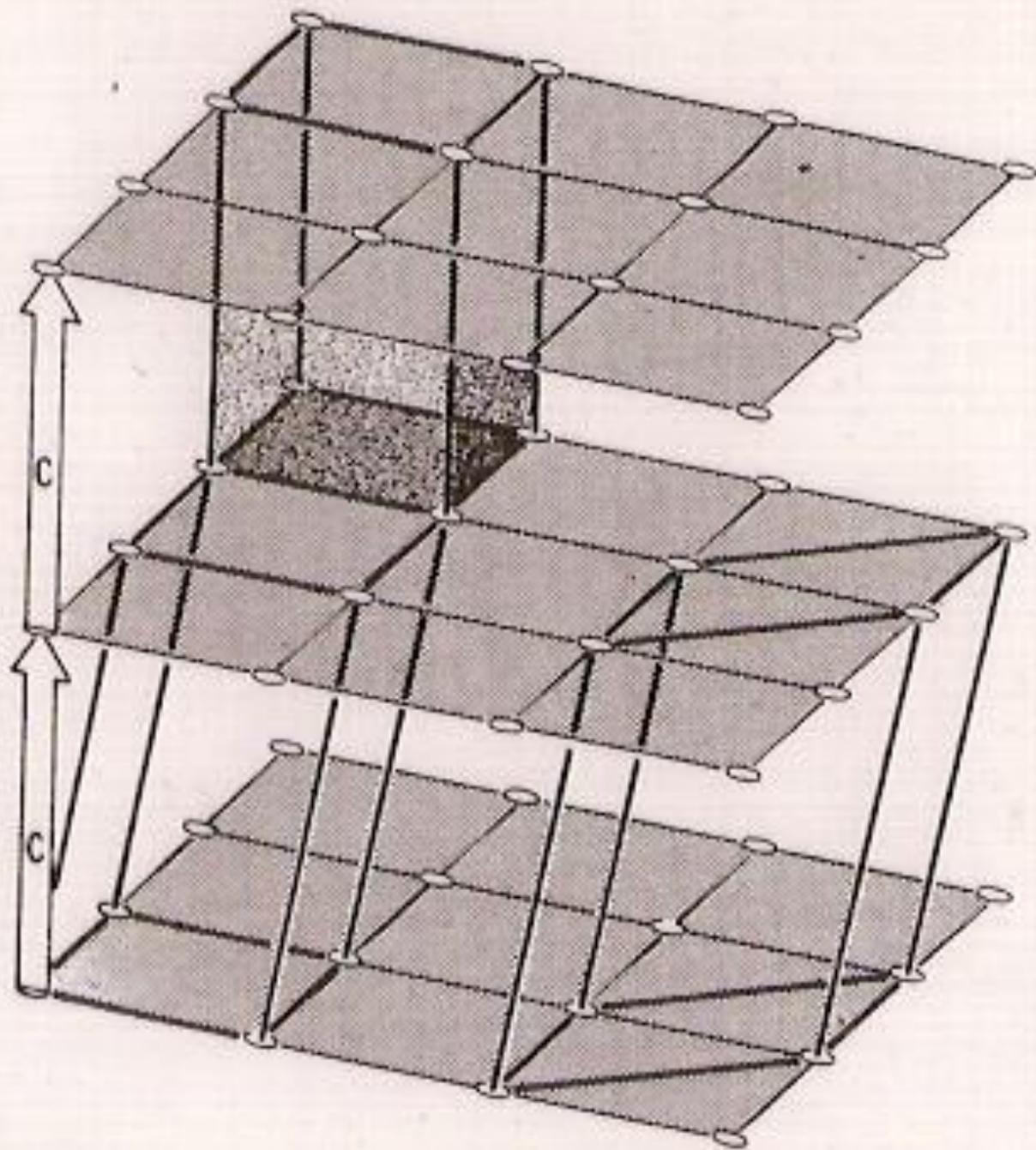
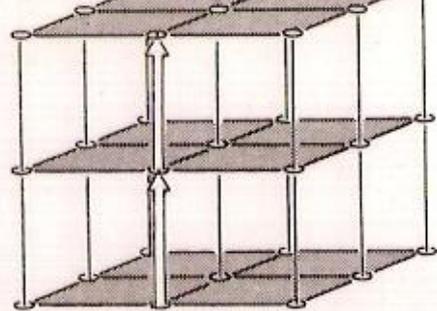
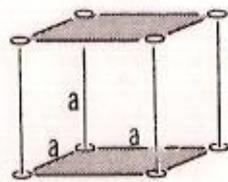


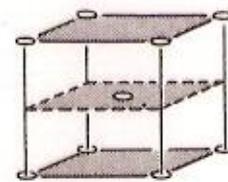
FIGURE 4-12



A



B



C

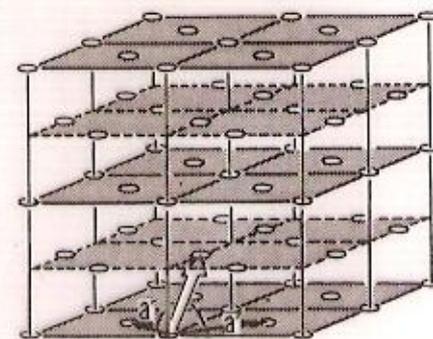
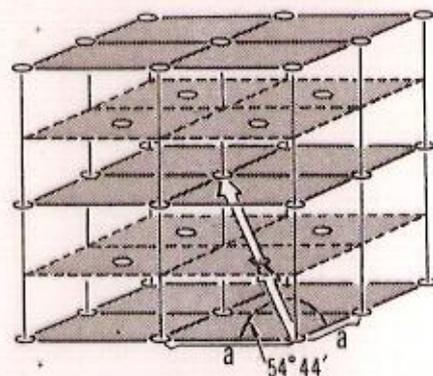
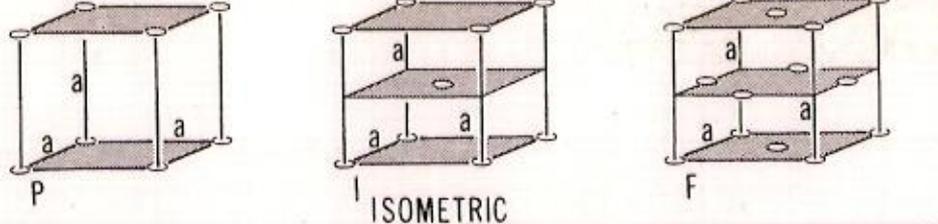
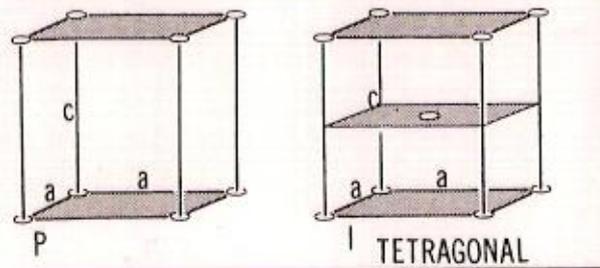


FIGURE 6-7

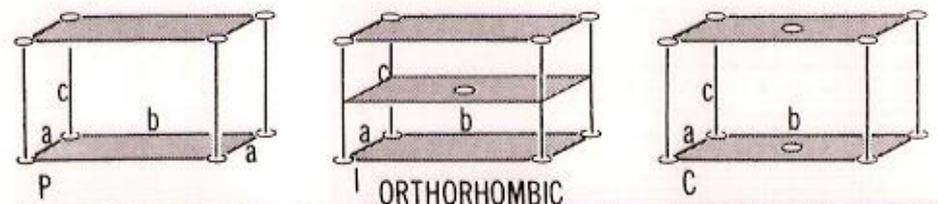
The three types of isometric lattices: (A) primitive *P*, (B) body centered *I*, (C) face centered *F*. These lattices result if tetranets are translated by a stacking vector (hollow arrow) which is (A) at 90° to the tetranet and equal in length to a , the shortest unit of translation within the plane of the tetranet; (B) at $54^\circ 44'$ to each a vector but equal in length to $0.866 a$; (C) at 45° to the tetranet but at 60° to each of the within-net vectors labeled a' , the stacking vector now equaling a' in length. A single unit cell is shown at the right for each lattice.



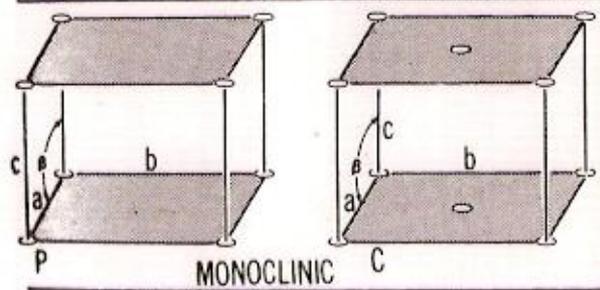
ISOMETRIC



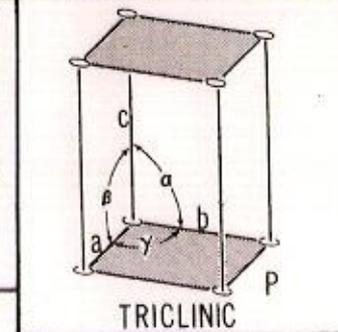
TETRAGONAL



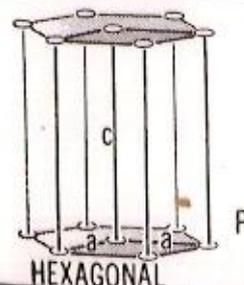
ORTHORHOMBIC



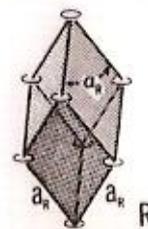
MONOCLINIC



TRICLINIC



HEXAGONAL



RHOMBOHEDRAL

FIGURE 6-13

The unit cells for the 14 Bravais lattices of space lattices

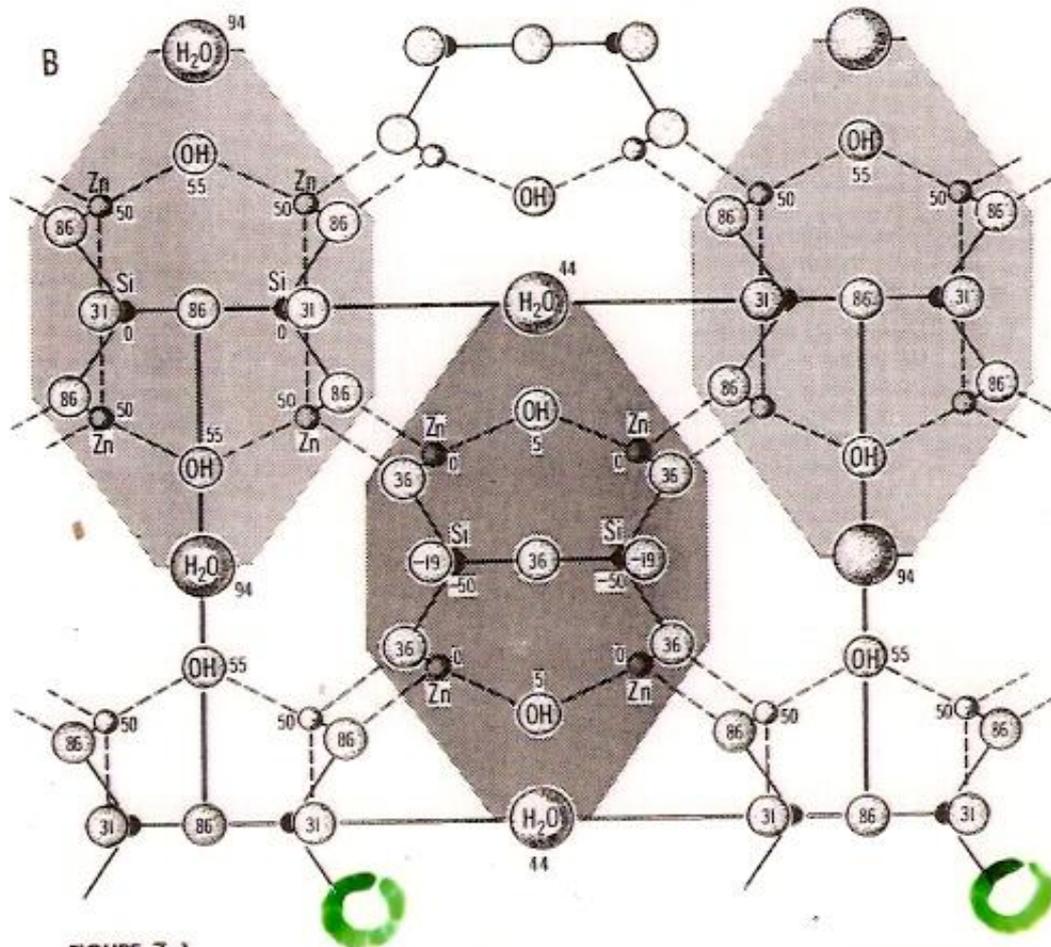
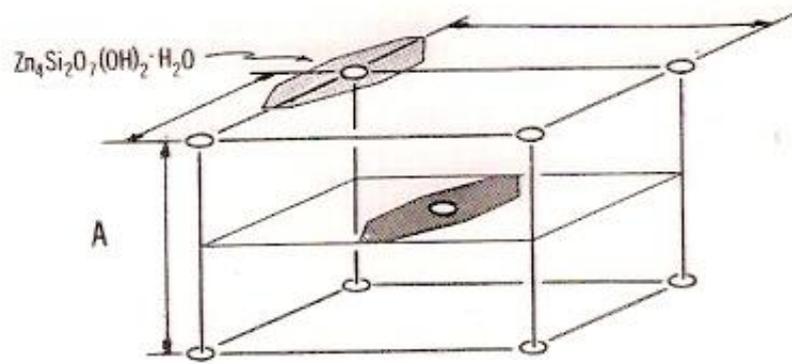
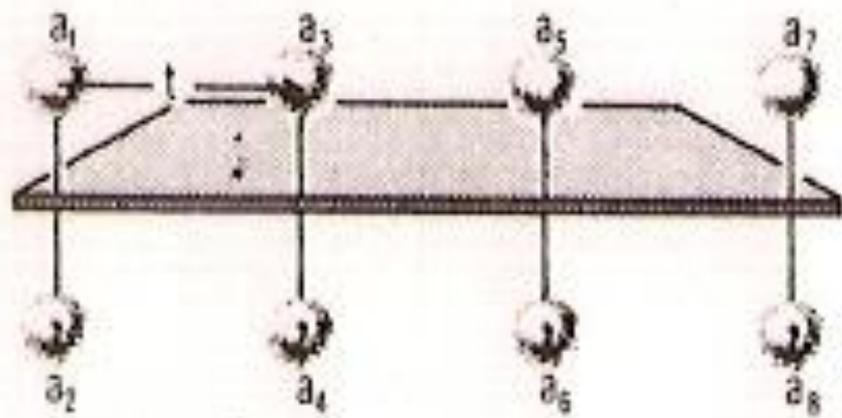
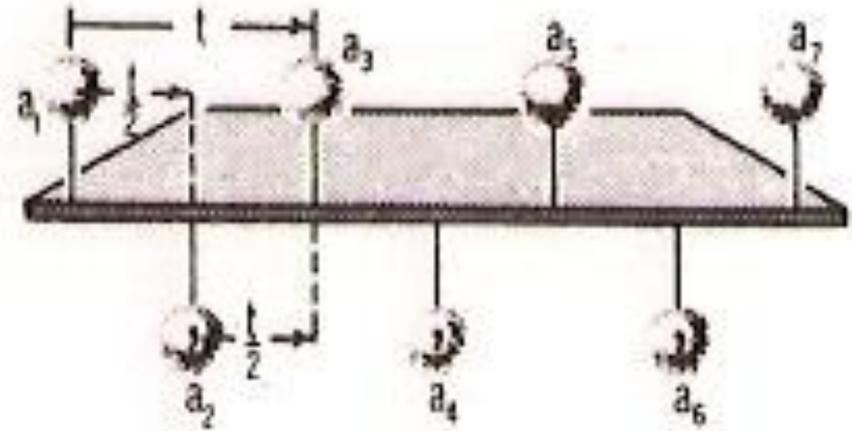


FIGURE 7-1



A



B

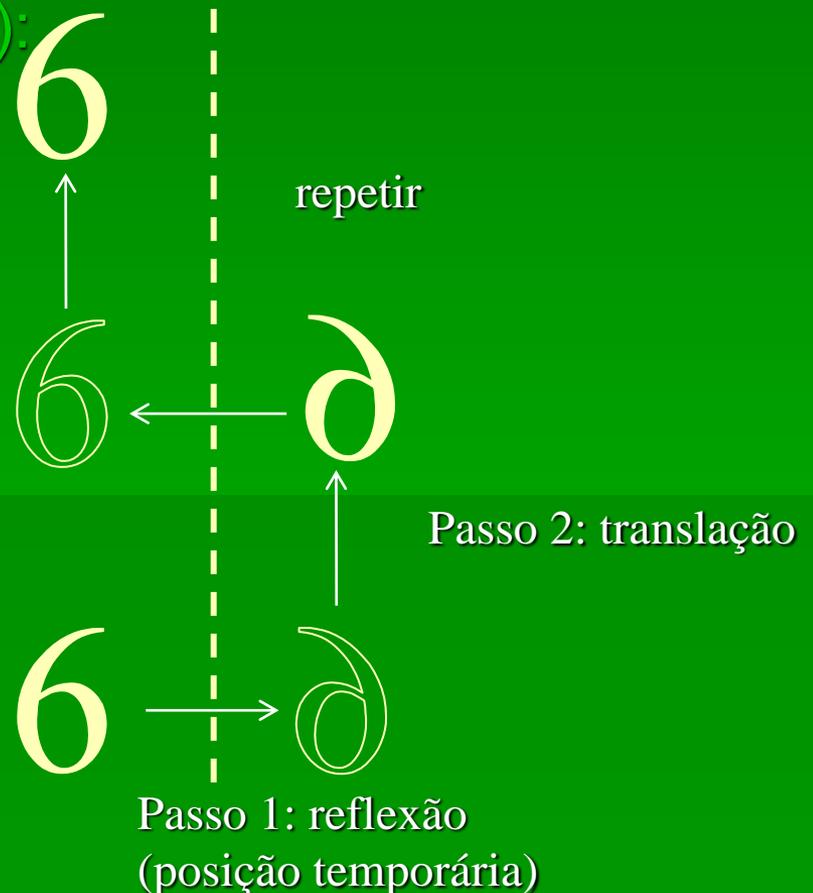
FIGURE 7-2

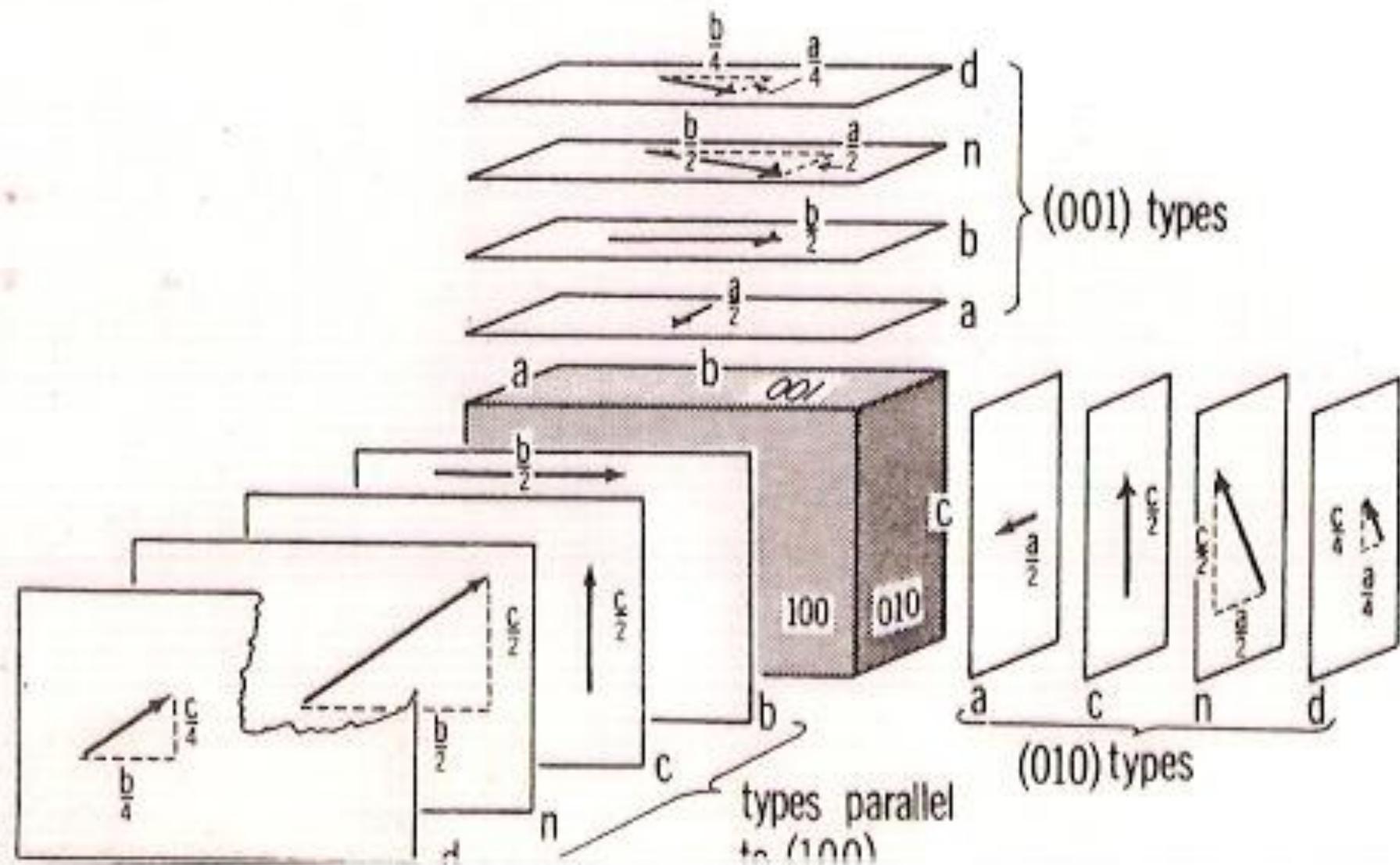
Translações

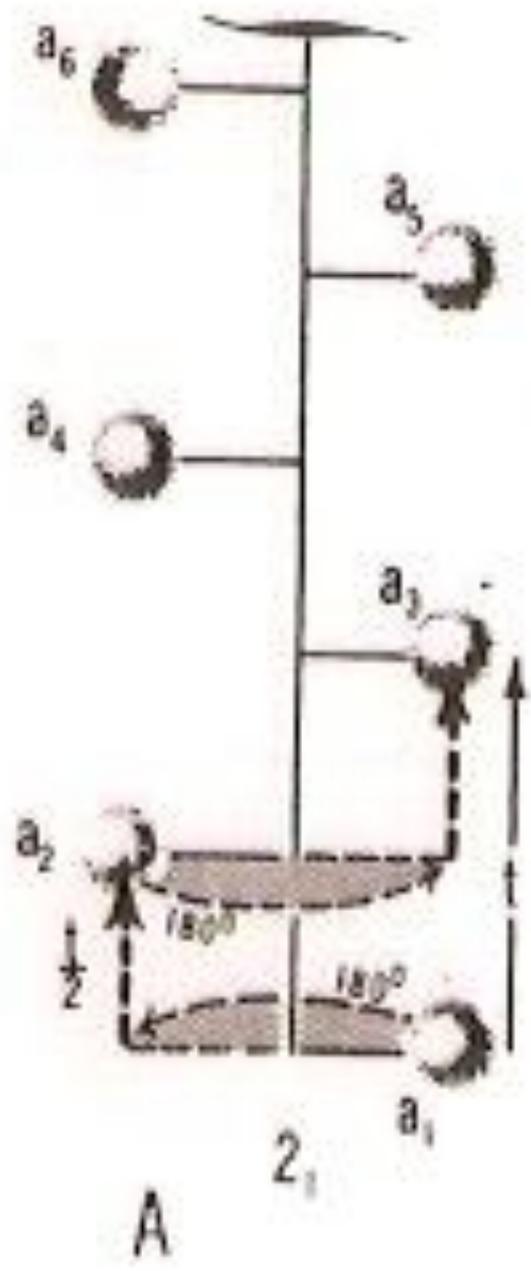
Existe uma nova operação de simetria 2-D quando consideramos translações

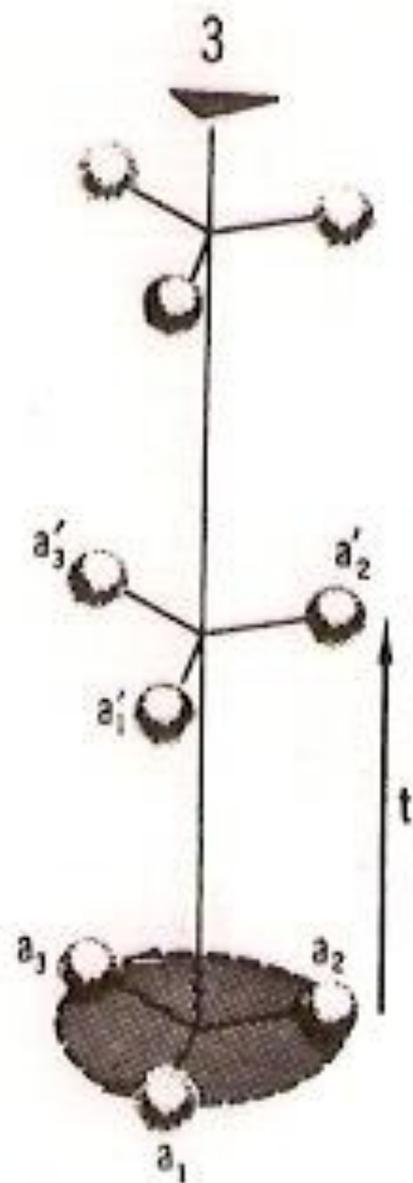
O Plano Deslizante (“Glide Plane”):

Uma reflexão combinada com translação

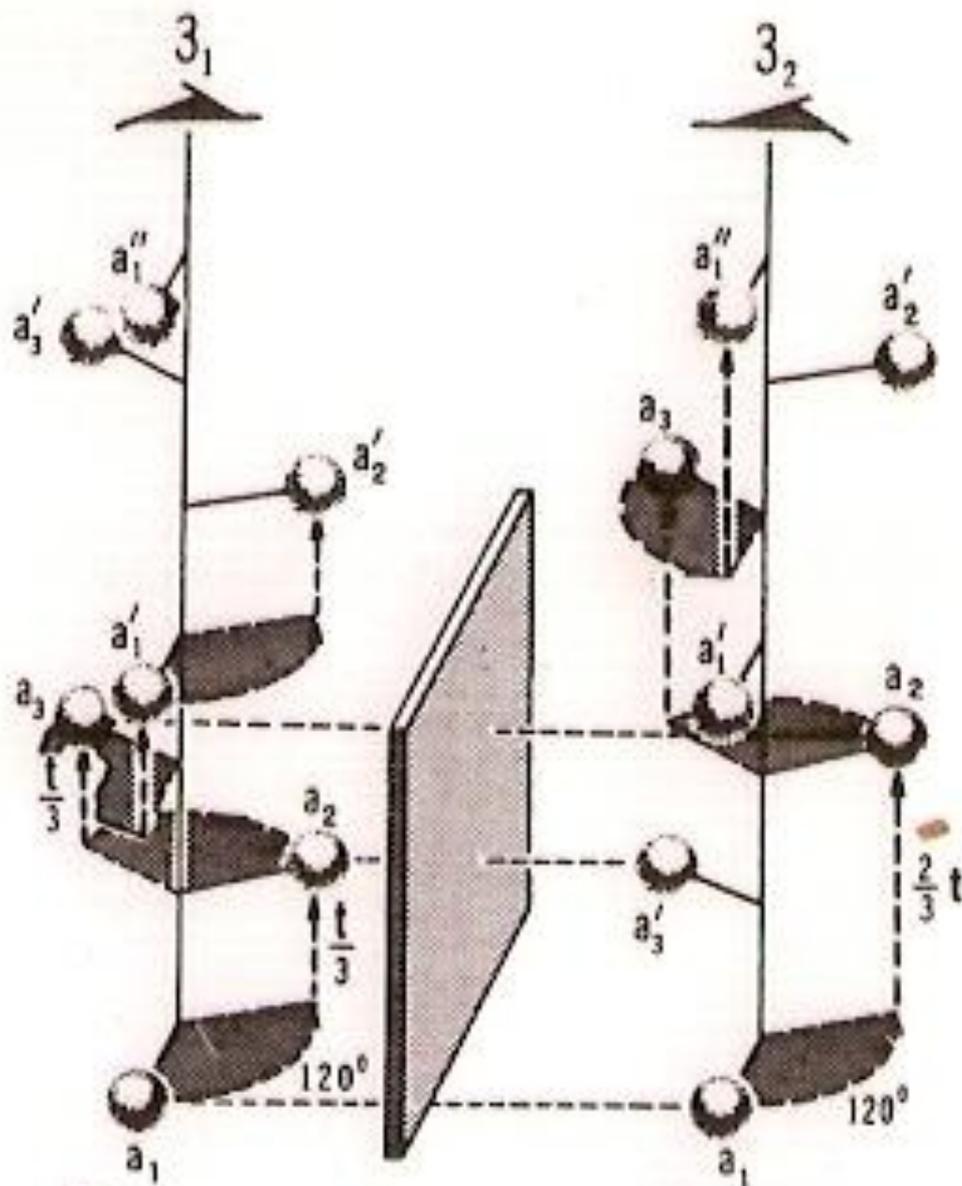






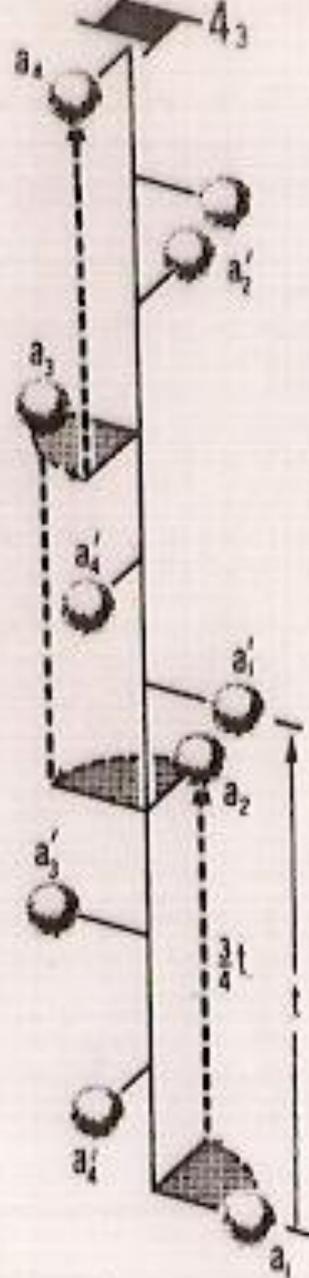
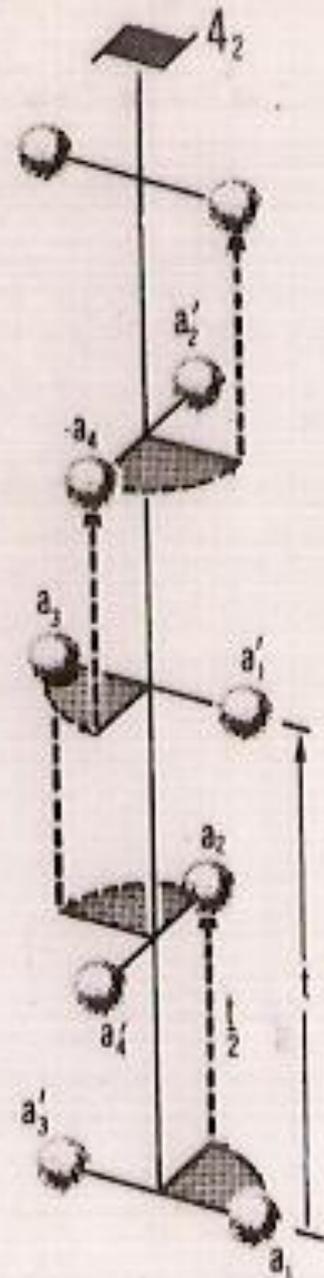
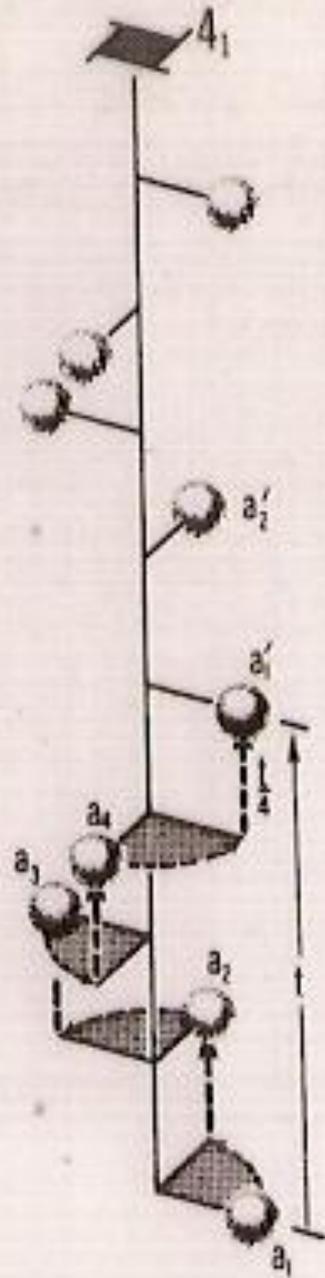
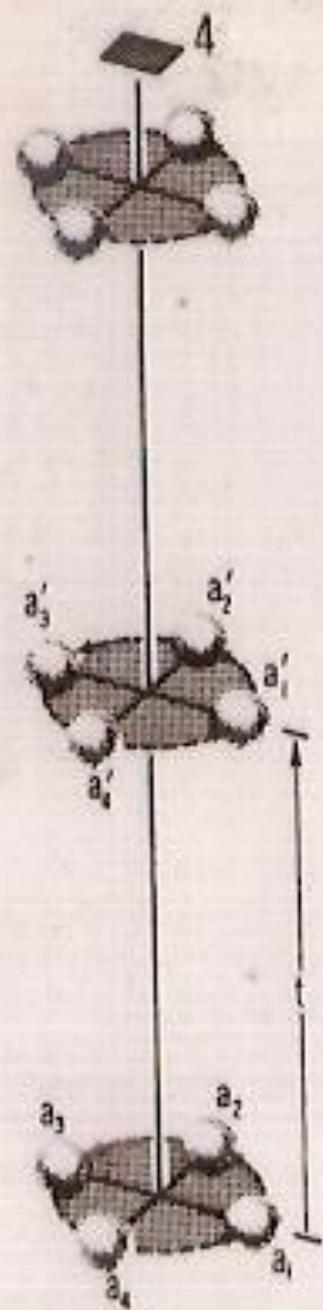


A



B

C



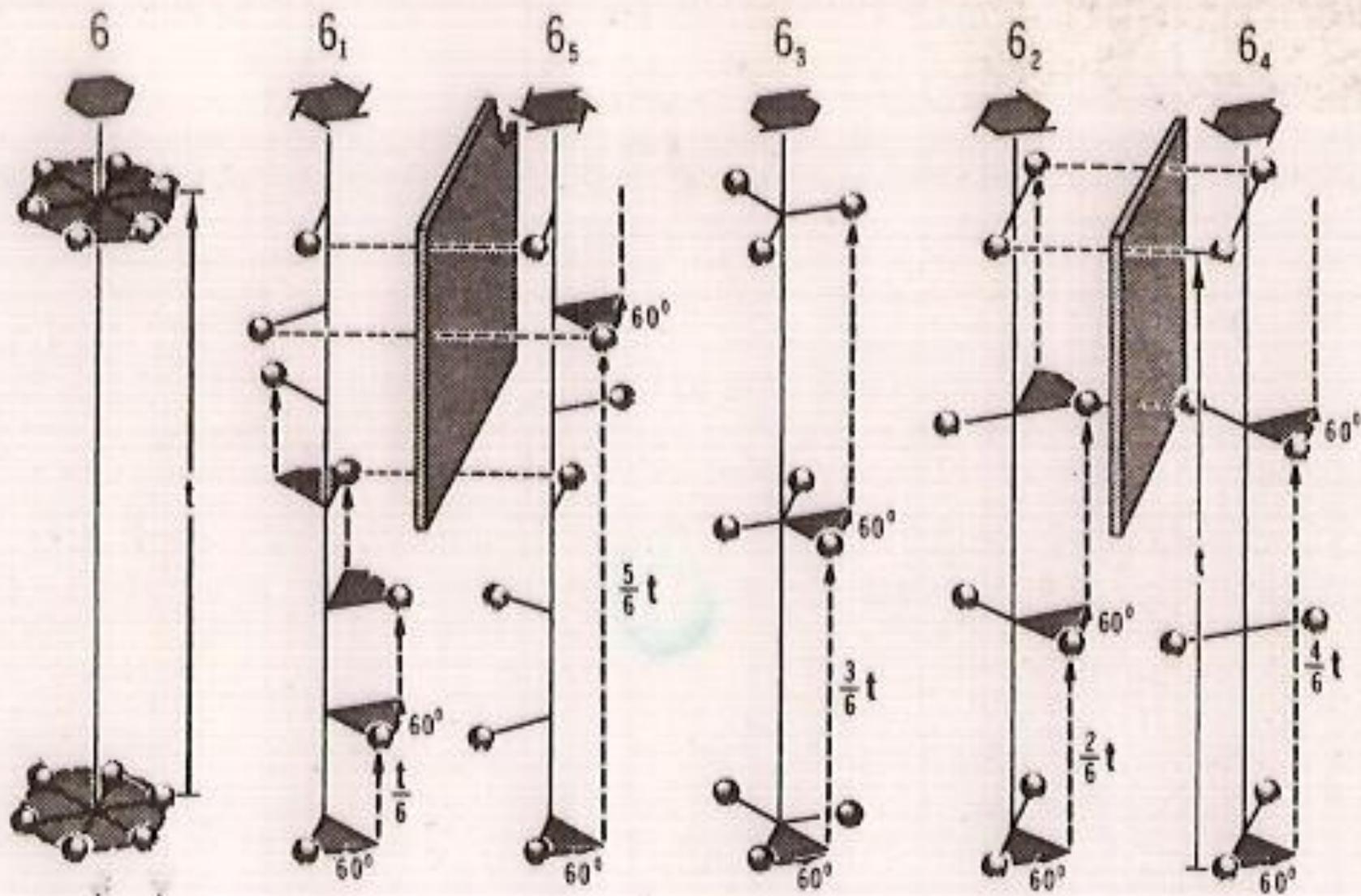
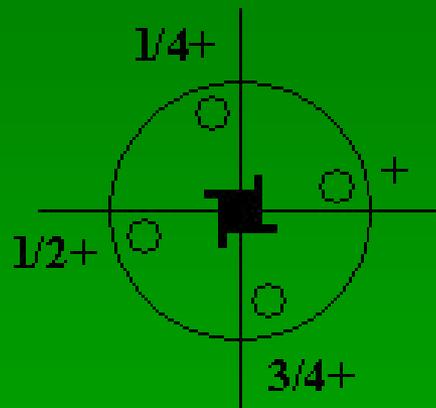
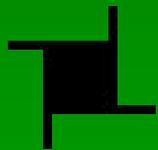


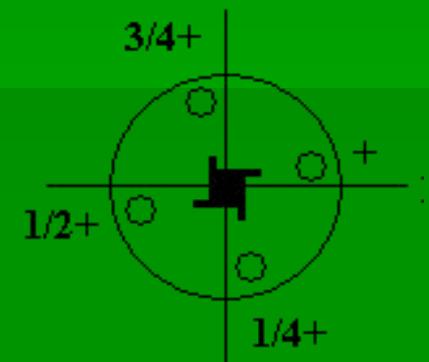
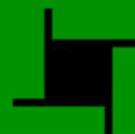
FIGURE 7-7

Exemplos de eixos helicoidais:

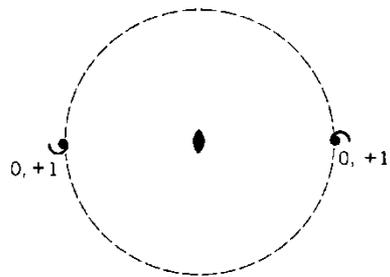
4_1



4_3

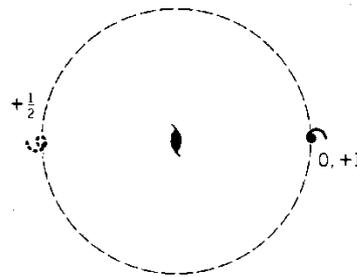


Projeções de eixos de rotação e eixos helicoidais

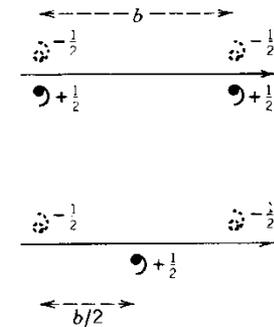


(a)

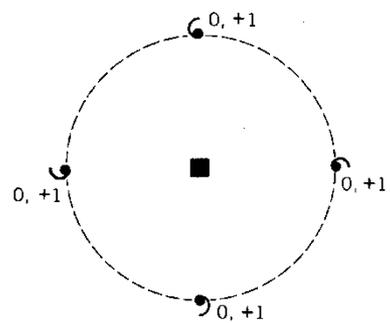
2



2₁

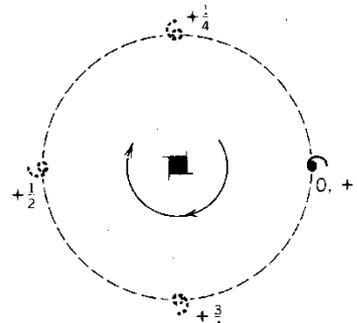


(b)

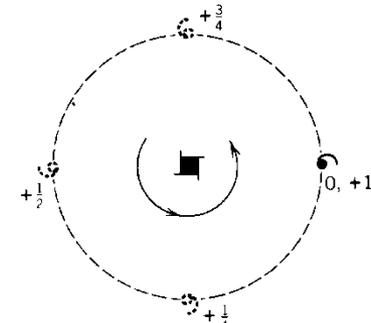


(c)

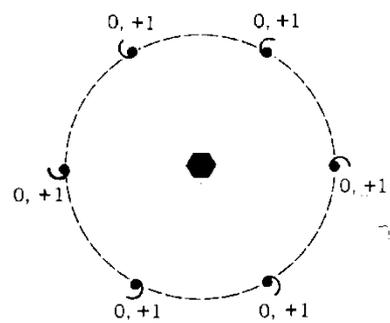
4



4₁ Right-handed

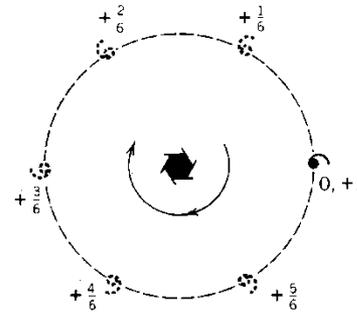


4₃ Left-handed

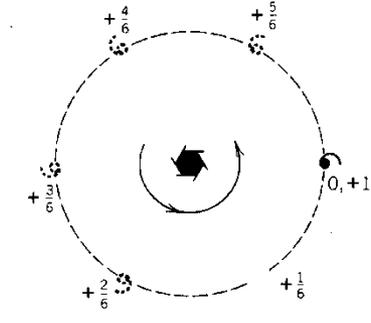


(d)

6



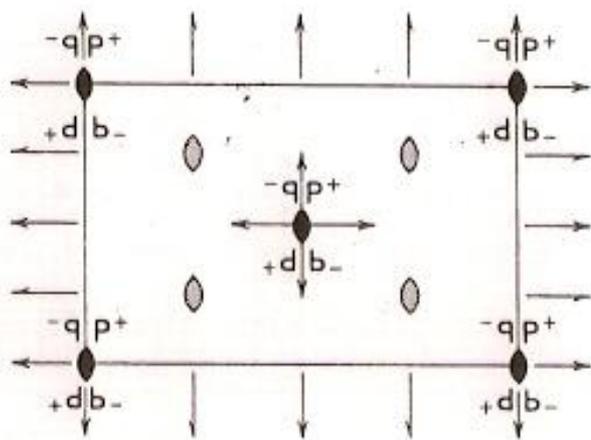
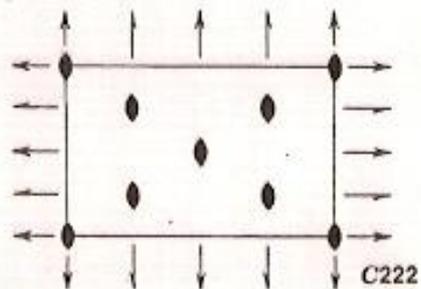
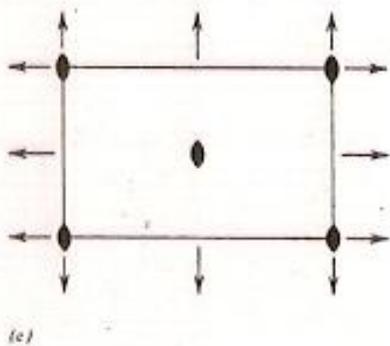
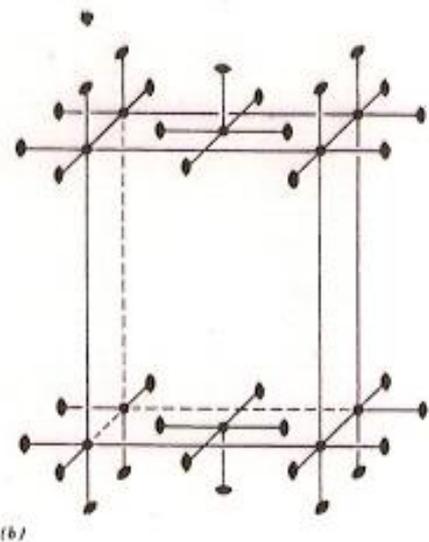
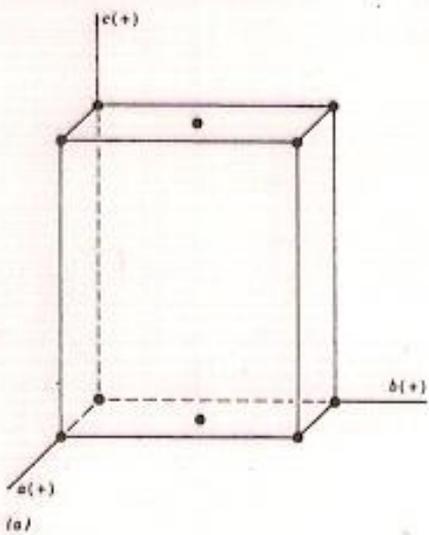
6₁ Right-handed



6₅ Left-handed

FIGURE 11.6 Graphical derivation of the total symmetry content in C_{222} . See text for discussion.

222



(a)

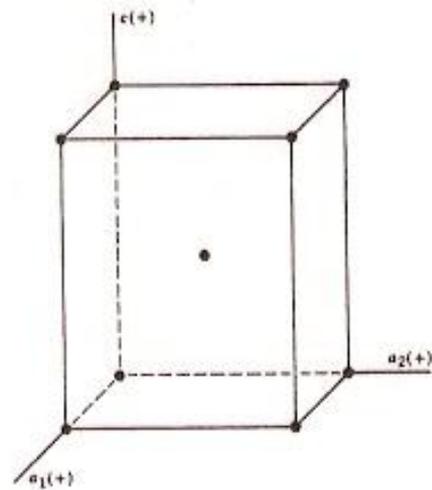
(b)

(c)

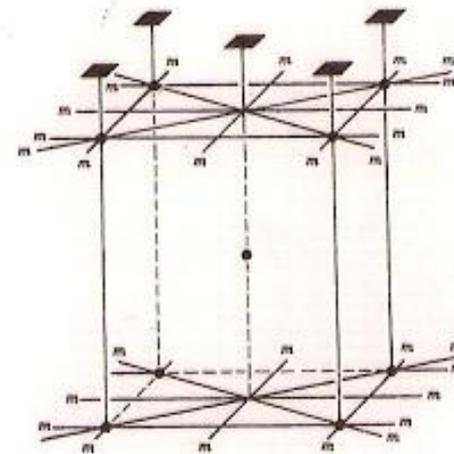
(d)

(e)

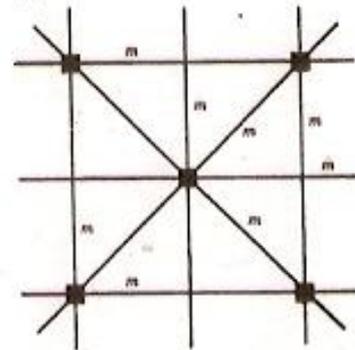
FIGURE 11.7 Graphical derivation of the total symmetry content in $I4mm$. See text for discussion. $4mm$



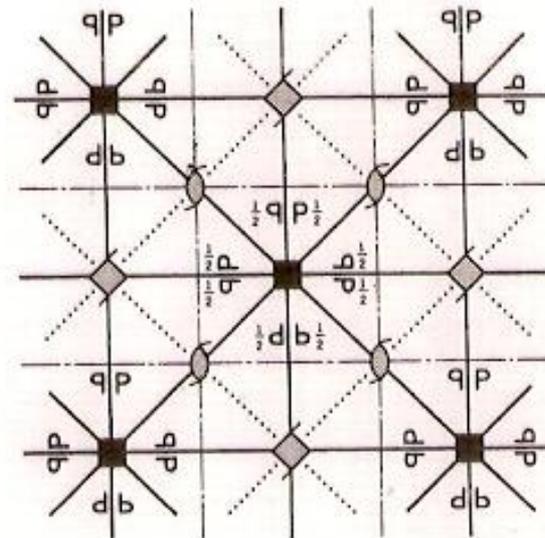
(a)



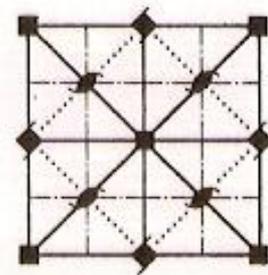
(b)



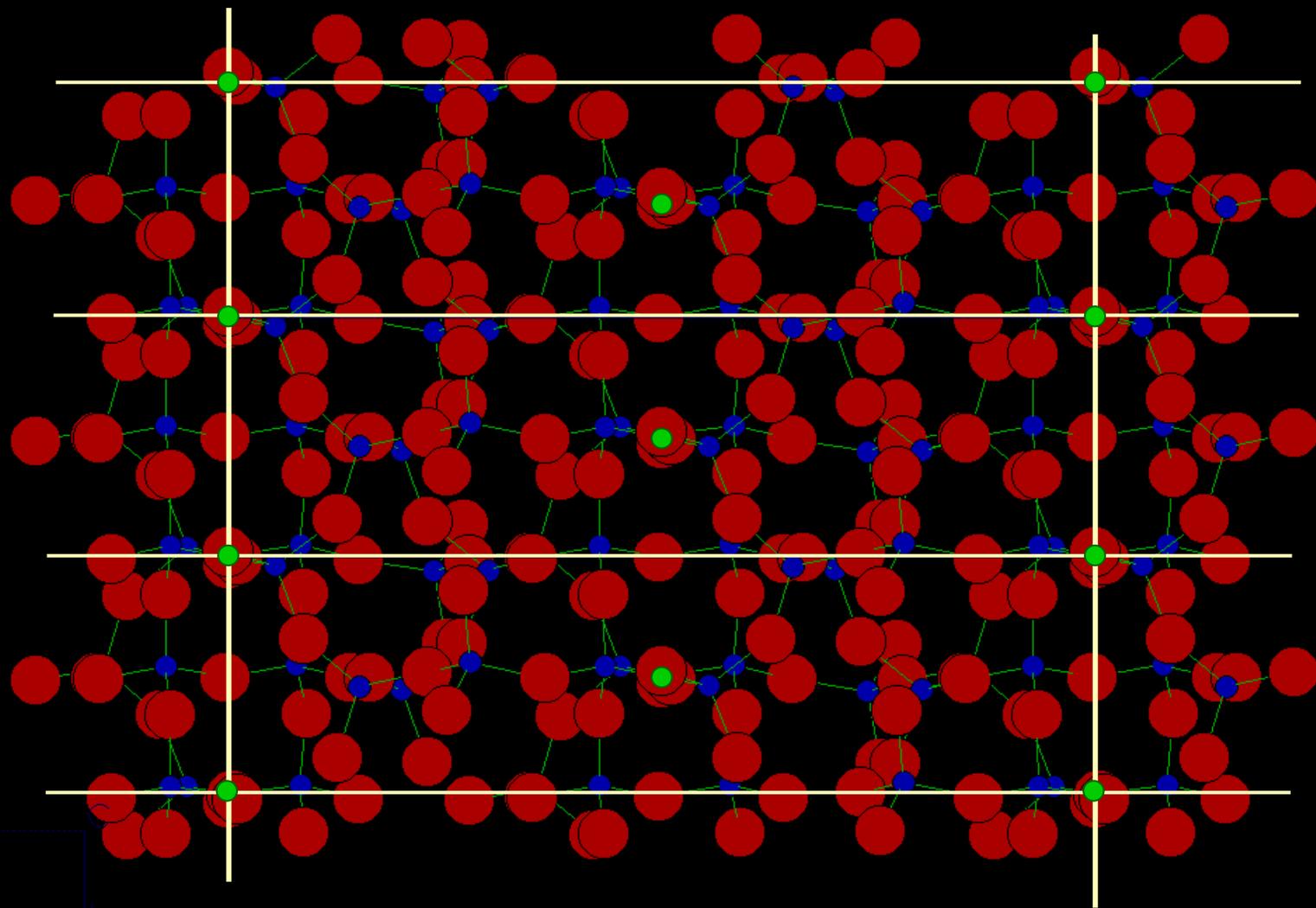
(c)



(d)



$I4mm$

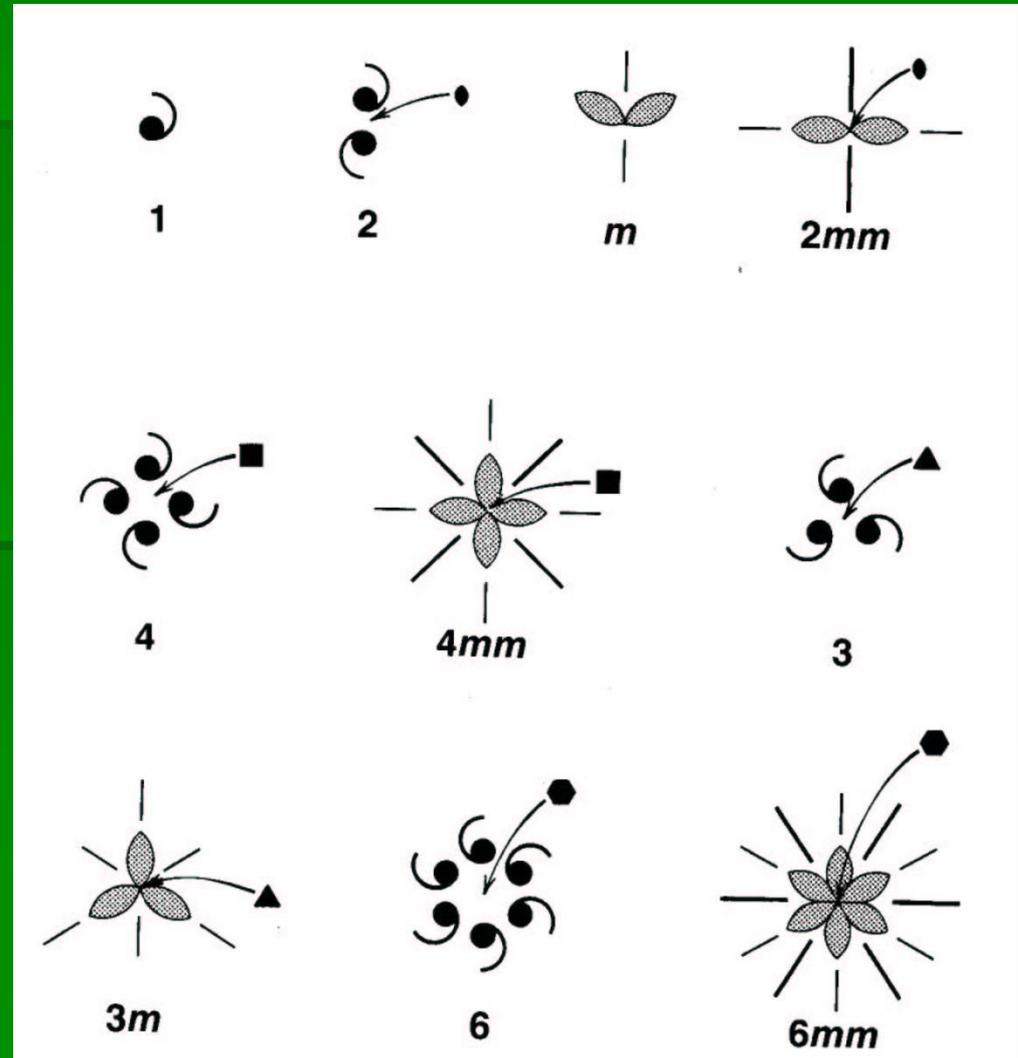


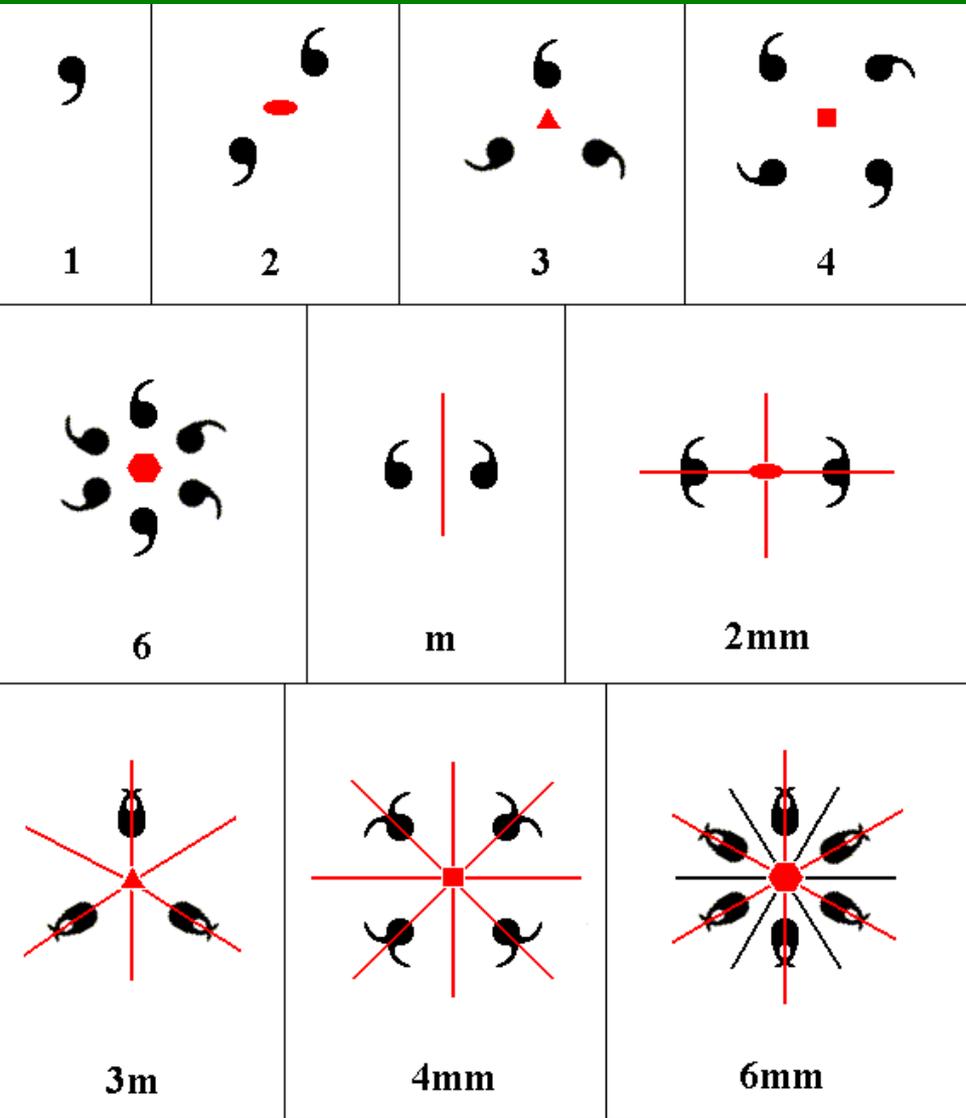
Tridimite: Cella Ortorrômbica C

Simetria

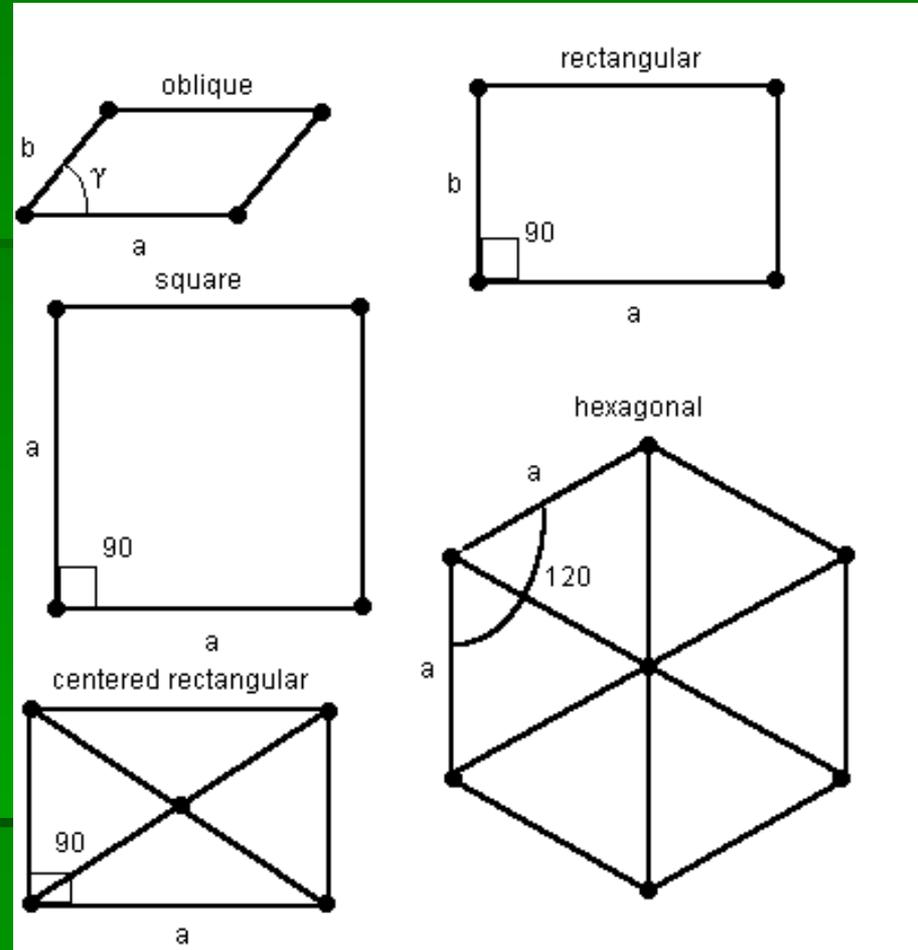
Motivos planos (2-D)

Apenas 10
possibilidades
de simetria





The Ten Planar Point Groups



≡ 17 grupos planares

Os 17 Grupos Espaciais 2-D

Grupos Espaciais 2-D resumem todas as possibilidades de combinação de retículos e motivos 2-D

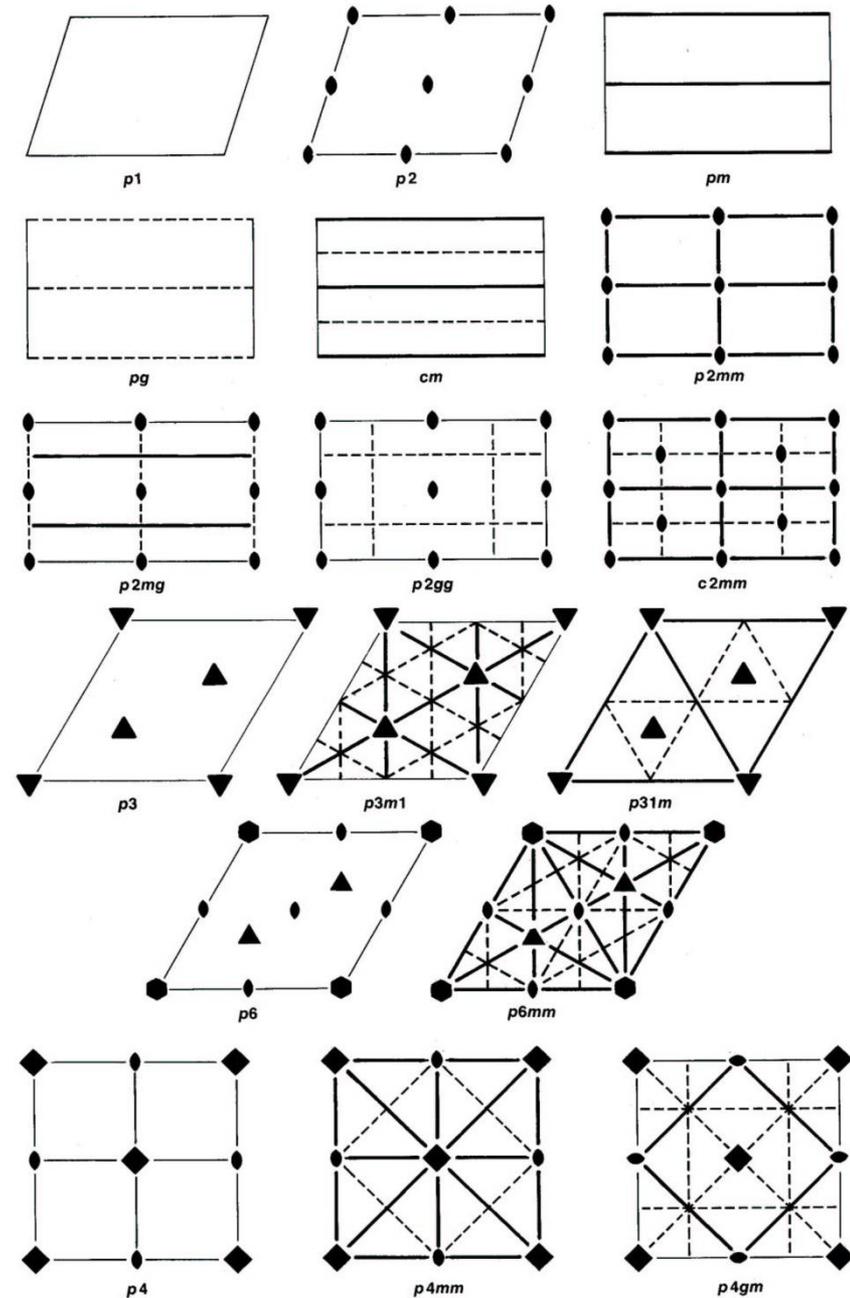


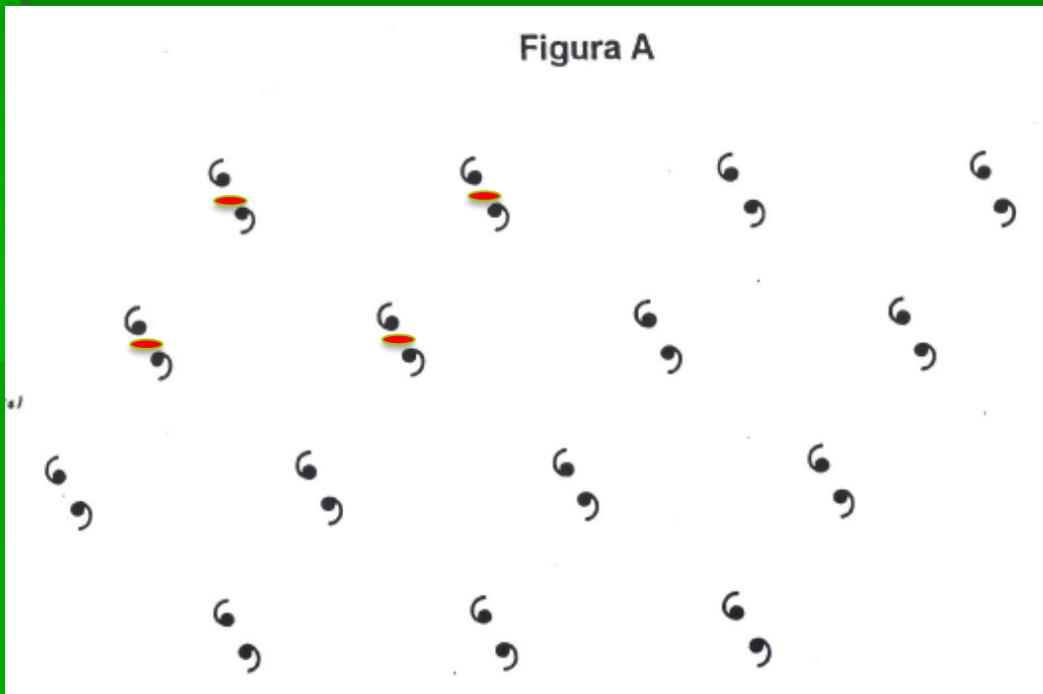
FIG. 3.14 Graphic representation of the symmetry content of the 17 plane groups. Heavy solid lines and dashed lines represent mirrors and glide lines, respectively, perpendicular to the page.

- Única operação simetria adicional
- planos deslizantes

Lattice	Point Group	Plane Group
Oblique P	1	P 1
	2	P 2
Rectangular P and C	m	P m P g C m
	2 m m	P 2 m m P 2 m g P 2 g g C 2 m m
Square P	4	P 4
	4 m m	P 4 m m P 4 g m
Hexagonal P	3	P 3
	3 m	P 3 m 1 P 3 1 m
	6	P 6
	6 m m	P 6 m m

Simetria dos motivos

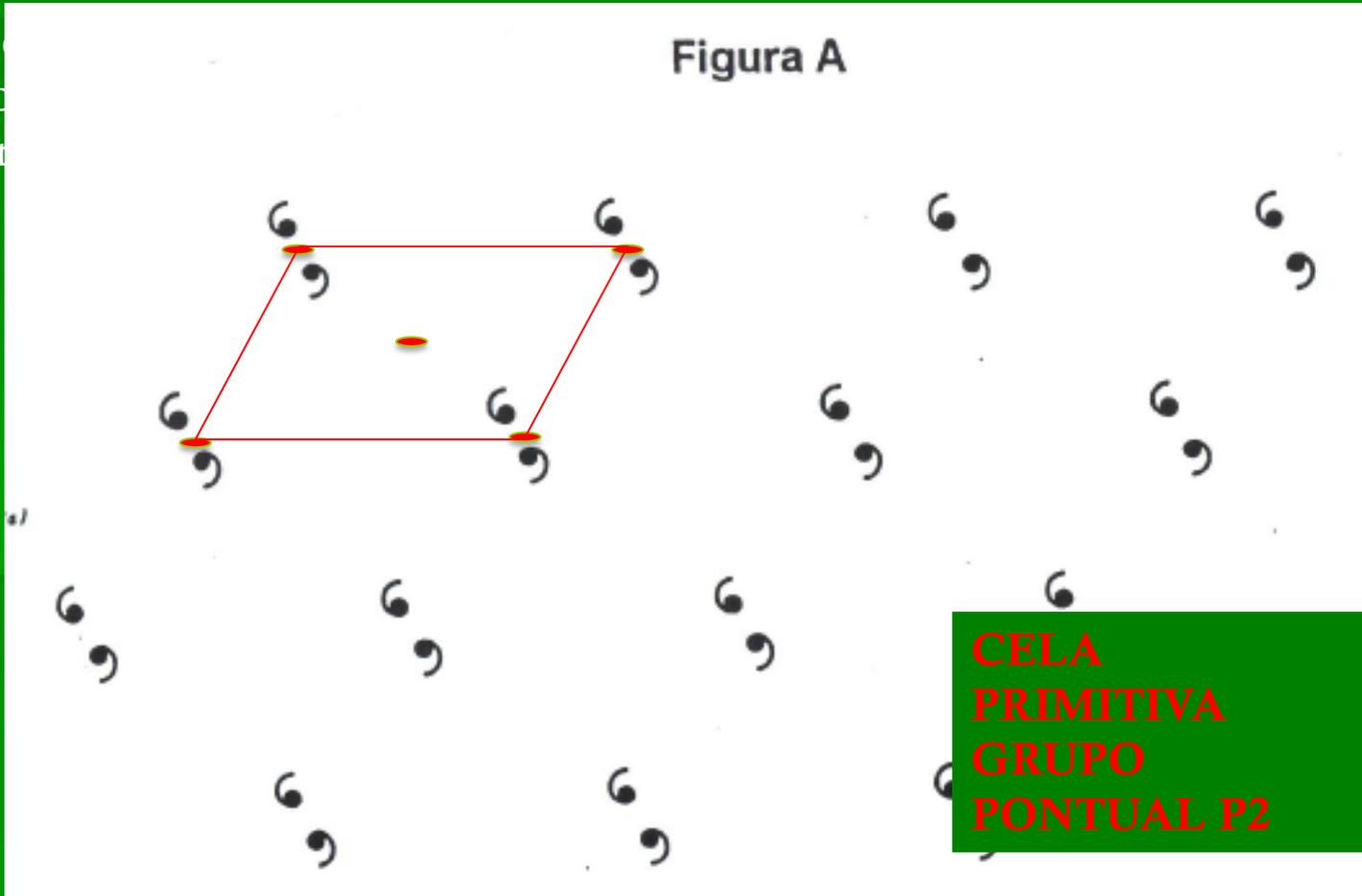
- Primeiro passo: determinar simetria do modelo



Simetria dos motivos

D
pc
sin

Figura A



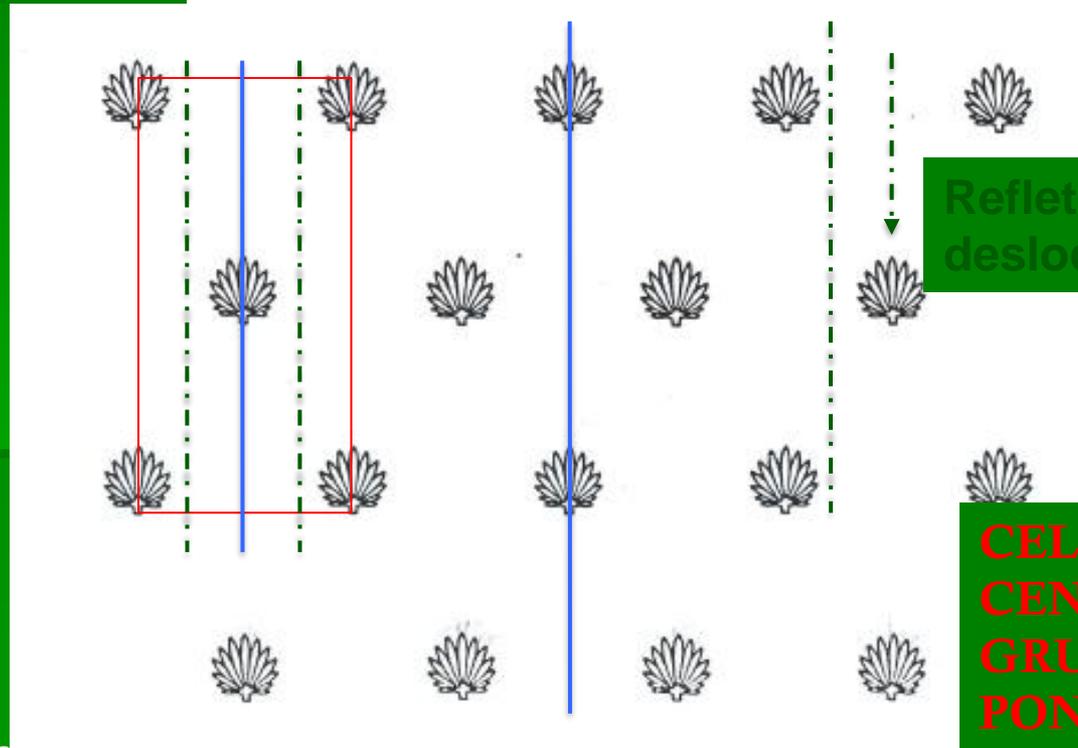
**CELA
PRIMITIVA
GRUPO
PONTUAL P2**

Simetria dos motivos

Planos deslizantes (g)

Figura B

Celas oblíquas violariam a simetria do motivo!



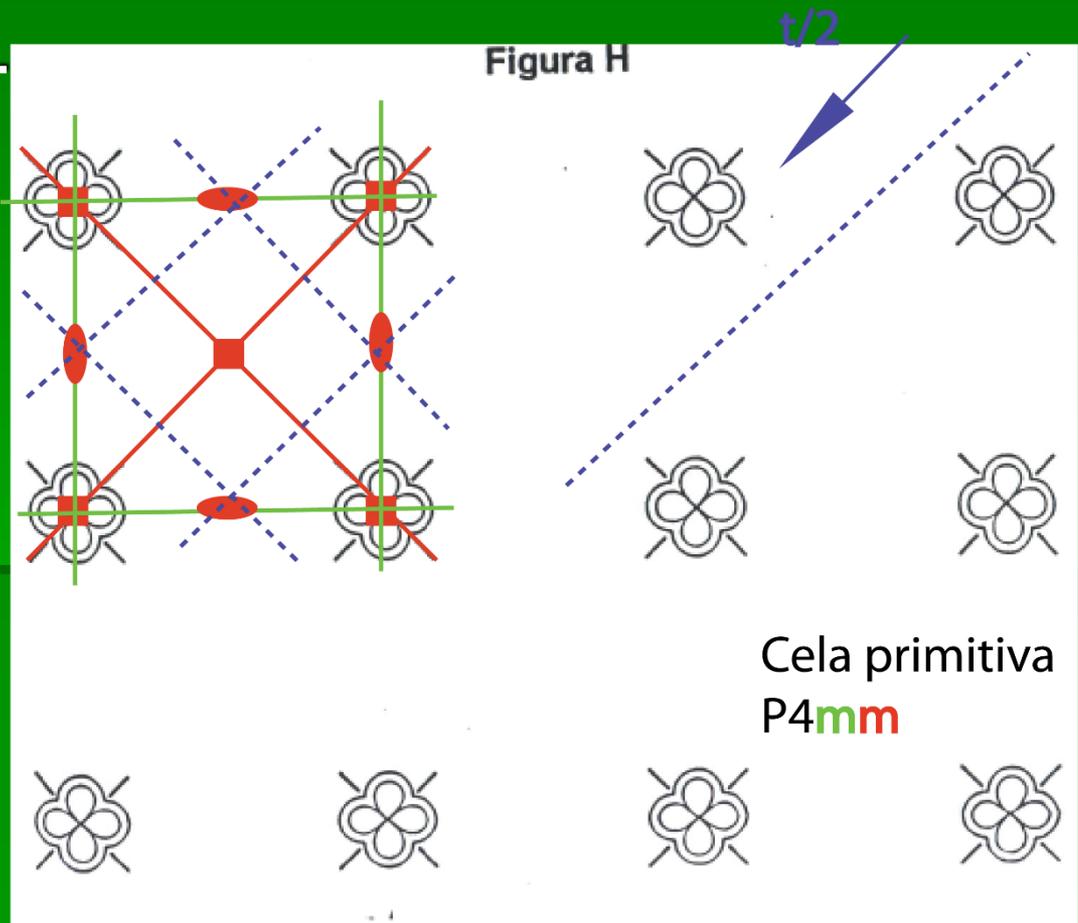
Reflete e desloca $\frac{1}{2}$ de t

**CELA
CENTRADA
GRUPO
PONTUAL $C2mg$**

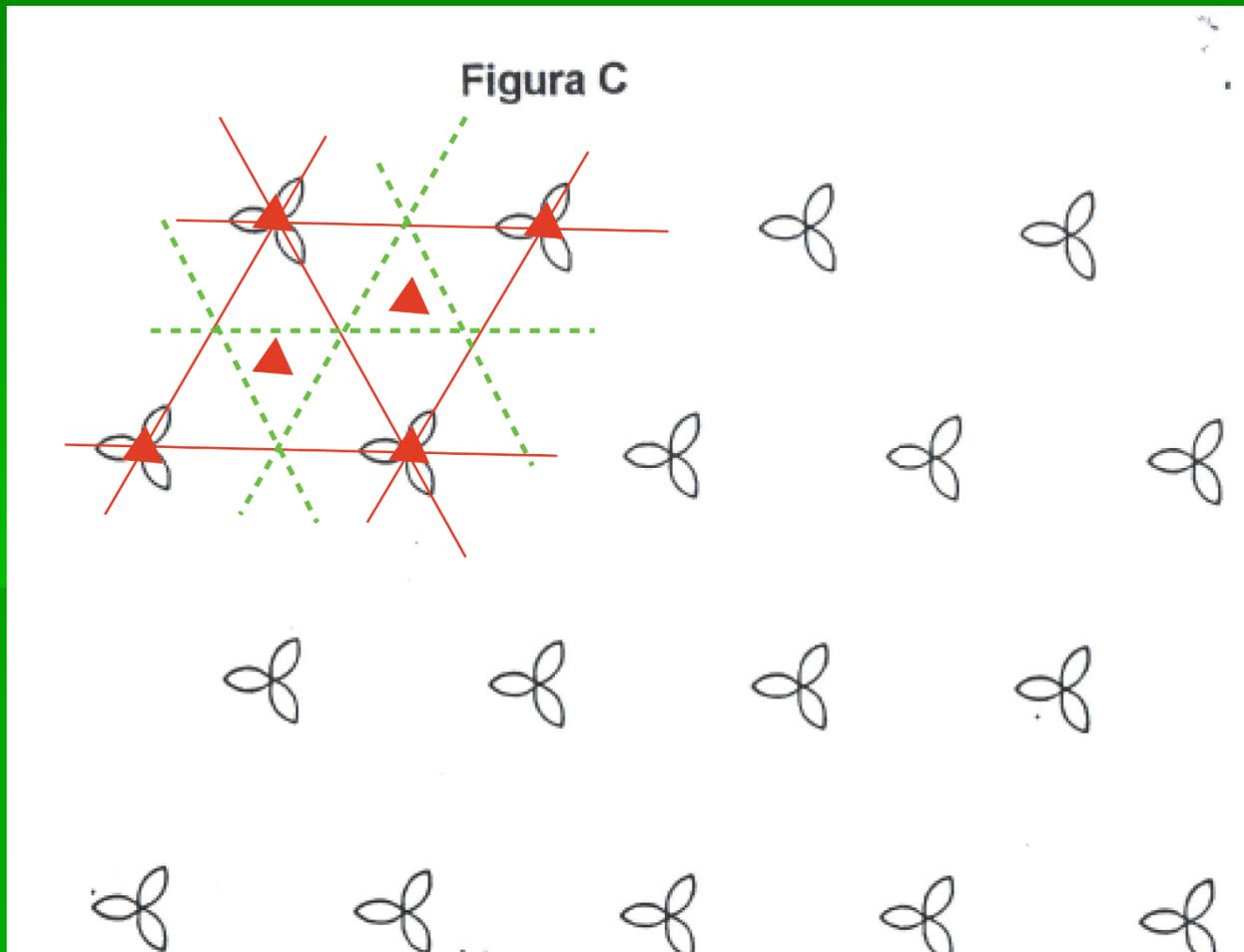
Planos de simetria

Simetria dos motivos

- Um pouco + difícil



Simetria dos motivos



**CELA
PRIMITIVA
GRUPO
PONTUAL $P3m$**

1. Simetria do motivo?

R: 2

2. Vetores de translação?

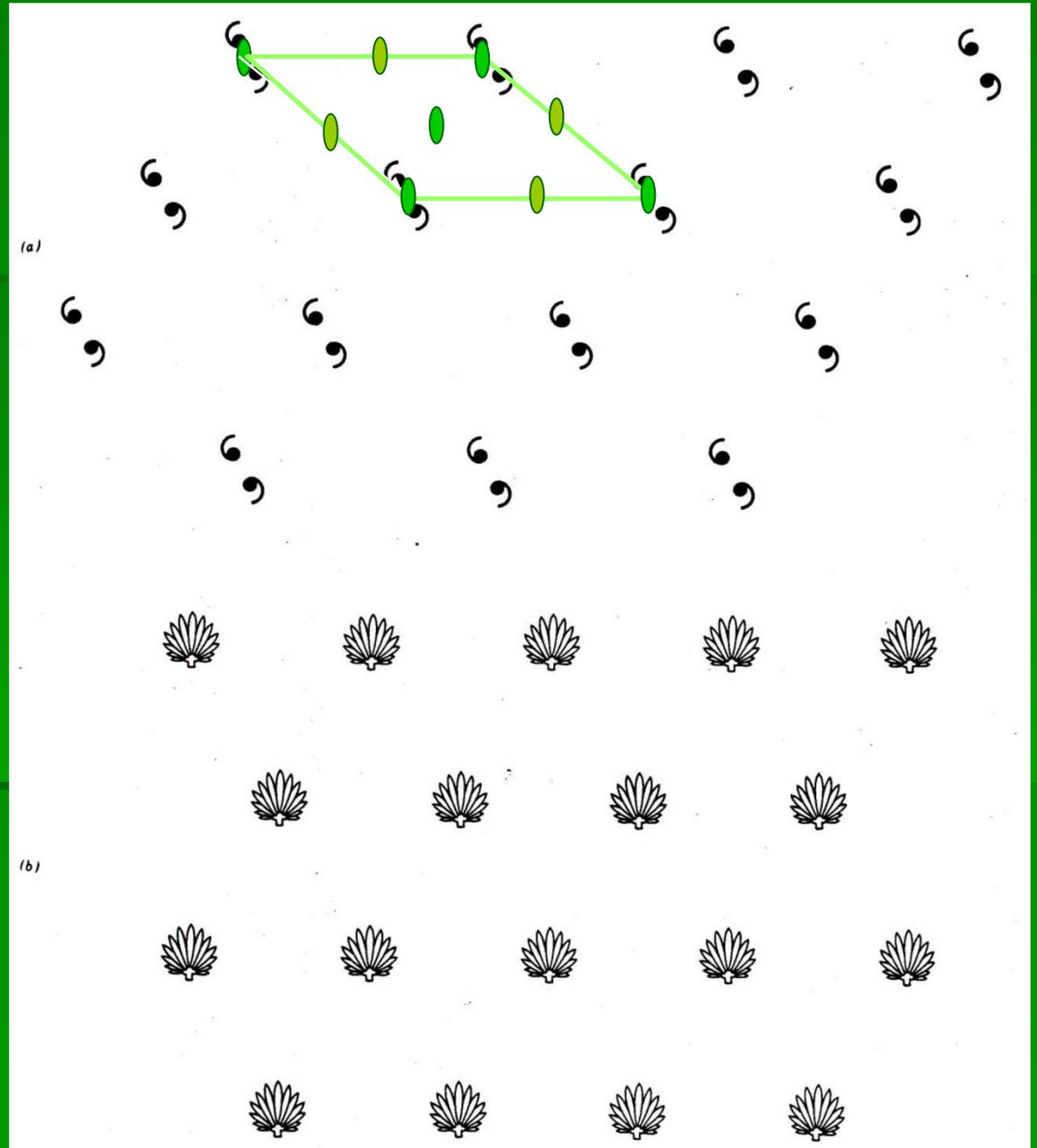
3. Cella unitária?

4. Z?

R: 1 (cela P)

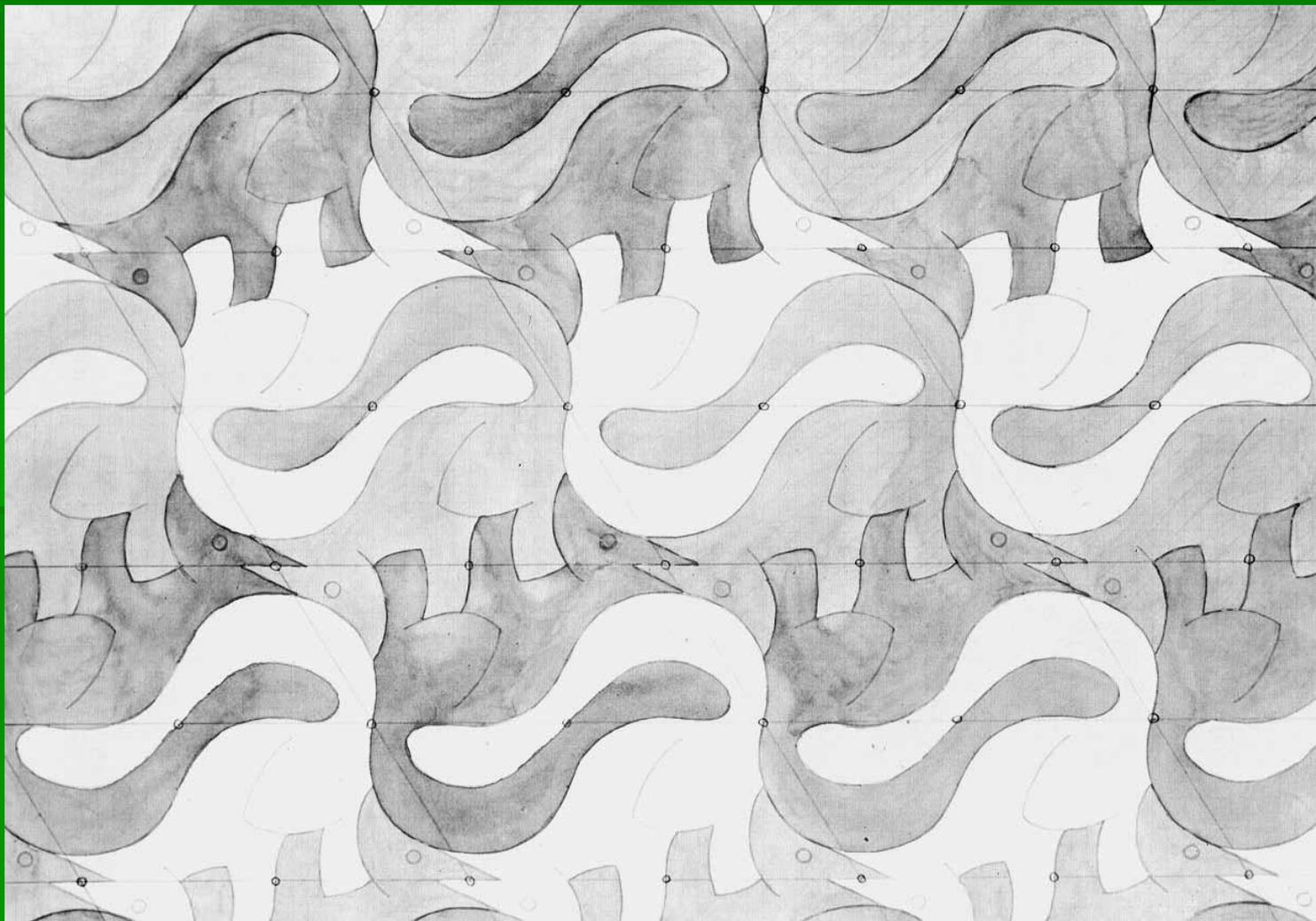
5. Grupo Espacial 2-D?

R: P 211



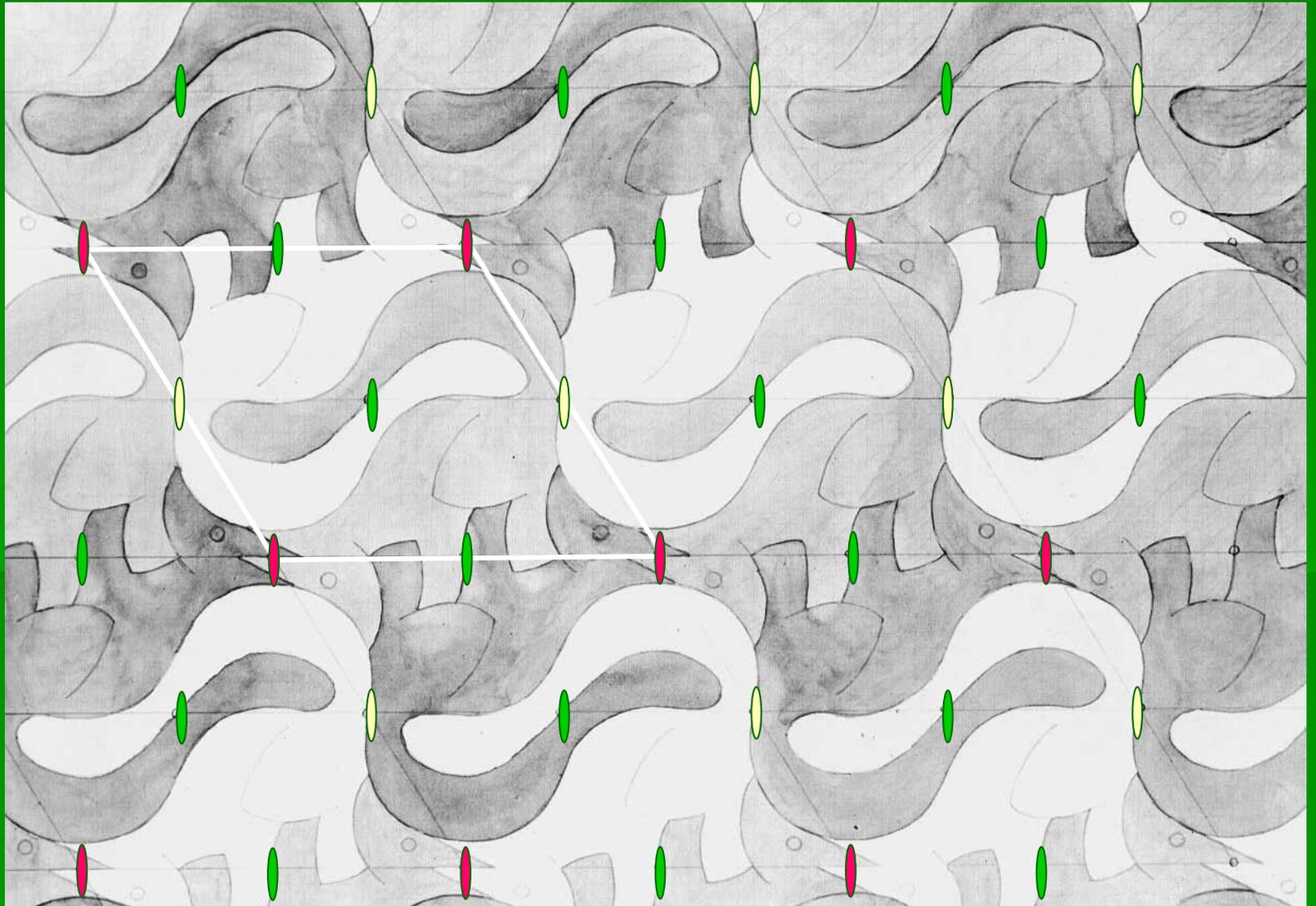
Simetria de Grupos Planares

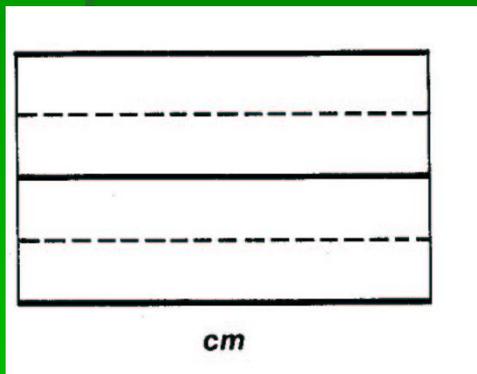
Combinando translações e grupos pontuais



Simetria de Grupos Planares

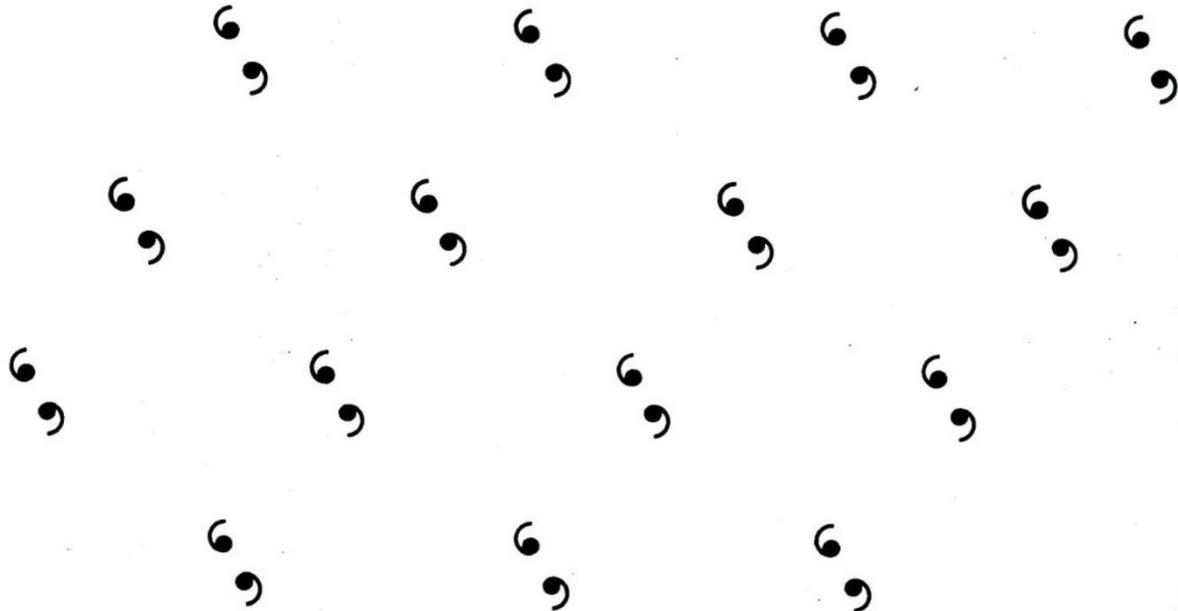
p211



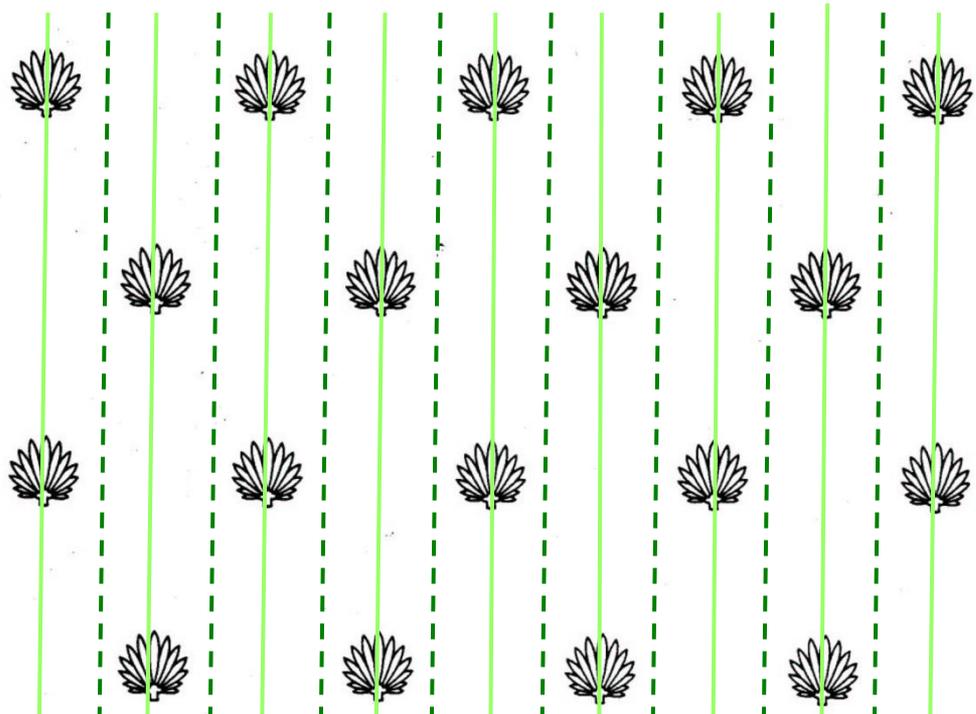


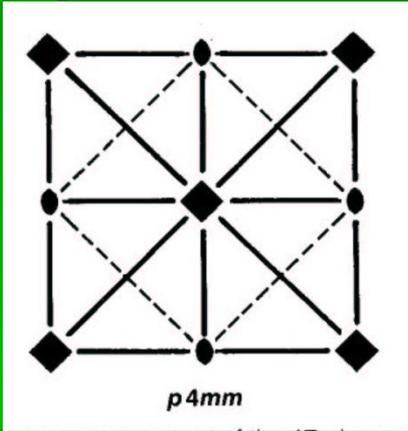
cm

(a)



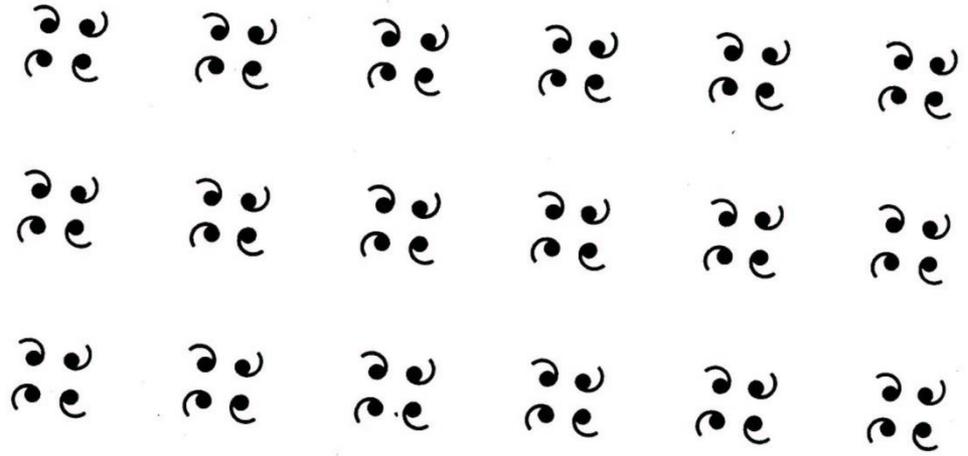
(b)



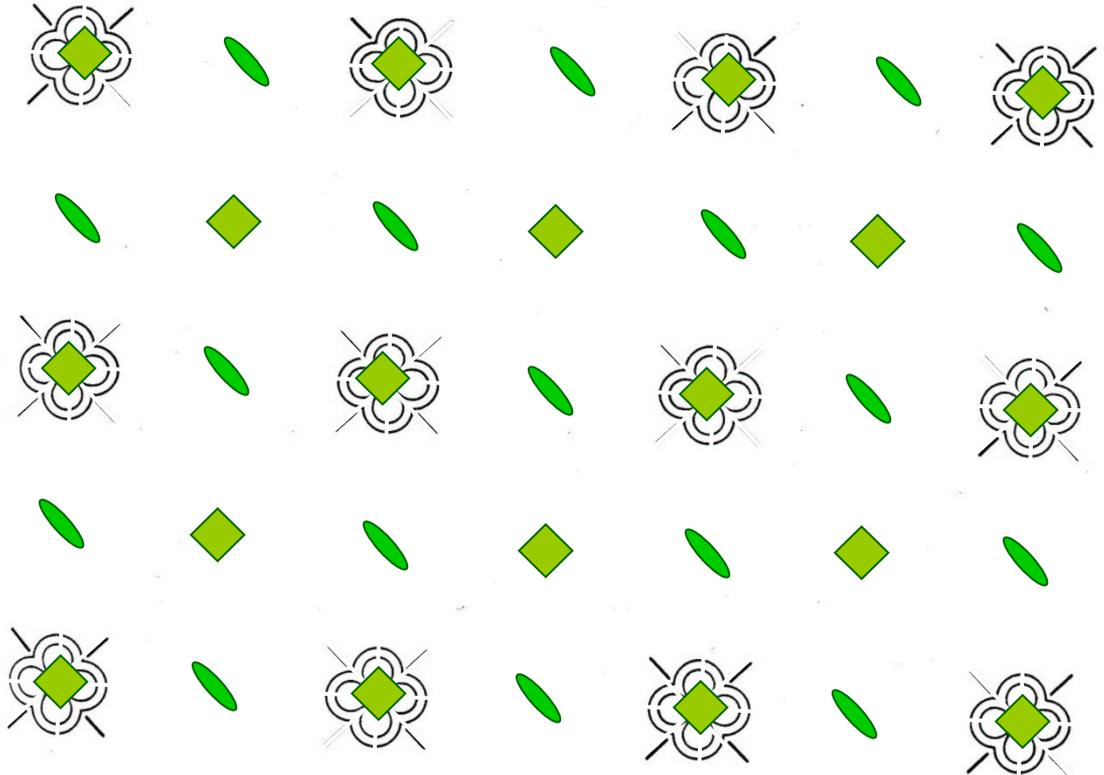


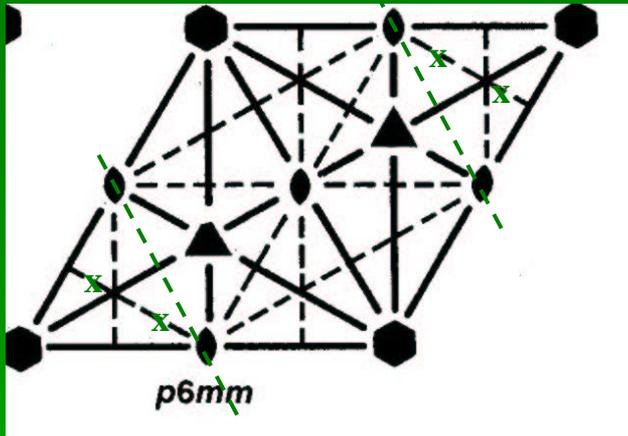
p4mm

(g)

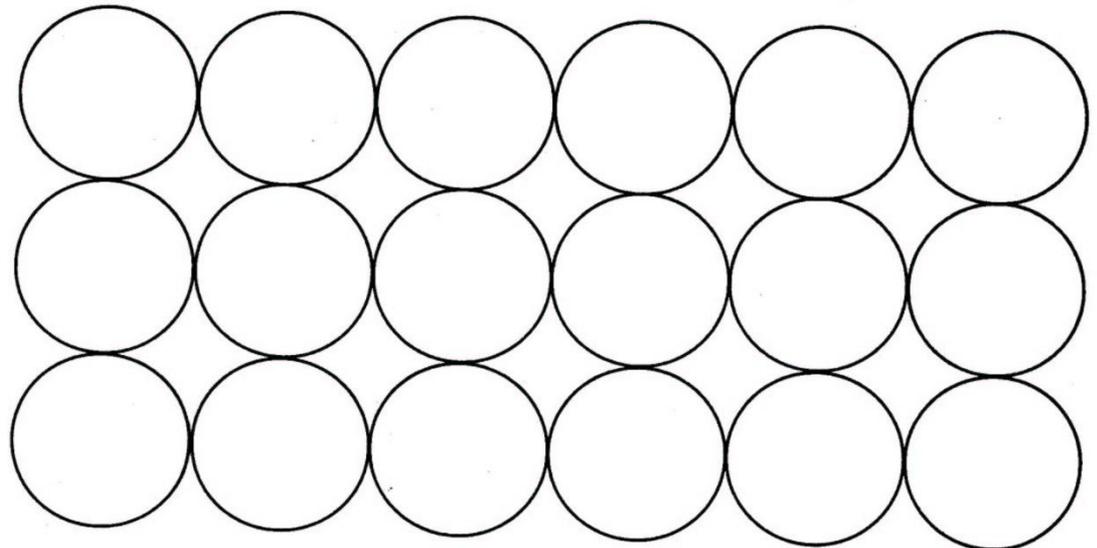
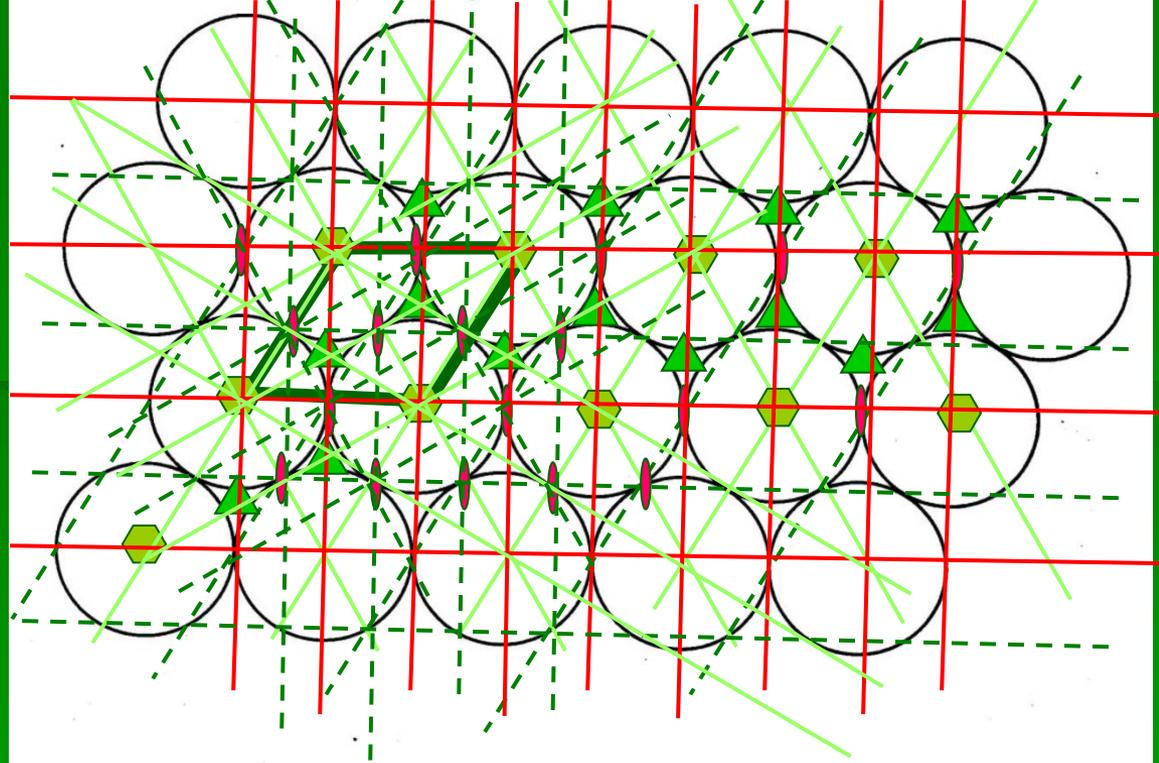


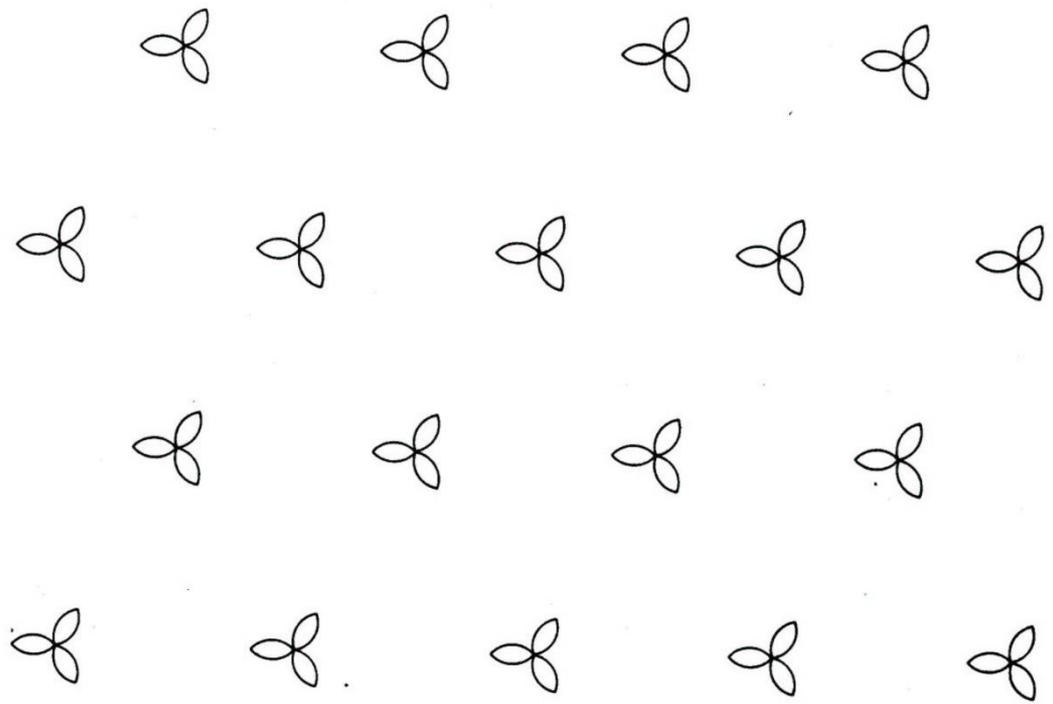
(h)



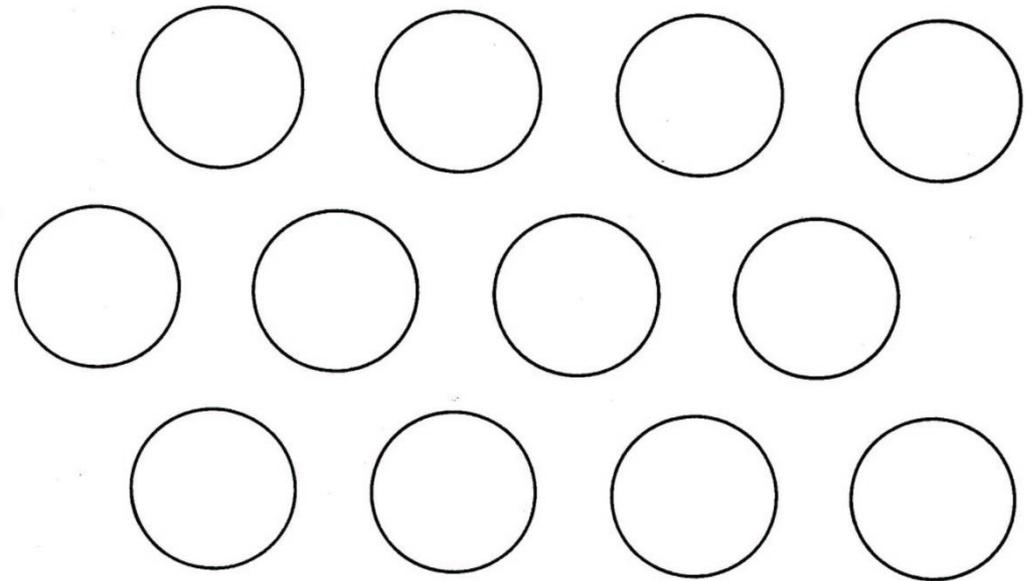


$p 6mm$



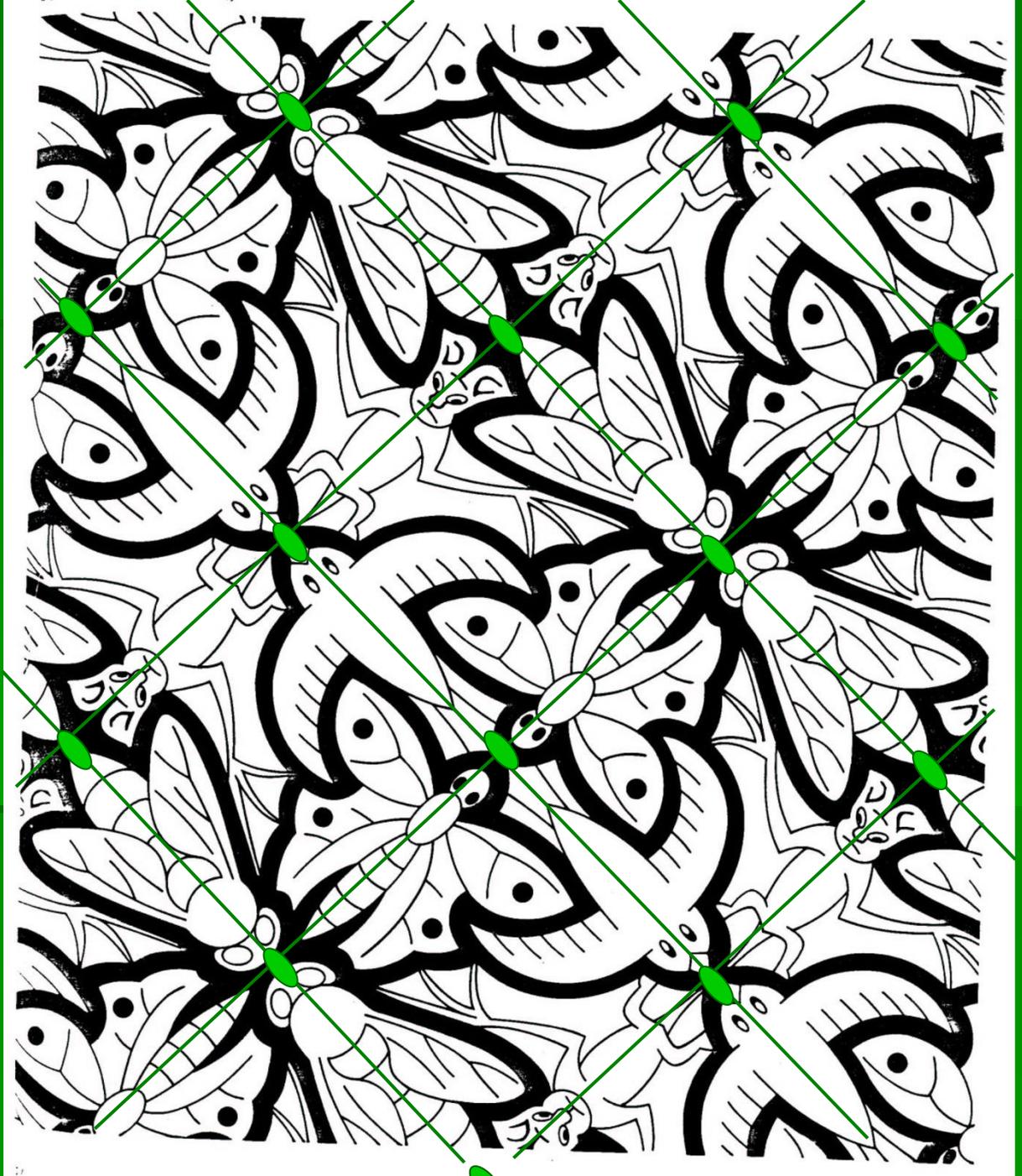


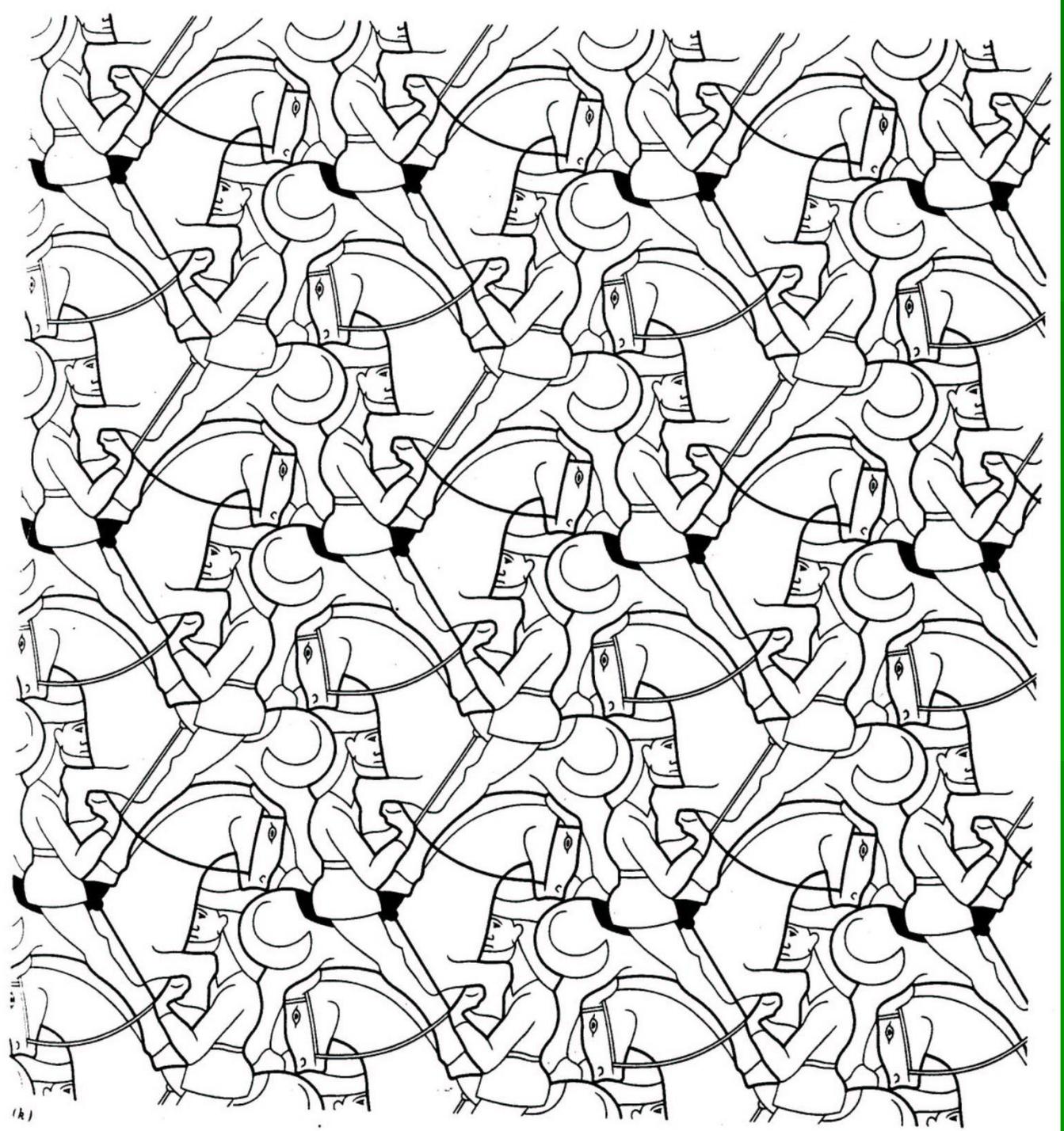
(c)



(d)

p 2mm





INTERNATIONAL TABLES for CRYSTALLOGRAPHY

Volume

A1

Symmetry relations between
space groups

Edited by
Hans Moraschek
and Ulrich Müller

2nd edition

Cristalografia estrutural

Simetria interna

- Simetria de translação: retículos planos
- Retículos tridimensionais (Bravais)
- Novos elementos de simetria:
 - Planos deslizantes (reflexão + translação)
 - Eixos helicoidais (rotação + translação)
- Os 230 Grupos Espaciais
- DRX e a estrutura interna dos cristais

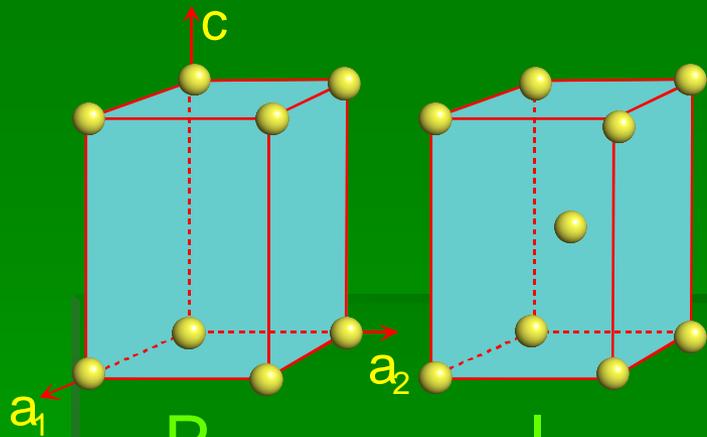
TABLE

Atomic co-ordinates ($\times 10^4$) with estimated
standard deviations in parentheses

ATOM	x	y	z
C-1	3183(3)	7374(5)	1797(9)
C-2	3020(4)	7831(5)	3692(9)
C-3	3718(4)	8265(5)	4581(9)
C-4	4106(3)	9097(5)	3345(10)
C-5	4236(4)	8566(5)	1481(10)
C-6	4575(4)	9337(6)	83(10)
O-1	3635(2)	6403(3)	2060(6)
O-2	2683(3)	7034(4)	4839(8)
O-3	3543(3)	8701(4)	6333(7)
C1-4	3561(1)	10338(1)	3106(3)
O-5	3552(2)	8166(3)	712(6)
O-6	4782(3)	8691(4)	-1490(7)
C-1'	3567(4)	5937(5)	-1160(9)
C-2'	3569(4)	5510(5)	827(9)
C-3'	2929(3)	4700(5)	1311(9)
C-4'	3300(4)	3741(5)	2262(10)
C-5'	4078(4)	3745(5)	1470(10)
O-2'	4236(2)	4905(3)	1152(7)
O-3'	2407(3)	5277(4)	2410(8)
O-4'	2960(3)	2700(4)	1939(8)
C-6'	4626(4)	3242(6)	2788(11)
C1-1'	3643(1)	4812(2)	-2727(3)
C1-6'	5548(1)	3304(2)	1922(3)

Table 4. Atomic coordinates for Catalão gorceixite indexed as monoclinic. (*) The equivalent isotropic displacement coefficients have been calculated from the published (Radoslovich, 1982) refined isotropic thermal parameters and kept constant during Rietveld refinement.

Atom	Wyckoff	Symmetry	Occupation	x	y	z	Uiso*100 (Å ²) (*)
Ba1	2a	m	0.76	0	0	0	0.671
Ca1	2a	m	0.19	0	0	0	
Sr1	2a	m	0.10	0	0	0	
P1	2a	m		0.2990(15)	0	0.9202(20)	0.861
P12	2a	m		0.6555(13)	0	0.0767(21)	0.431
Al1	2a	m	0.91	0.9833(14)	0	0.4785(26)	0.469
Fe1	2a	m	0.09	0.9833(14)	0	0.4785(26)	
Al2	4b	1	0.91	0.7491(13)	0.2400(18)	0.5088(22)	0.443
Fe2	4b	1	0.09	0.7491(13)	0.2400(18)	0.5088(22)	
O1	2a	m		0.4372(26)	0	0.1933(30)	0.507
O12	2a	m		0.598(4)	0	0.8247(27)	1.102
O2	2a	m		0.1514(15)	0	0.825(4)	0.823
O22	2a	m		0.8230(14)	0	0.173(4)	0.697
O3	4b	1		0.3614(15)	0.1478(25)	0.8400(25)	1.051
O33	4b	1		0.6722(25)	0.1920(19)	0.1989(25)	0.823
OH1	2a	m		0.2733(28)	0	0.425(5)	0.899
OH12	2a	m		0.7260(29)	0	0.594(5)	1.254
OH2	4b	1		0.9147(14)	0.1980(24)	0.5738(29)	0.443
OH22	4b	1		0.0734(14)	0.1855(24)	0.4314(30)	0.621

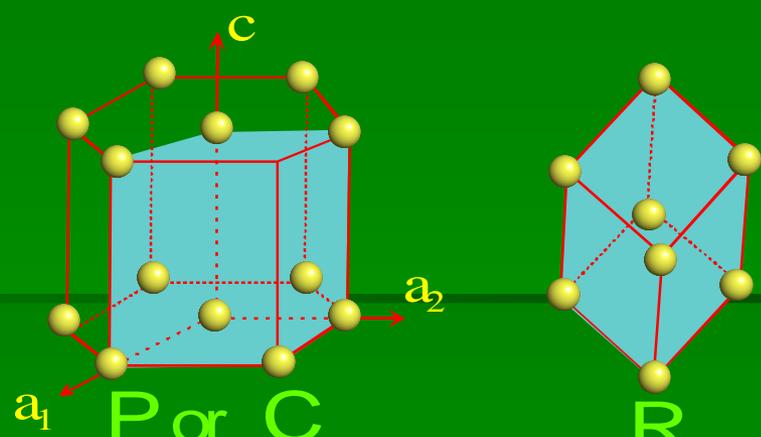


P

I

Tetragonal

$$\alpha = \beta = \gamma = 90^\circ \quad a_1 = a_2 \neq c$$



P or C

R

Hexagonal

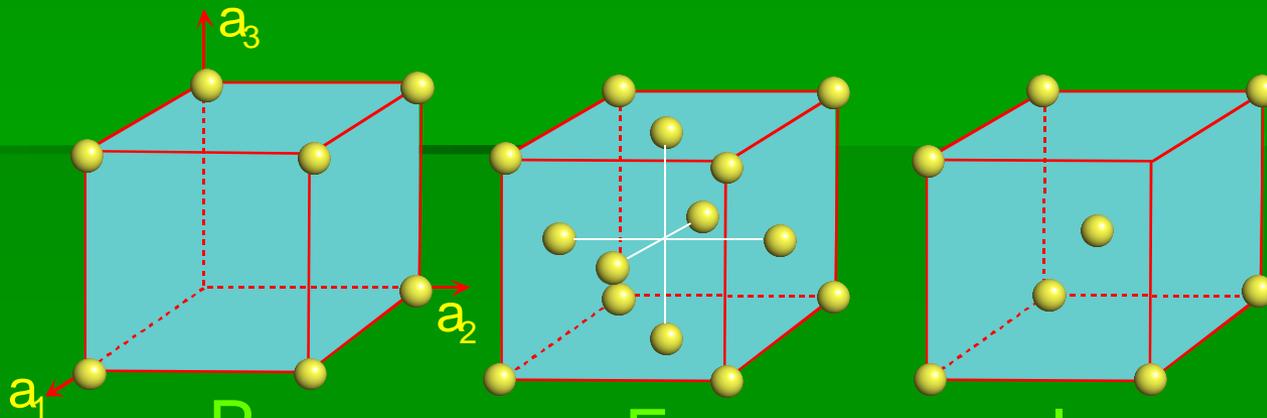
Rhombohedral

$$\alpha = \beta = 90^\circ \quad \gamma = 120^\circ$$

$$a_1 = a_2 \neq c$$

$$\alpha = \beta = \gamma \neq 90^\circ$$

$$a_1 = a_2 = a_3$$



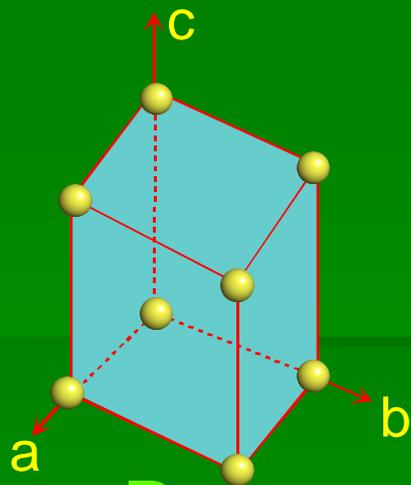
P

F

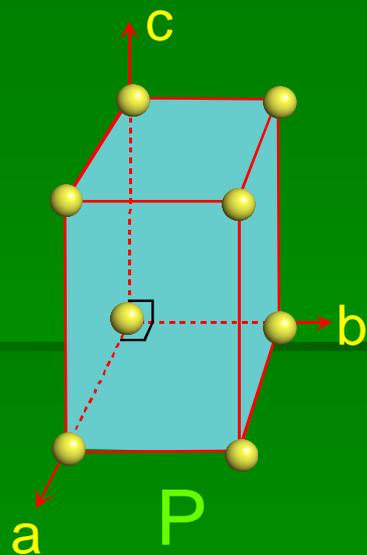
I

Isométrico

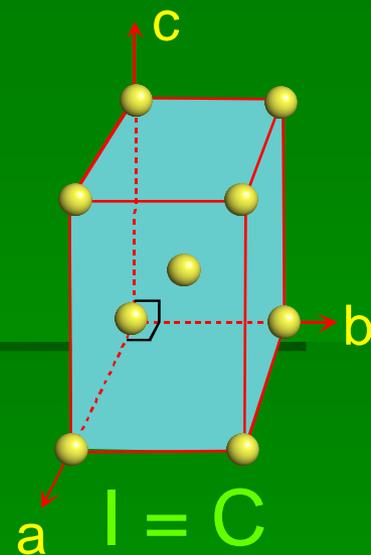
$$\alpha = \beta = \gamma = 90^\circ \quad a_1 = a_2 = a_3$$



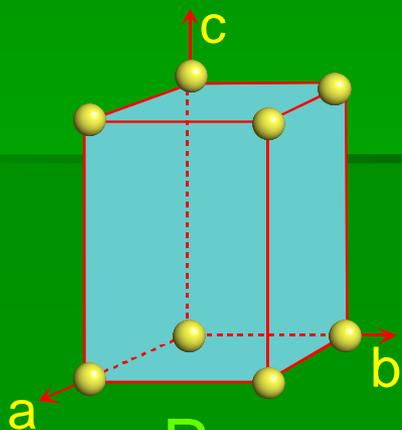
P
Triclínico
 $\alpha \neq \beta \neq \gamma$
 $a \neq b \neq c$



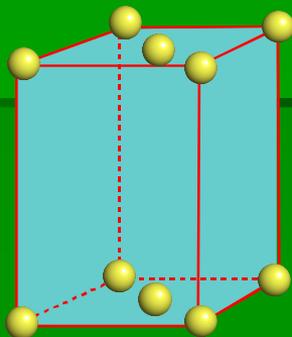
P
Monoclínico
 $\alpha = \gamma = 90^\circ \neq \beta$
 $a \neq b \neq c$



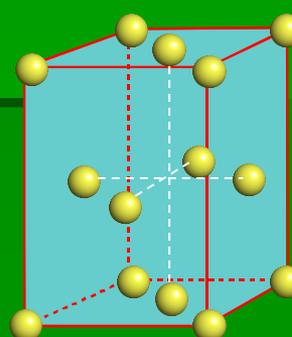
I = C



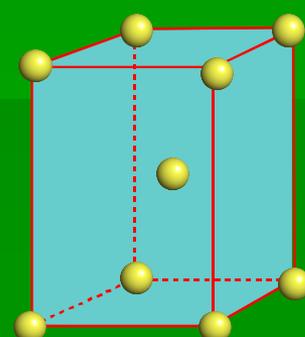
P



C



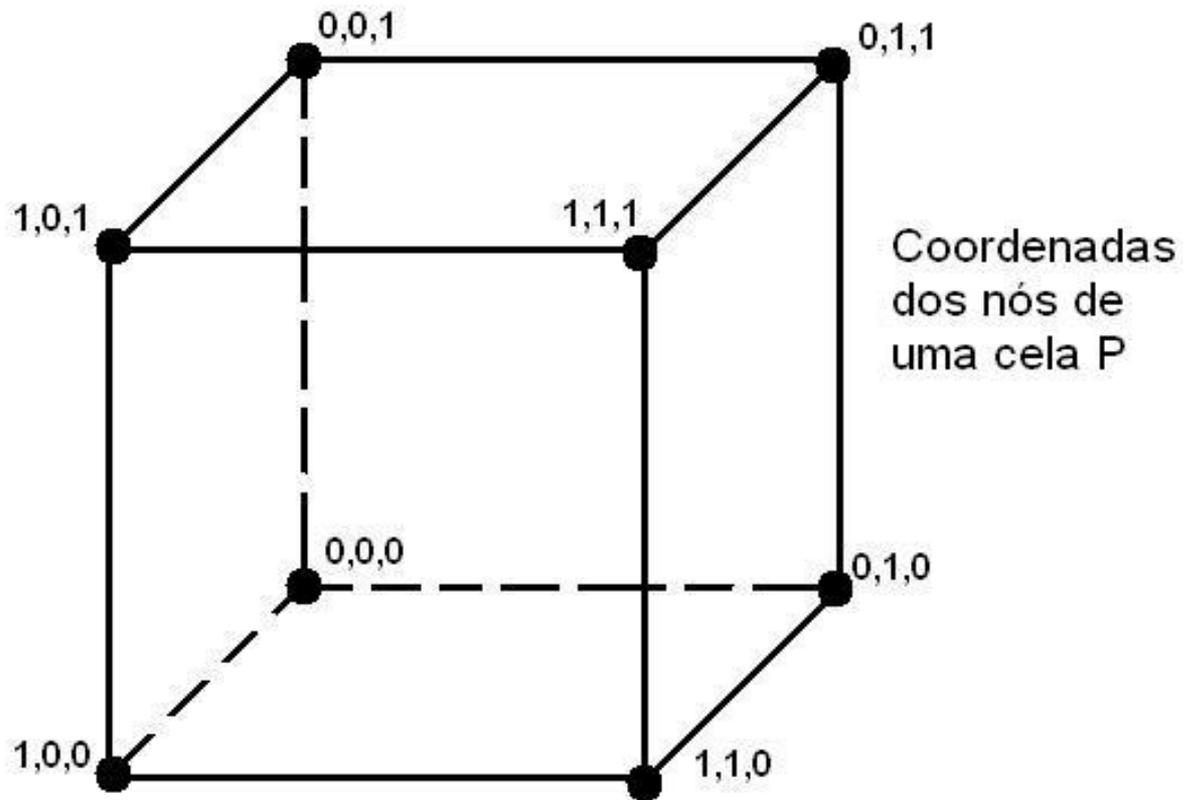
F



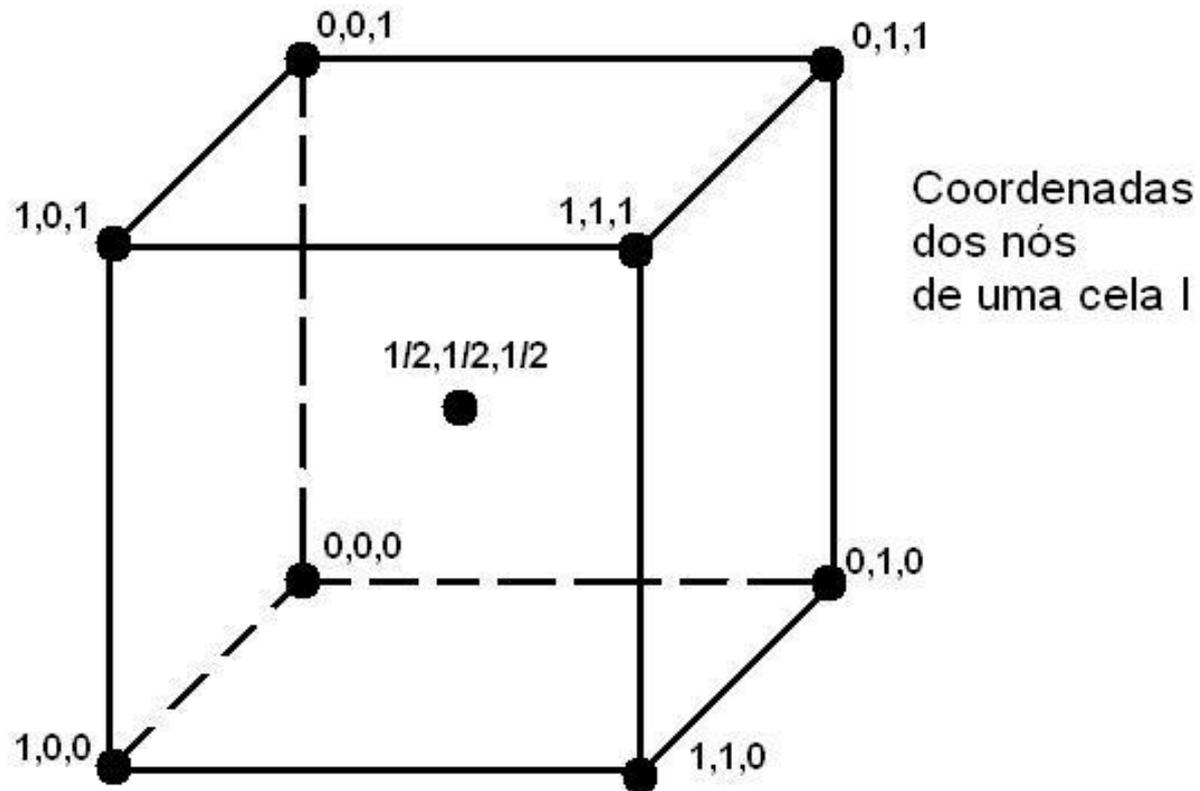
I

Ortorrômbico
 $\alpha = \beta = \gamma = 90^\circ$ $a \neq b \neq c$

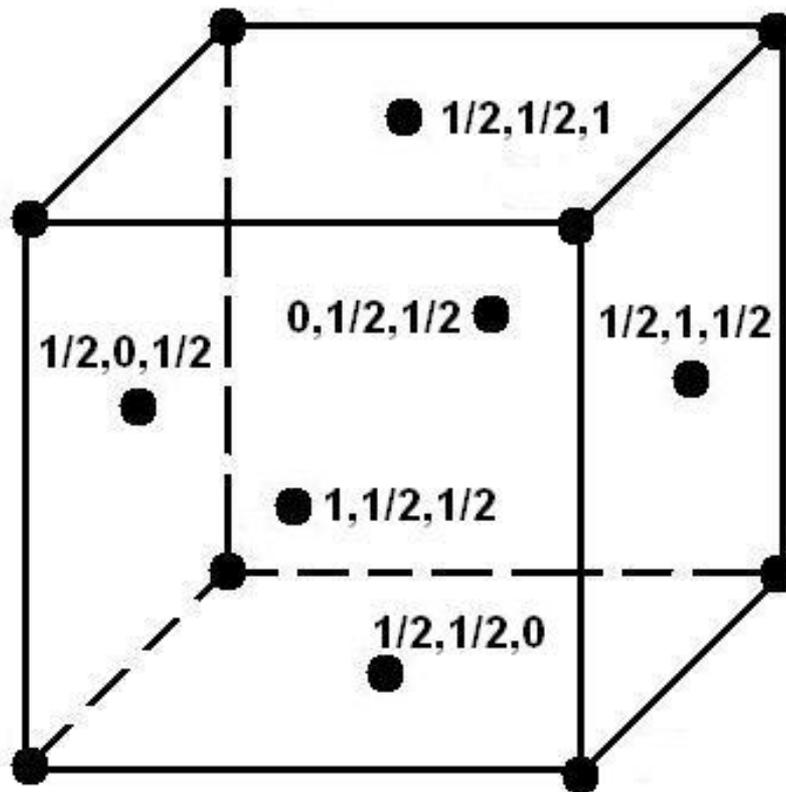
Cela genérica P: coordenadas dos nós (apenas nos vênrtices!)



- Celas I (de corpo centrado) – coordenadas dos nós:



Celas F – coordenadas dos nós do centro das faces;



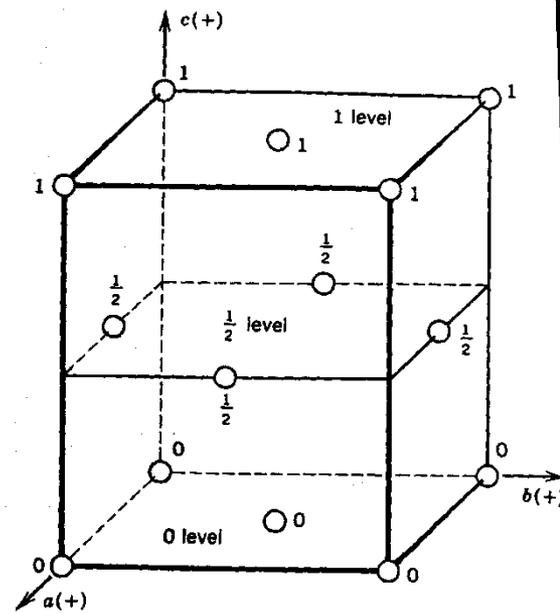
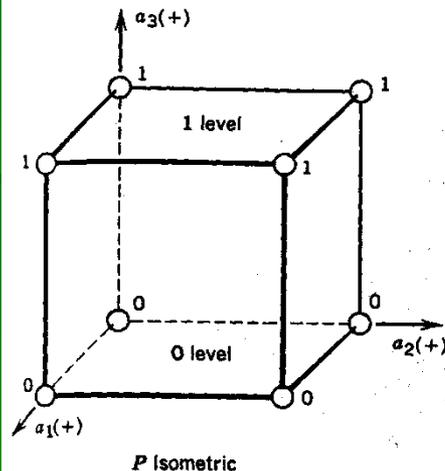
Coordenadas dos nós do centro das faces de uma cela F



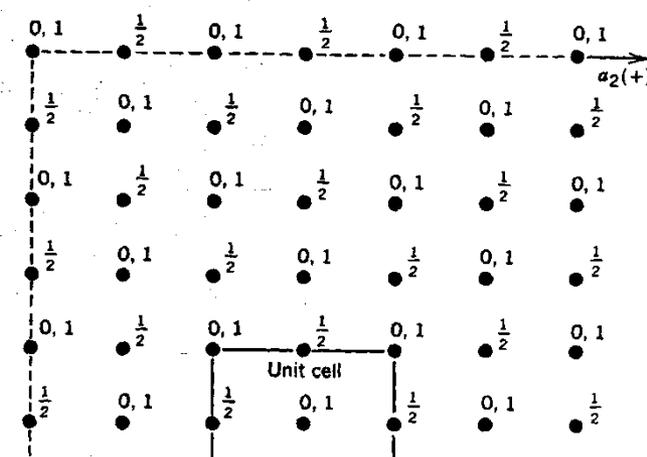
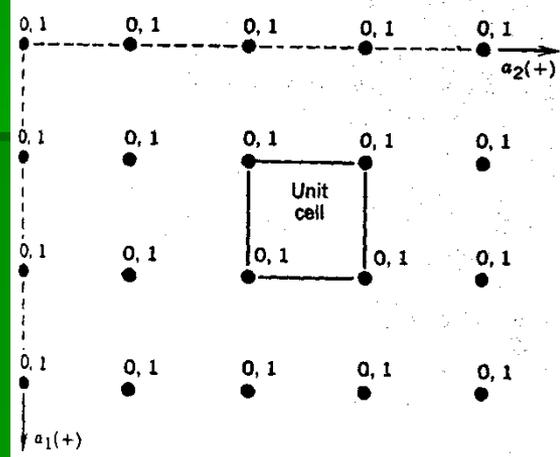
Projeções ortográficas de retículos de Bravais

(projeções no plano $(001)_0$)

FIGURE 11.3 Unit cells and their projections. (a) Perspective views of an isometric P cell and an orthorhombic F cell. (b) Projection of these same cells onto the plane of the page ($= 0$ level) in extended lattices.



(a)



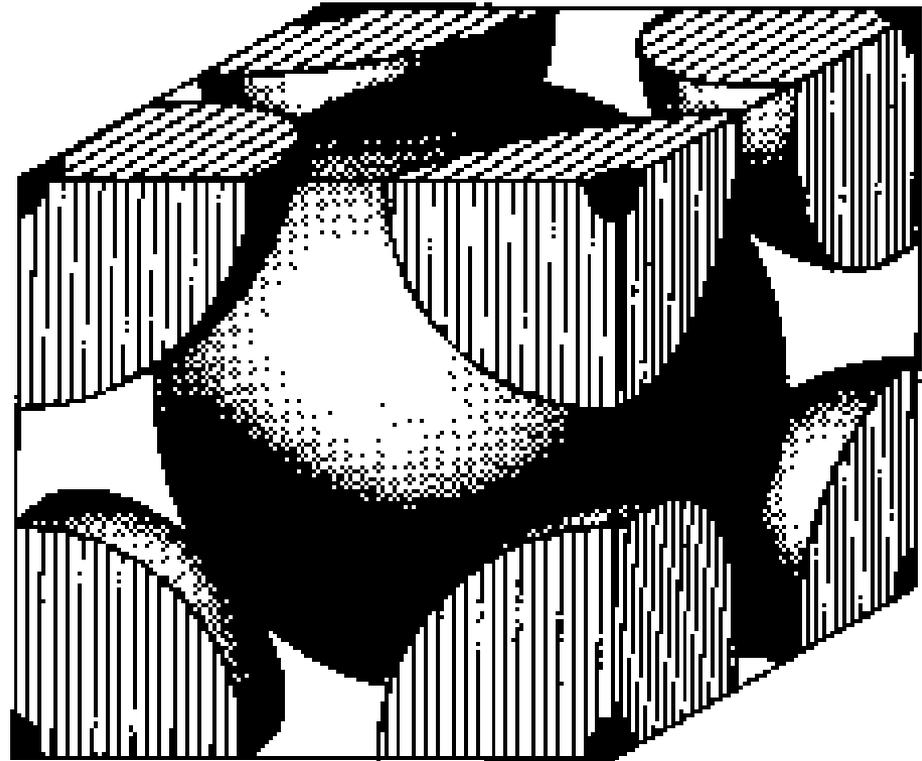
(b)

Cela unitária do Fe metálico – perspectiva:

Conteúdo atômico
da cela:

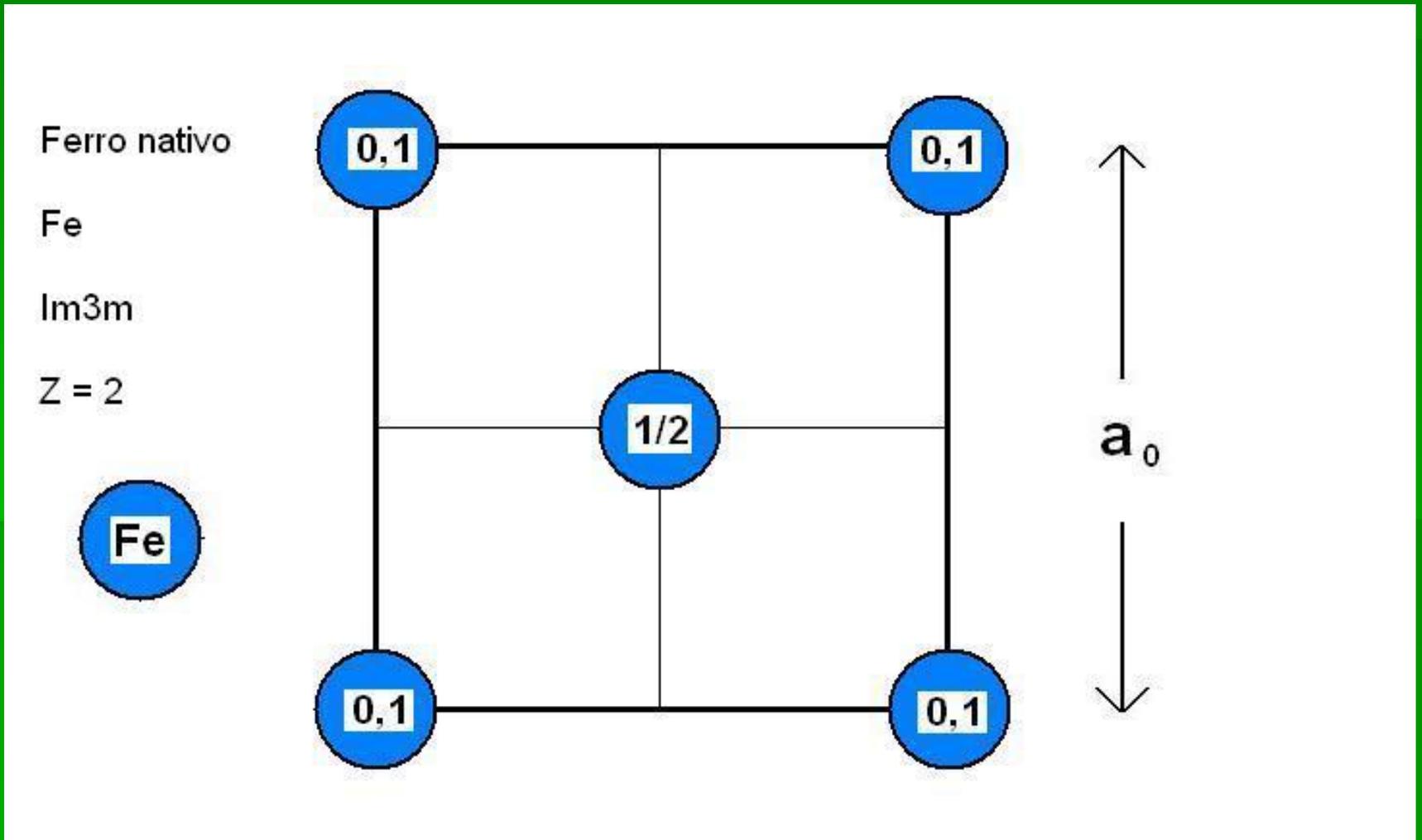
$$Z = 2$$

$8 \times 1/8$ (vértices) +
 1×1 (centro)



Body Centered Molecule

Projeção de cela unitária: ferro nativo (Fe):



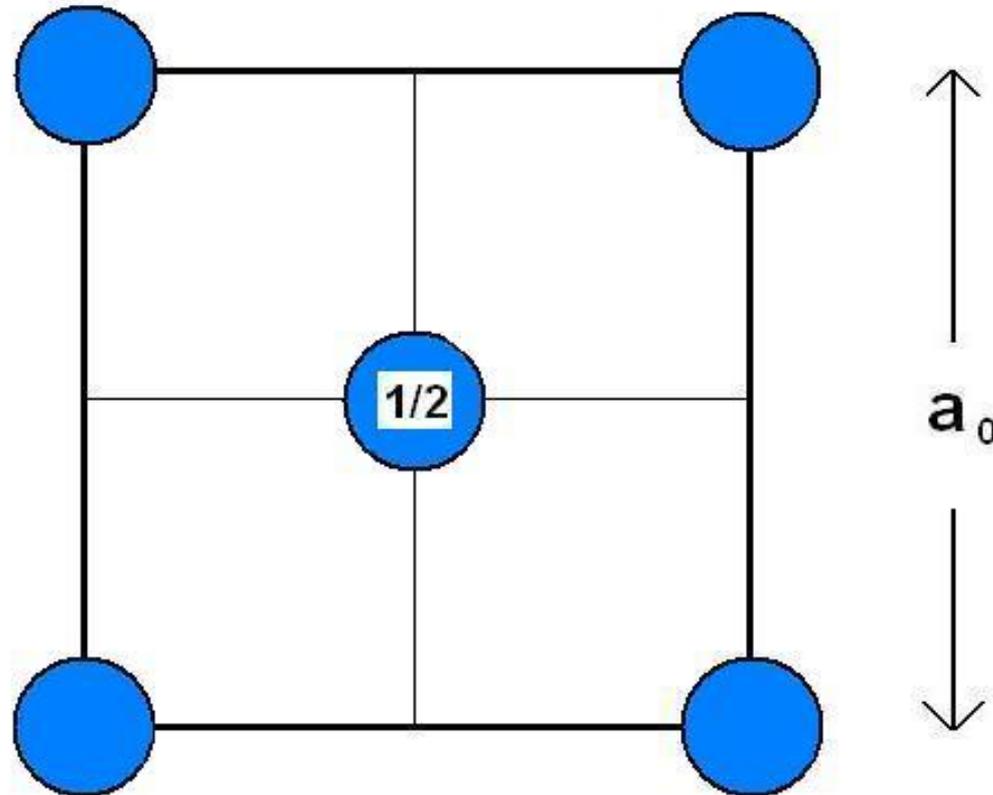
Projeção da cela unitária do ferro nativo (Fe), sem a indicação das cotas 0 e 1:

Ferro nativo

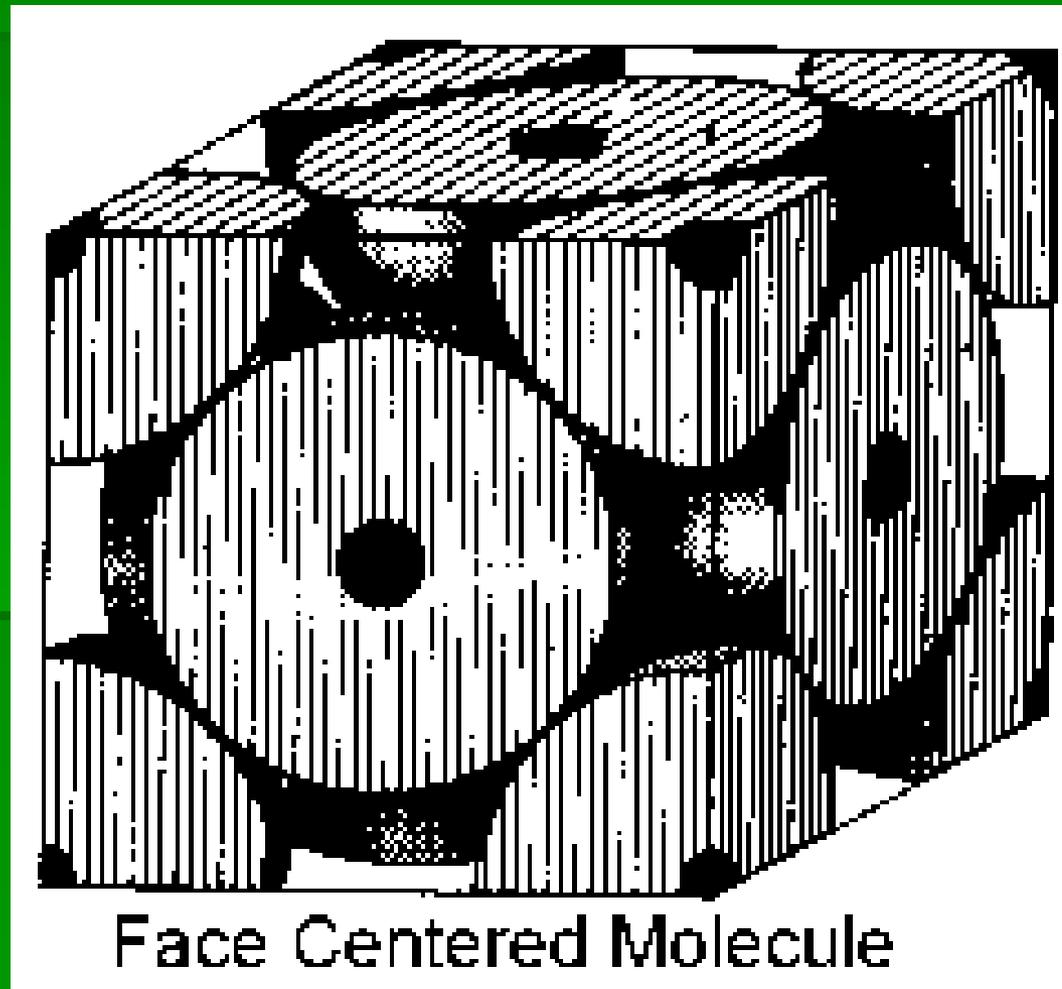
Fe

$Im\bar{3}m$

$Z = 2$



Cela unitária do ouro – perspectiva:



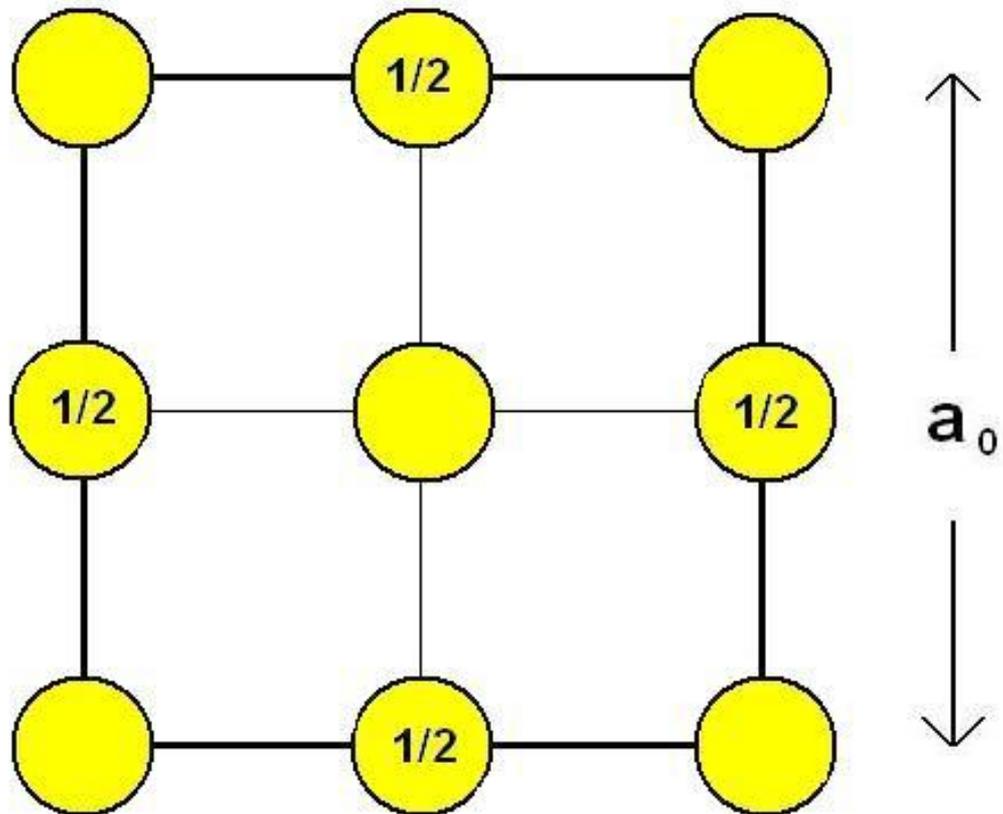
Projeção da cela unitária do ouro:

Ouro nativo

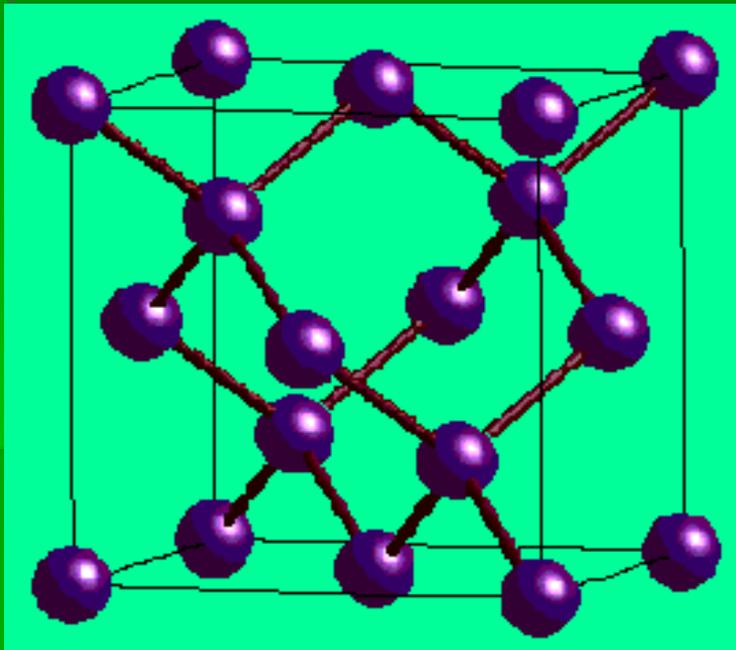
Au

Fm3m

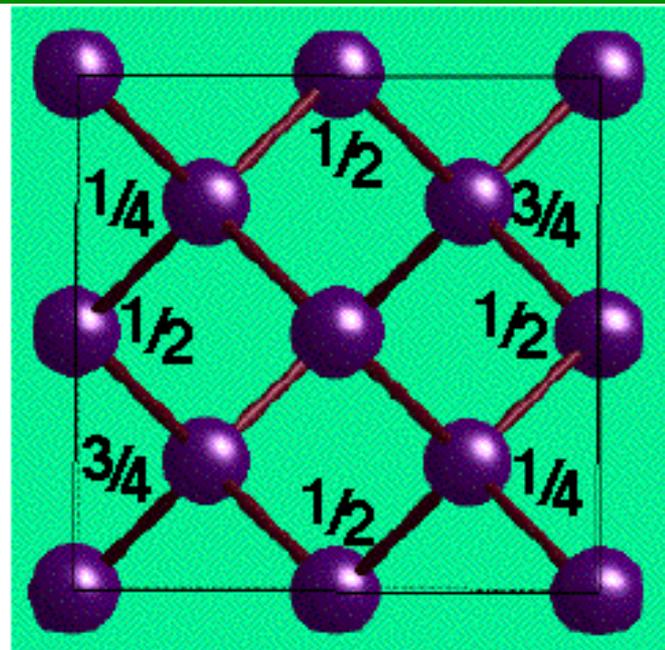
Z=4



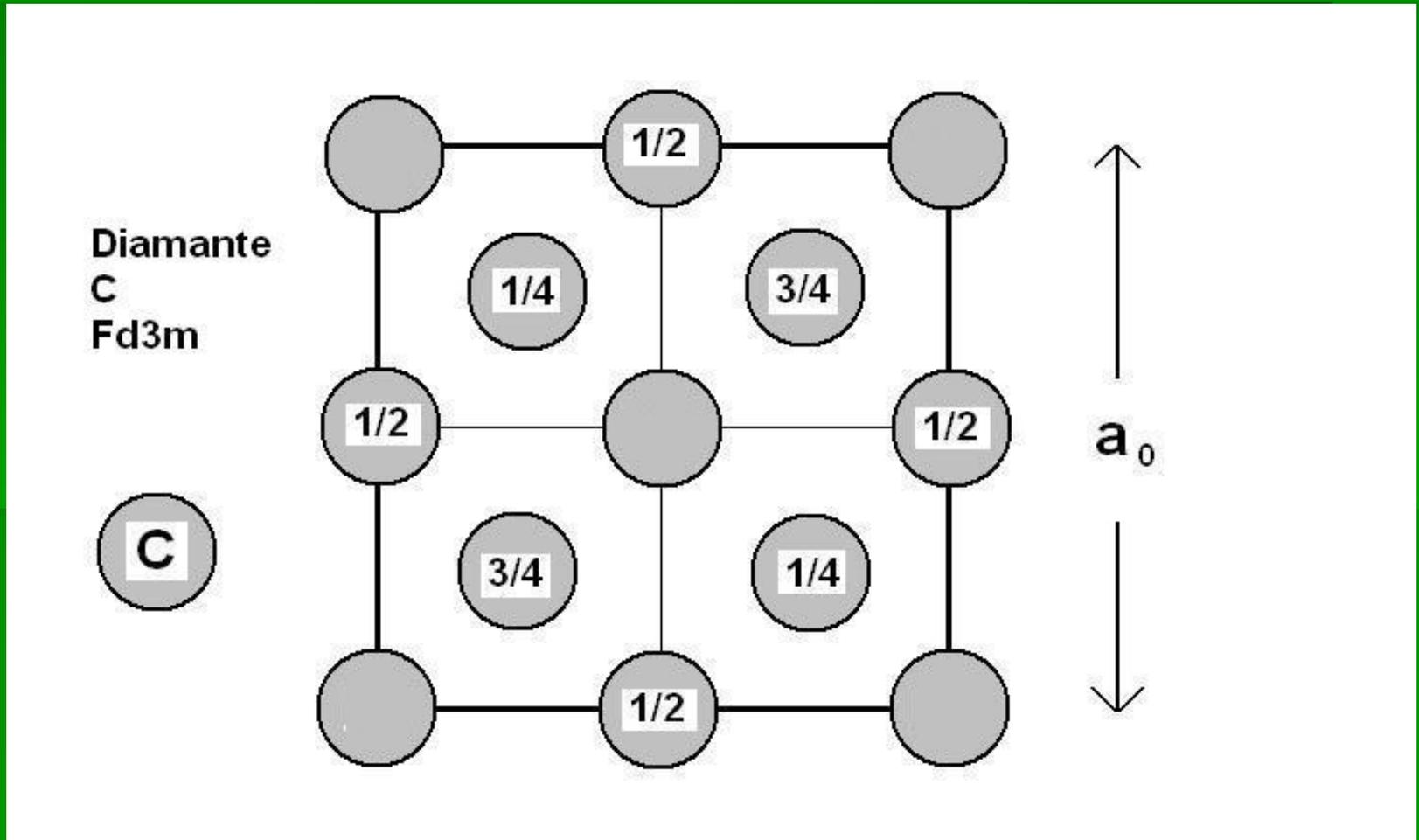
Estrutura do diamante – C – perspectiva e projeção:



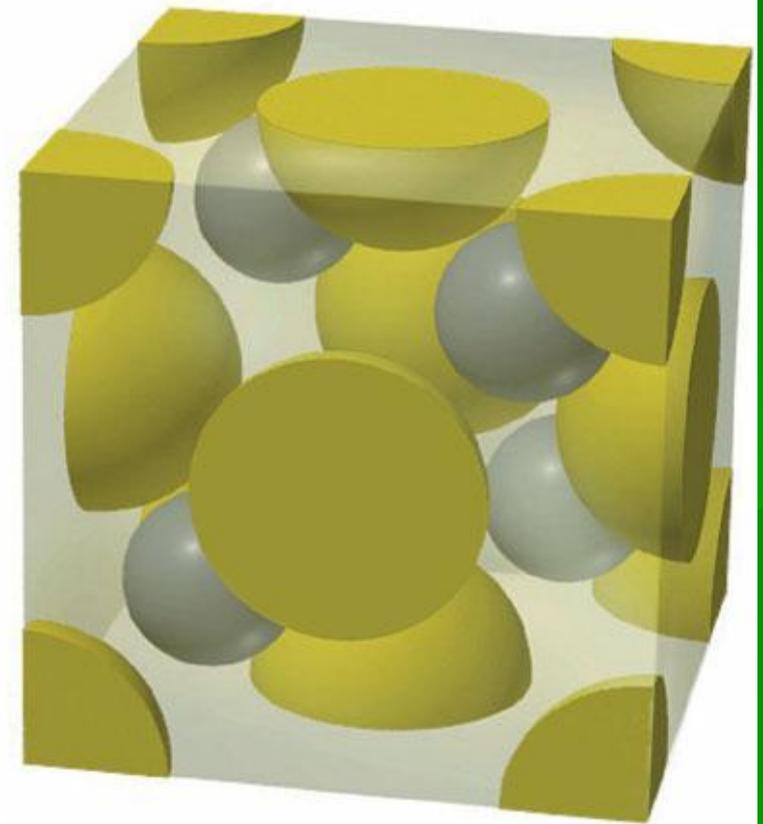
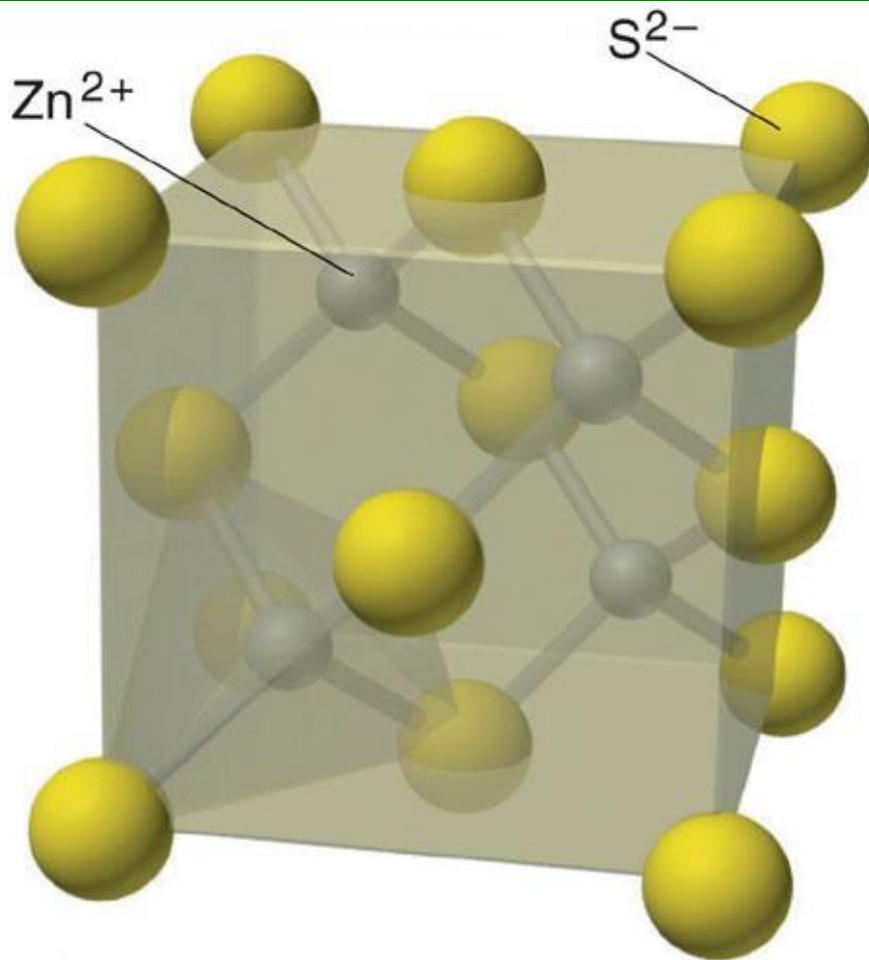
Unit
Cell



Exemplo de projeção da célula unitária: diamante, C, $Fd\bar{3}m$, com átomos de C em $(0,0,0)$ e $(1/4,1/4,1/4)$

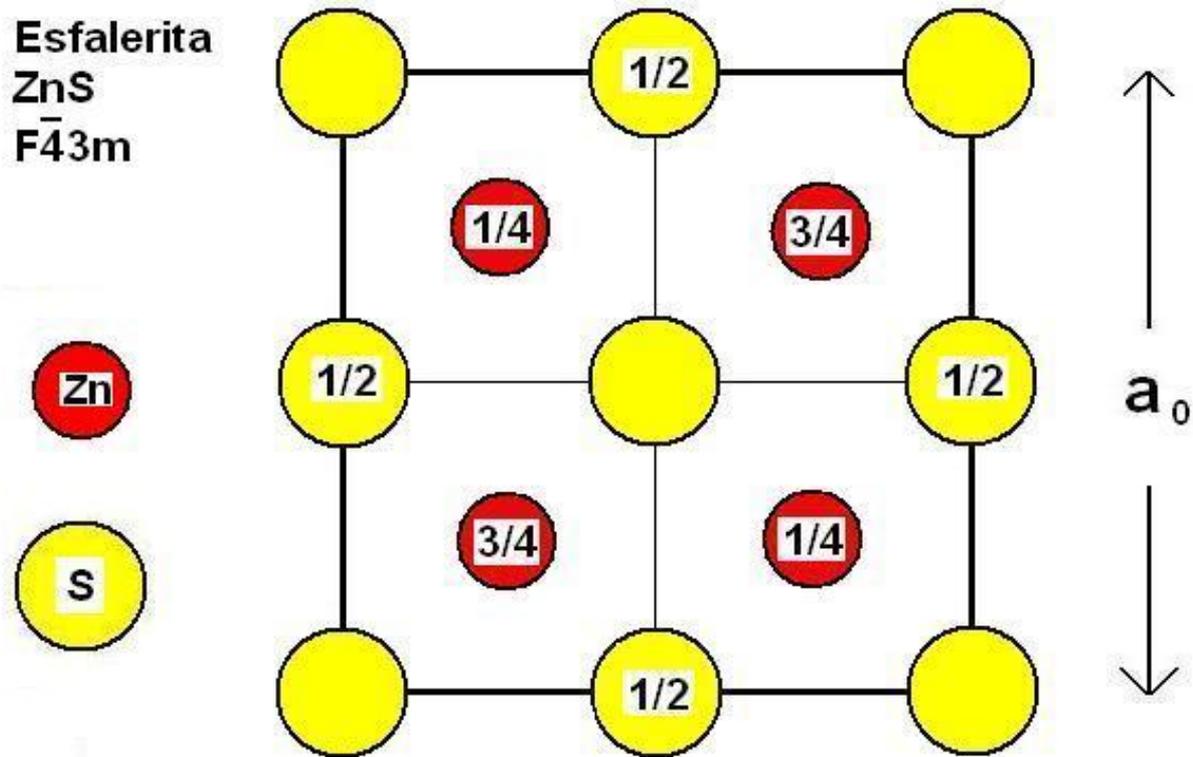


Estrutura da esfalerita – ZnS – em perspectiva:

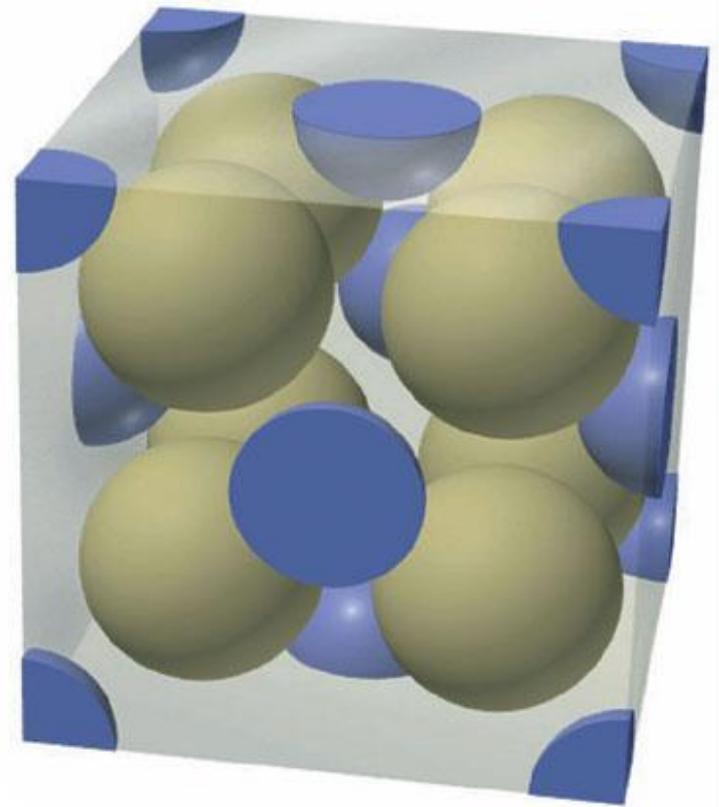
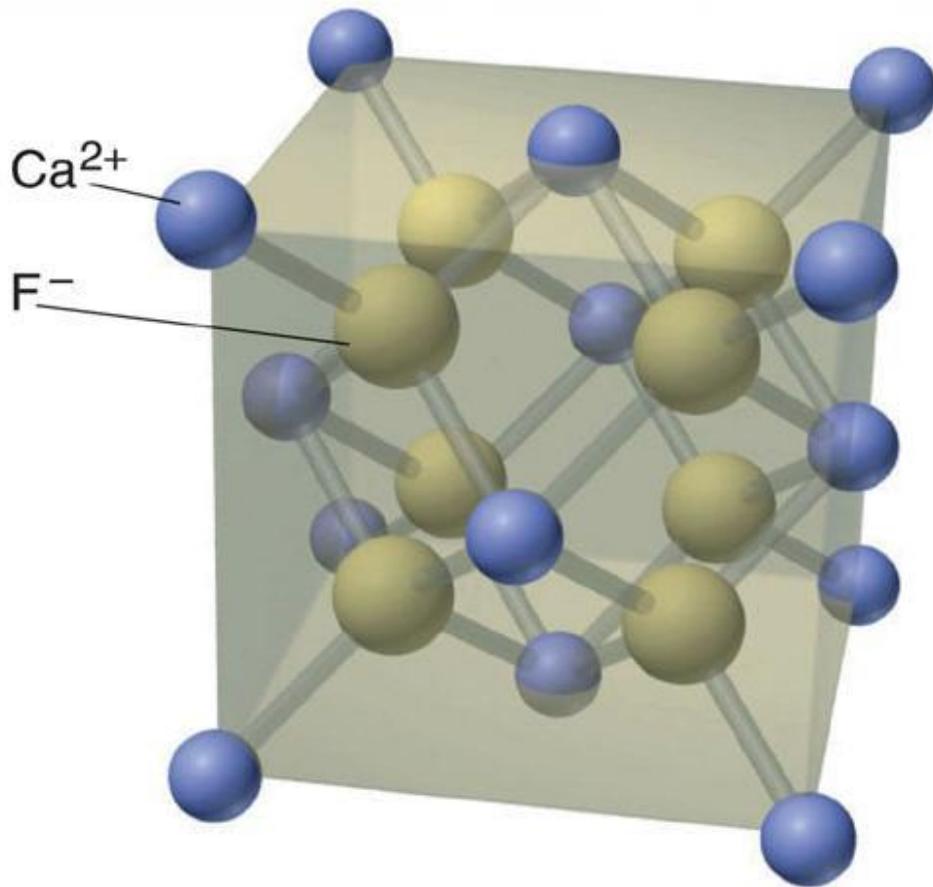


Exemplo de projeção da cela unitária: esfalerita, ZnS , $\bar{F}43m$, com S em $(0,0,0)$ e Zn em $(1/4,1/4,1/4)$

Esfalerita
 ZnS
 $\bar{F}43m$



Estrutura da fluorita - CaF_2 – em perspectiva:



Exemplo de projeção da célula unitária: fluorita, CaF_2 , $\text{Fm}\bar{3}\text{m}$, com Ca em $(0,0,0)$ e F em $(1/4,1/4,1/4)$ e $(3/4,1/4,1/4)$

