



Mineralogija

Sveučilišni prijediplomski studij Znanosti o okolišu – 1. godina (253566)

Doc. dr. sc. Petra Schneider

akad. god.: 2024./25.

Sadržaj

- Kristalne klase
- Kristalni sustavi
- Triklinski sustav
- Monoklinski sustav
- Rompski sustav
- Tetragonski sustav
- Heksagonski sustav
- Kubični sustav
- Komplementarne forme
- Pseudoforme
- Određivanje simetrije



Kristalne klase
Kristalni razredi
Točkine (točkaste) grupe

→ **32 moguće kombinacije elemenata simetrije**

Podjela klasa na temelju stupnja simetrije:

- **holoedrija** – klasa maksimalnog stupnja simetrije u nekom sustavu, njena simetrija jednaka je simetriji osnovnog križa
- **hemiedrija, tetartoedrija, ogdoedrija** – klase kod kojih je stupanj simetrije sveden na $1/2$, $1/4$, $1/8$
- **hemimorfija** – zbog gubitka horizontalne ravnine simetrije razlikuju se gornja i donja polovica kristala

KRISTALNI SUSTAVI = skup kristalnih razreda koji pokazuju zajednička simetrijska obilježja, tj. sukladnosti sa simetrijom osnovnog križa

- 1) kubični
- 2) tetragonski
- 3) heksagonski (+/- trigonski)
- 4) rompski
- 5) monoklinski
- 6) triklinski

Prilog 1

! Prisutnost nekih elemenata simetrije nužno zahtijeva prisutnost dodatnih elemenata simetrije:

- parna os simetrije i na nju okomita ravnina simetrije zahtijevaju prisustvo centra simetrije

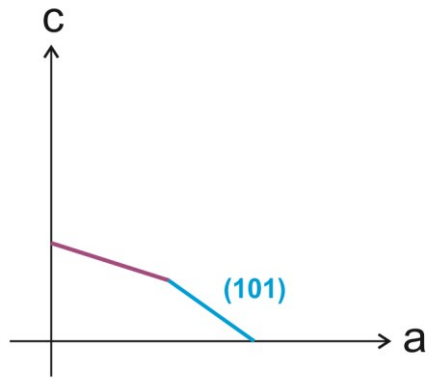
$$2, 4, 6 \perp m \rightarrow \mathbf{C}$$

- presjecištem dviju međusobno okomitih ravnina simetrije ide digira

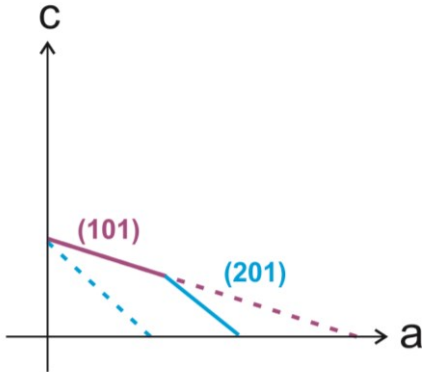
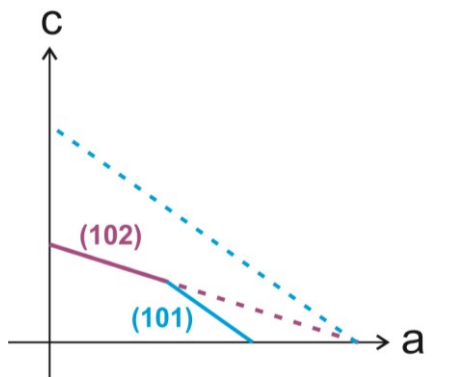
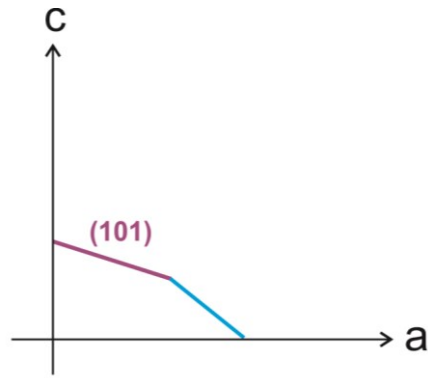
$$m \perp m \rightarrow \mathbf{2}$$

Indeksiranje ploha

(1)

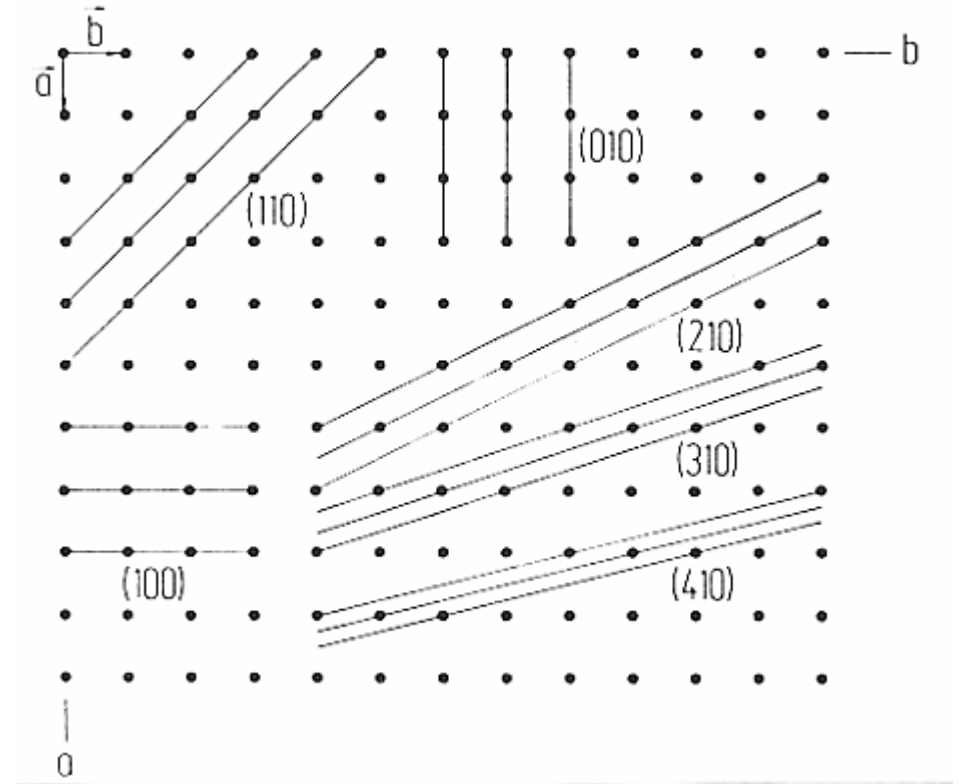


(2)



! Zakon o stalnosti kutova:

U različitim uzorcima istog minerala, kutovi između odgovarajućih ploha su isti pri konstantnoj temperaturi i tlaku.



Označavanje mrežnih ravnina

→ jedan indeks označava čitav set paralelnih mrežnih ravnina

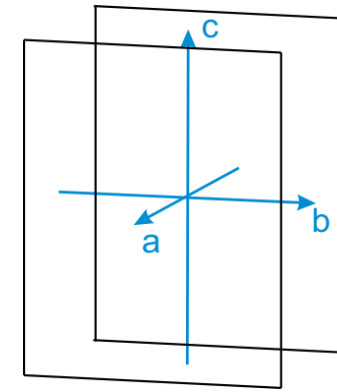
Stereografska projekcija - crtanje

Element simetrije	Oznaka	Grafički simbol
Centar simetrije	$C, \bar{1}$	
Ravnina simetrije	P, m	
Digira	$L^2, 2$	
Trigira	$L^3, 2$	
Tetragira	$L^4, 2$	
Heksagira	$L^6, 2$	
Rotoinverzna tetragira	$L_{(4)}^2, 2$	
Zona	-	

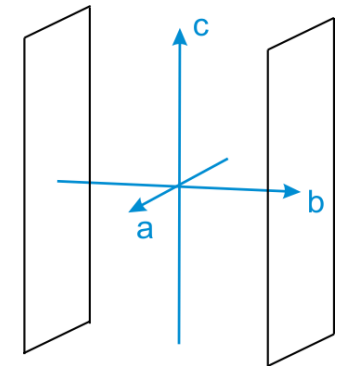
Forme

PINAKOID = otvorena forma od 2 paralelne plohe:

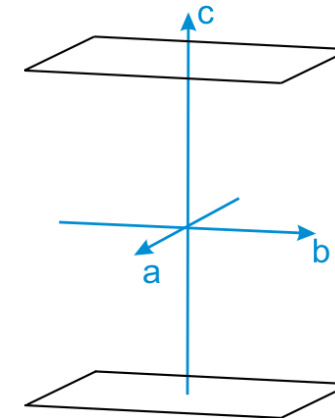
- **prednji (prvi)** – plohe sijeku samo os a , $\{100\}$
- **bočni (drugi)** – plohe sijeku samo os b , $\{010\}$
- **bazni (treći)** – plohe sijeku samo os c , $\{001\}$
- **I. položaj (a-pinakoid)** – plohe ne sijeku os a (paralelan s a);
siječe osi b i c , $\{0kl\}$
- **II. položaj (b-pinakoid)** – plohe ne sijeku os b (paralelan s b);
siječe osi a i c , $\{h0l\}$
- **III. položaj (c-pinakoid)** – plohe ne sijeku os c (paralelan s c);
siječe osi a i b , $\{hk0\}$
- **IV. (opći) položaj** – plohe sijeku sve 3 osi, $\{hkl\}$



prednji pinakoid



bočni pinakoid

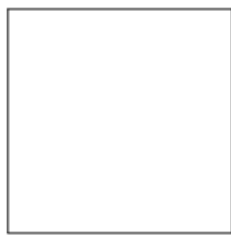


bazni pinakoid

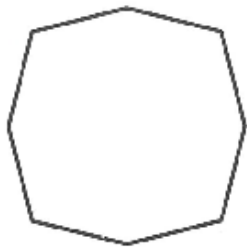
Forme

PRIZMA = otvorena forma od 3 ili više (4, 6, 8, 12) paralelnih plohe koje se sjeku u međusobno paralelnim bridovima, tj. paralelne su s nekim pravcem

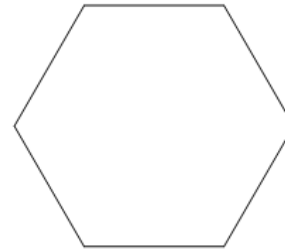
→ naziv prema **kristalnom sustavu** (presjeku) i **položaju**



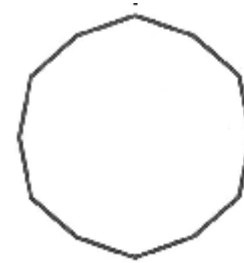
tetragonska



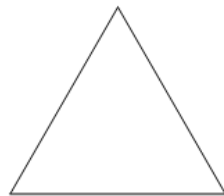
ditetragonska



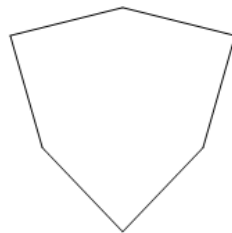
heksagonska



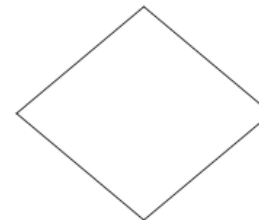
diheksagonska



trigonska



ditrigonska



rompska
monoklinska

Forme

PRIZMA = otvorena forma od 3 ili više (4, 6, 8, 12) paralelnih plohe koje se sijeku u međusobno paralelnim bridovima, tj. paralelne su s nekim pravcem

→ naziv prema **kristalnom sustavu** (presjeku) i **položaju**

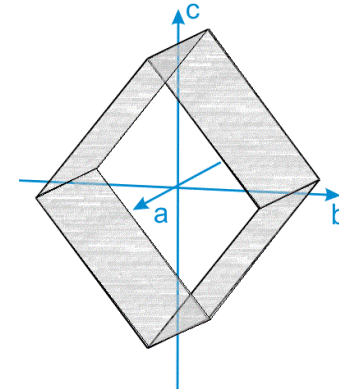
! U **rompskom** sustavu i **monoklinskom** sustavu:

I. položaj – plohe paralelne s osi a (siječe osi b i c)
 $\{0kl\}$ pr. $\{011\}$

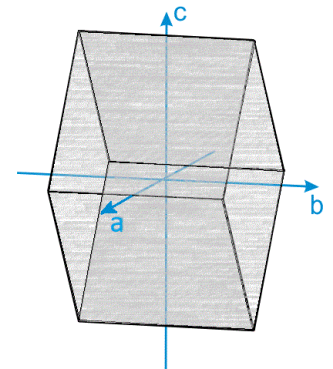
II. položaj – plohe paralelne s osi b (siječe osi a i c)
 $\{h0l\}$ pr. $\{101\}$

III. položaj – plohe paralelne s osi c (siječe osi a i b)
 $\{hk0\}$ pr. $\{110\}$

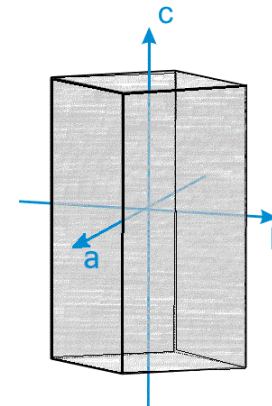
IV. položaj – plohe sijeku sve tri osi
 $\{hkl\}$ pr. $\{111\}$



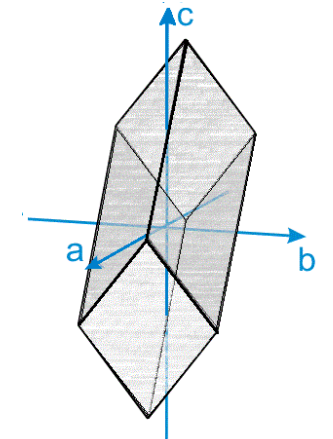
I. položaj



II. položaj



III. položaj

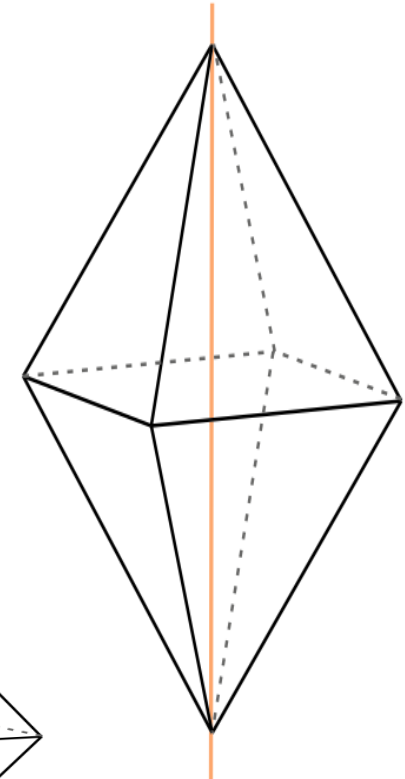
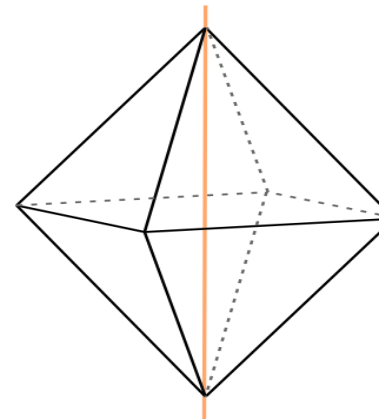
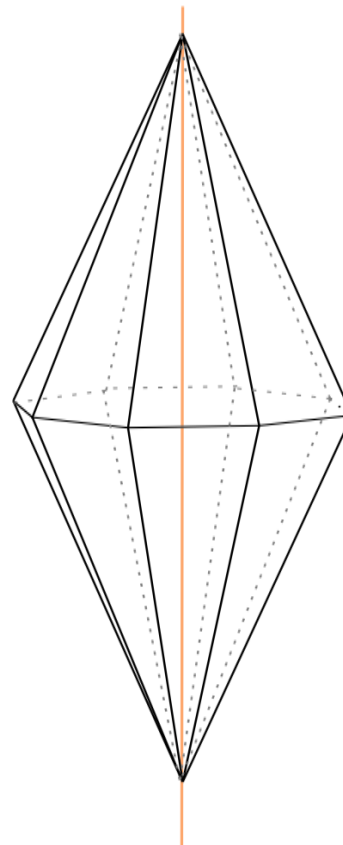
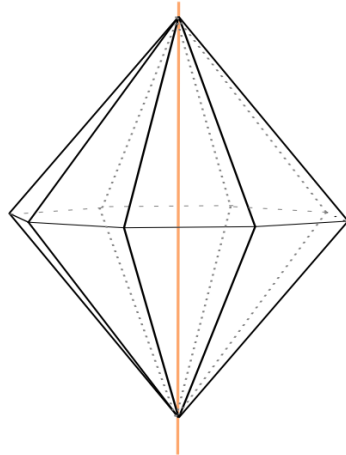
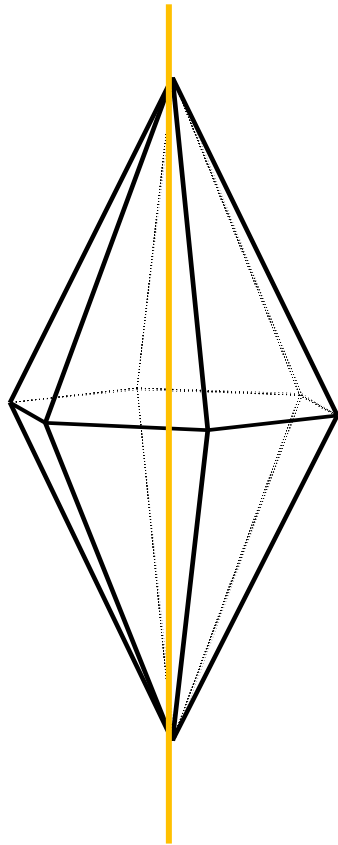


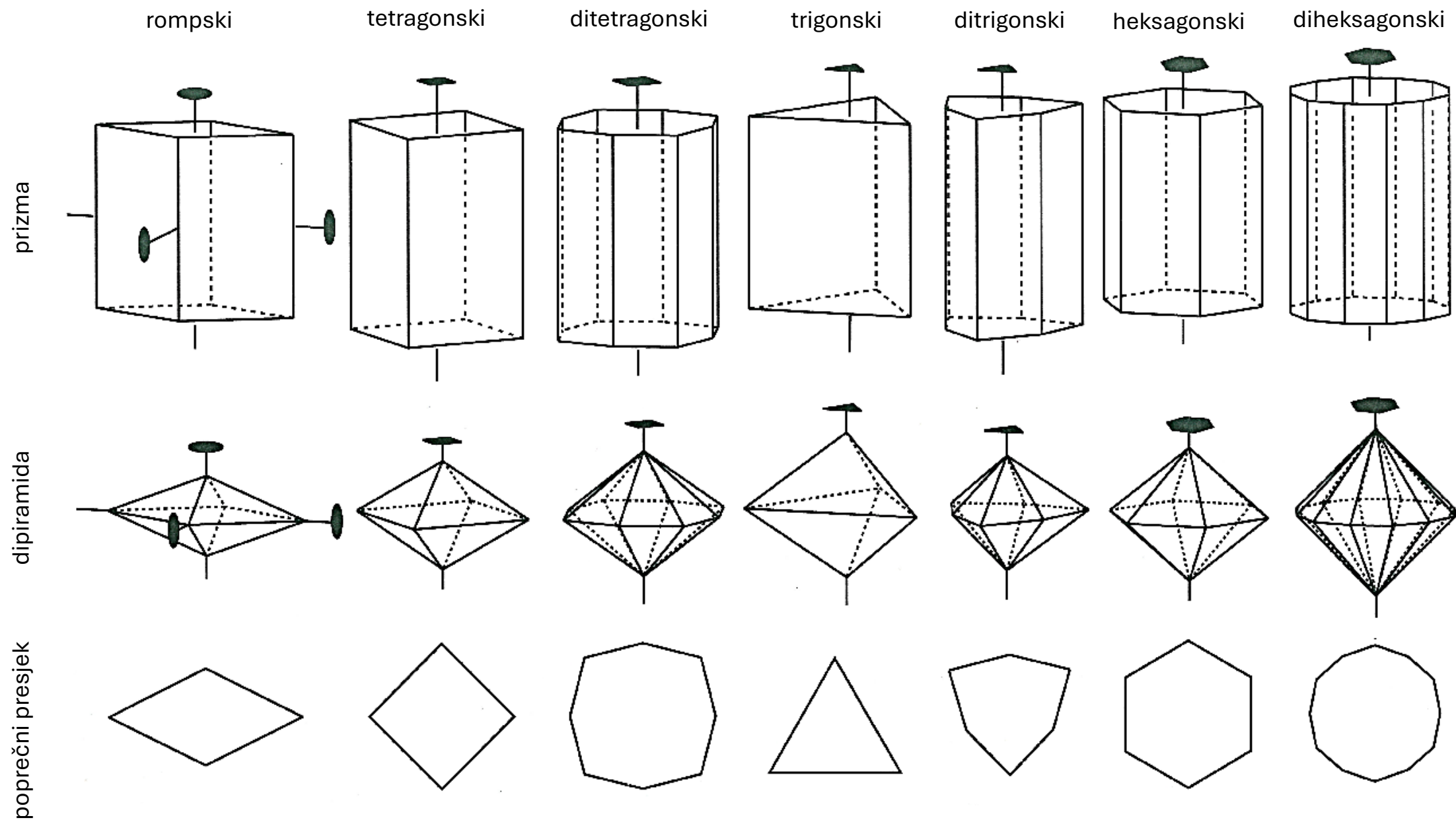
IV. položaj

Forme

DIPIRAMIDA (BIPIRAMIDA) = zatvorena forma od 6 ili više (8, 12, 16 ili 24) ploha koje su pod jednakim kutom *nagnute* u odnosu na neki pravac (=os c)

→ naziv prema **kristalnom sustavu** (presjeku)





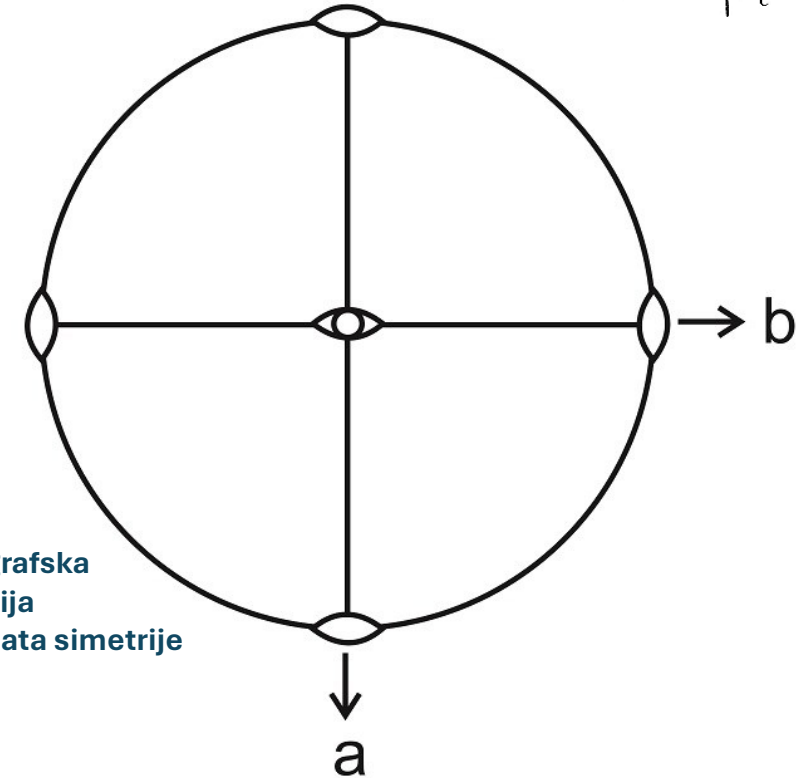
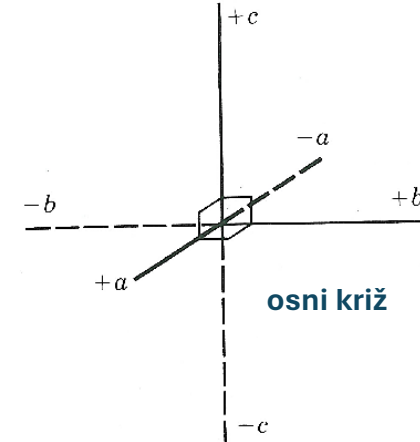
Rompski sustav

Hermann-Mauguin-ov simbol	smjer na koji se odnosi simbol na odgovarajućem mjestu u Hermann-Mauguin-ovom simbolu i broj ekvivalentnih smjerova			Schönflies-ov simbol
	1	2	3	
1) $\frac{2}{m} \frac{2}{m} \frac{2}{m}$	$\langle 100 \rangle$ 1	$\langle 010 \rangle$ 1	$\langle 001 \rangle$ 1	D_{2h}
2) $m m 2$				C_{2v}
3) $2 2 2$	kristalografska os a	kristalografska os b	kristalografska os c	D_2

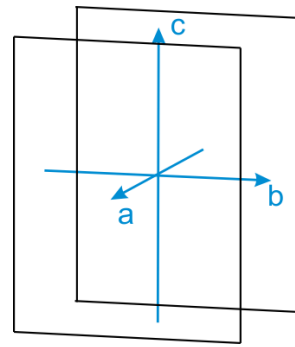
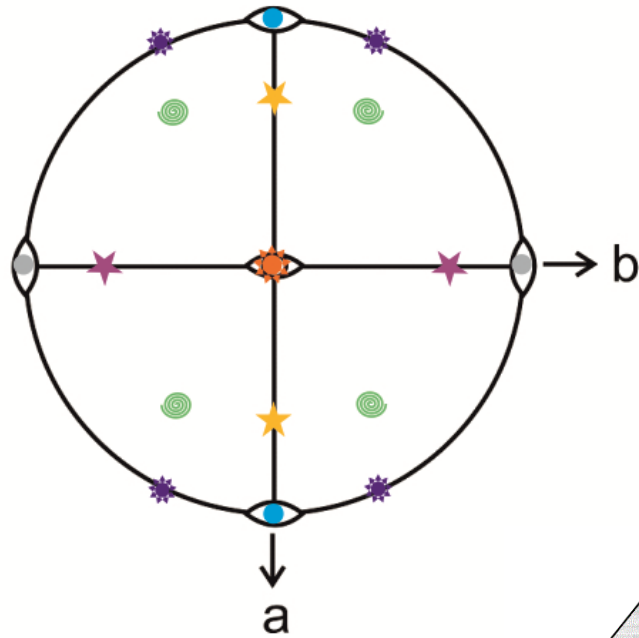
Karakteristike sustava:

$$a \neq b \neq c$$

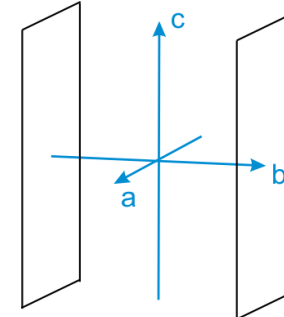
$$\alpha = \beta = \gamma = 90^\circ$$



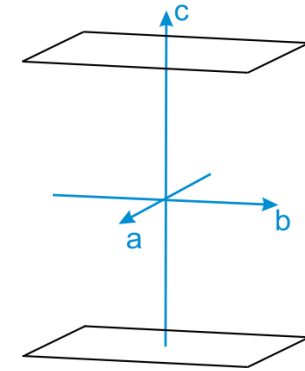
Holoedrija rompskog sustava $\left(\frac{2}{m} \frac{2}{m} \frac{2}{m}\right)$ - forme



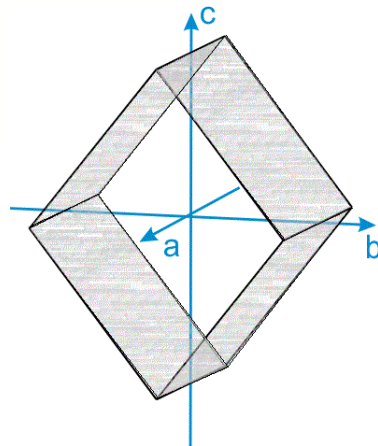
● **prednji pinakoid**
 $\{100\}$
2 plohe



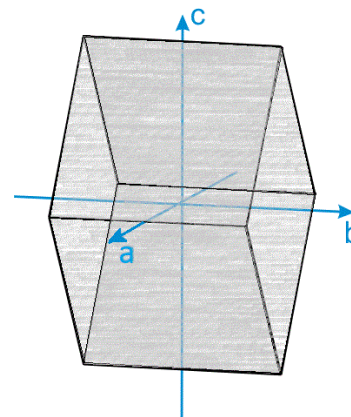
● **bočni pinakoid**
 $\{010\}$
2 plohe



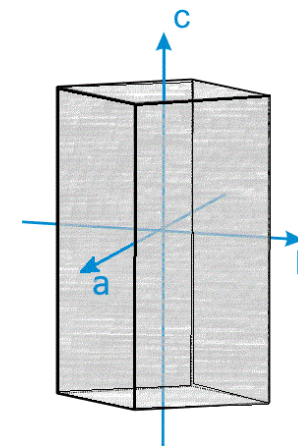
☀ **bazni pinakoid**
 $\{001\}$
2 plohe



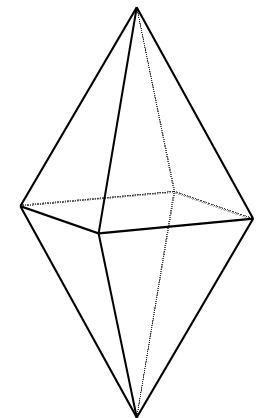
★ **rompska prizma I. položaja**
 $\{0kl\}$ pr. $\{011\}$
4 plohe



★ **rompska prizma II. položaja**
 $\{h0l\}$ pr. $\{101\}$
4 plohe

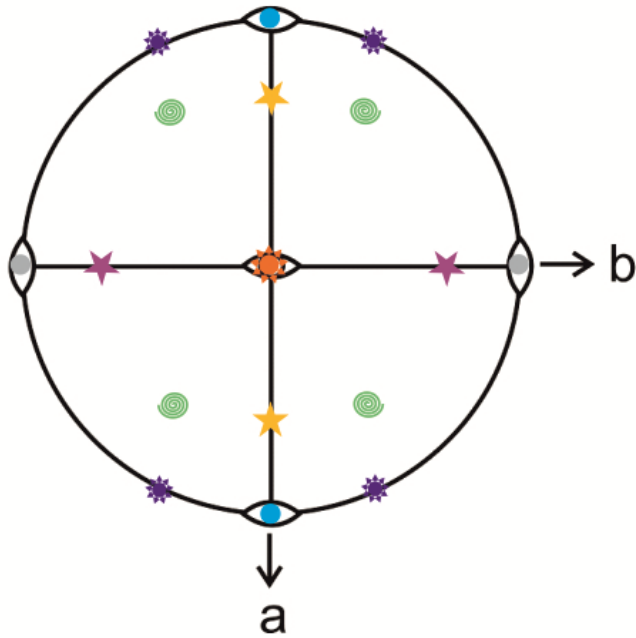


✳ **rompska prizma III. položaja**
 $\{hk0\}$ pr. $\{110\}$
4 plohe



☰ **rompska dipiramida**
 $\{hkl\}$ pr. $\{111\}$
8 ploha

Holoedrija rompskog sustava $\left(\frac{2}{m} \frac{2}{m} \frac{2}{m}\right)$ - forme



- prednji pinakoid, $\{100\}$, 2 plohe
- bočni pinakoid, $\{010\}$, 2 plohe
- ☀ bazni pinakoid, $\{001\}$, 2 plohe
- ★ rompska prizma I. položaja, $\{0kl\}$ pr. $\{011\}$, 4 plohe
- ★ rompska prizma II. položaja, $\{h0l\}$ pr. $\{101\}$, 4 plohe
- ★ rompska prizma III. položaja, $\{hk0\}$ pr. $\{110\}$, 4 plohe
- ⊙ rompska dipiramida, $\{hkl\}$ pr. $\{111\}$, 8 ploha

! 7 mogućih formi unutar svake klase

- 7 različitih položaja u odnosu na kristalografske osi
- 7 različitih tipova Millerovih indeksa

OPĆA FORMA = plohe sijeku sve tri kristalografske osi u različitim udaljenostima

- $\{hkl\}$
- najveći mogući broj ploha u toj klasi
- karakteristična za svaku pojedinu kristalnu klasu



Naziv klase prema općoj formi: **rompska dipiramidska klasa**

Monoklinski sustav

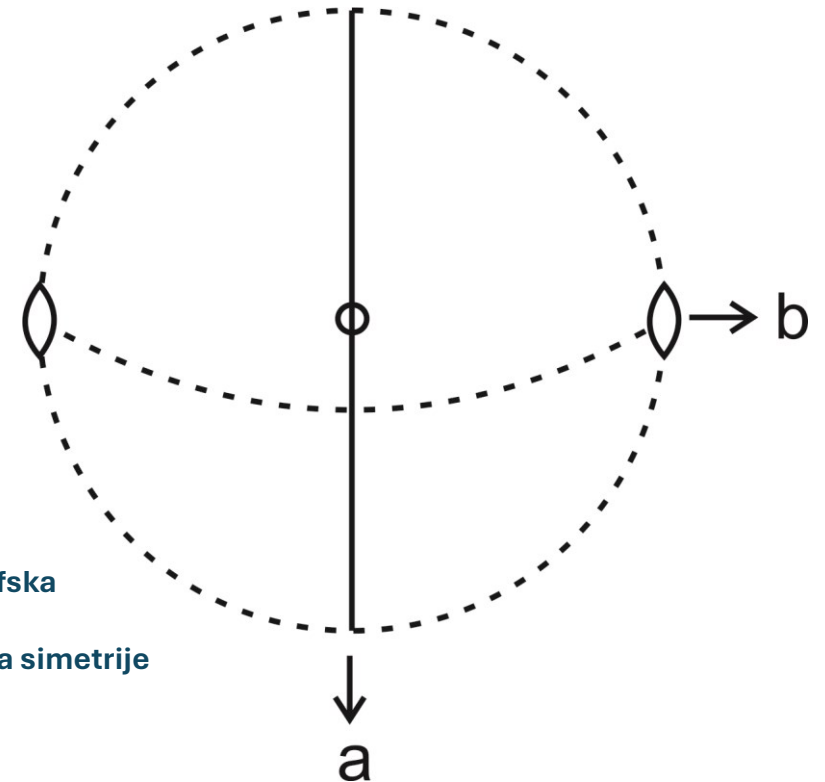
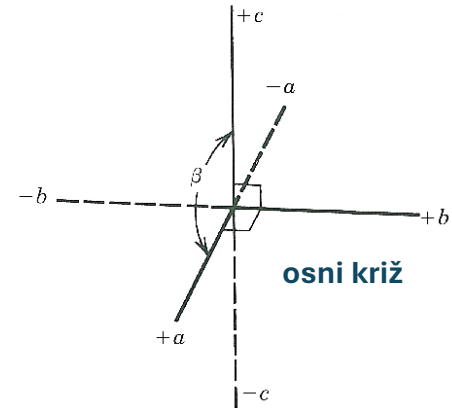
Hermann-Mauguin-ov simbol	smjer na koji se odnosi simbol na odgovarajućem mjestu u Hermann-Mauguin-ovom simbolu i broj ekvivalentnih smjerova			Schönflies-ov simbol
	1	2	3	
1) $\frac{2}{m}$	$\langle 010 \rangle$ 1			C_{2h}
2) m				C_s
3) 2	kristalografska os b			C_2

Karakteristike sustava:

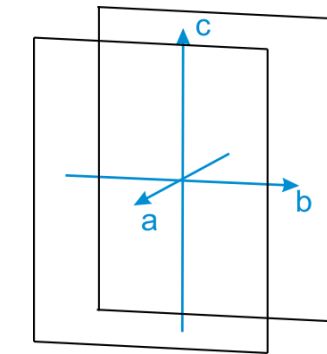
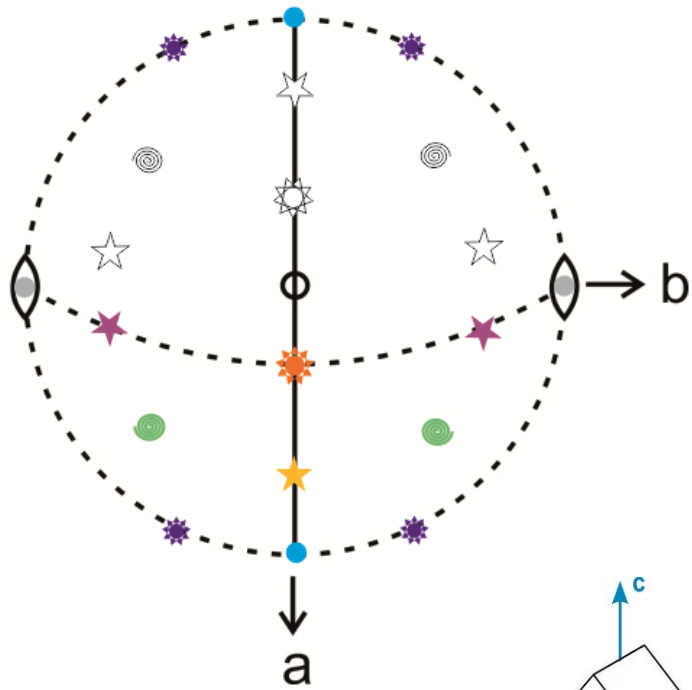
$$a \neq b \neq c$$

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

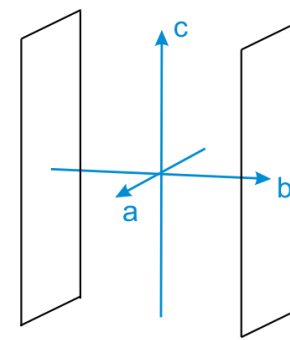
$$\beta > 90^\circ$$



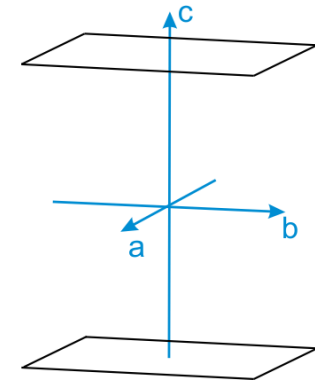
Holoedrija monoklinskog sustava $\left(\frac{2}{m}\right)$ - forme



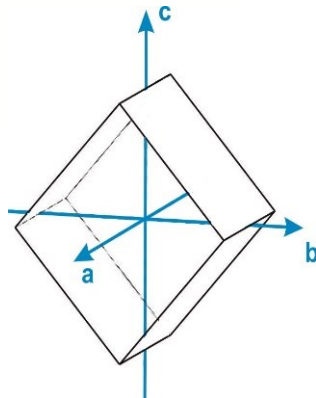
● **prednji pinakoid**
{100}
2 plohe



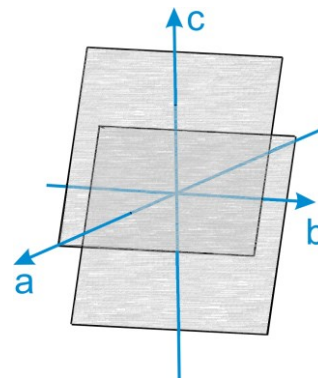
● **bočni pinakoid**
{010}
2 plohe



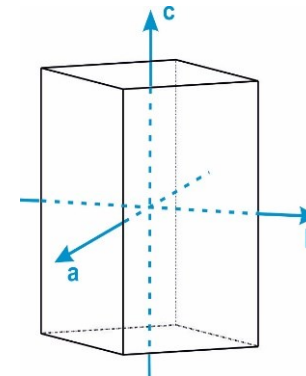
☀ **bazni pinakoid**
{001}
2 plohe



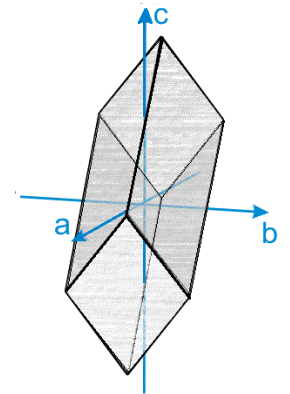
★ **monoklinska prizma I. položaja**
{0kl} pr. {011}
4 plohe



★ **pinakoid II. položaja**
{h0l} pr. {101}
2 plohe



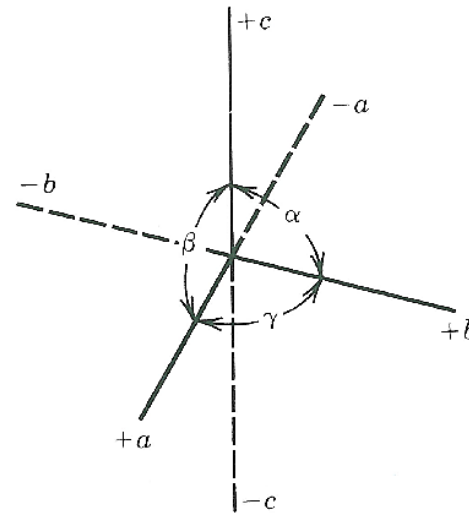
☀ **monoklinska prizma III. položaja**
{hk0} pr. {110}
4 plohe



☀ **monoklinska prizma IV. položaja**
{hkl} pr. {111}
4 plohe

Triklinski sustav

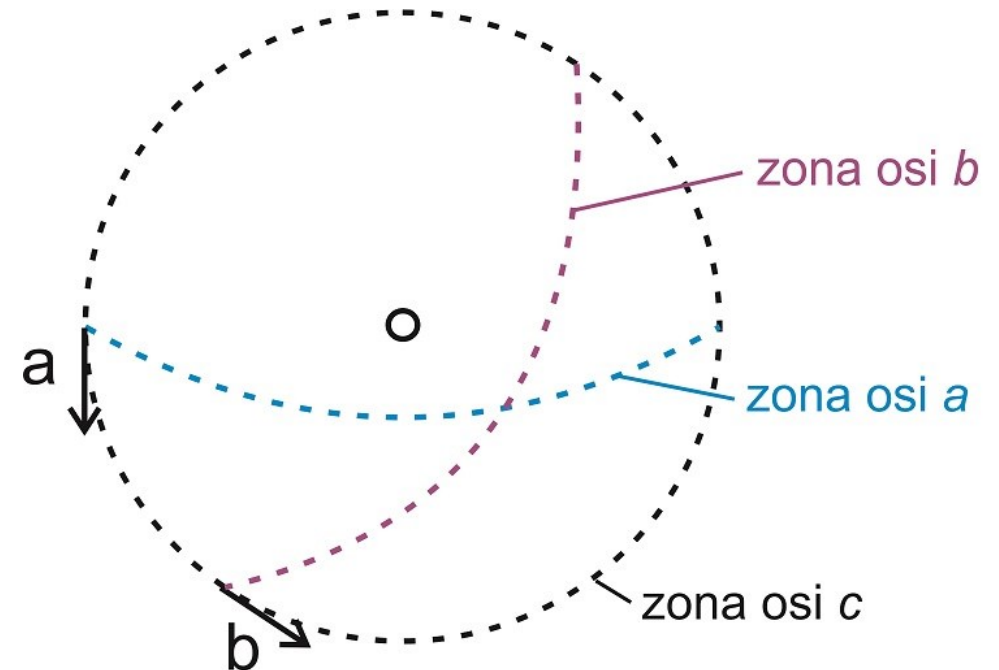
Hermann-Mauguin-ov simbol	smjer na koji se odnosi simbol na odgovarajućem mjestu u Hermann-Mauguin-ovom simbolu i broj ekvivalentnih smjerova			Schönflies-ov simbol
	1	2	3	
1) $\bar{1}$				C_i
2) 1				C_1



Karakteristike sustava:

$$a \neq b \neq c$$

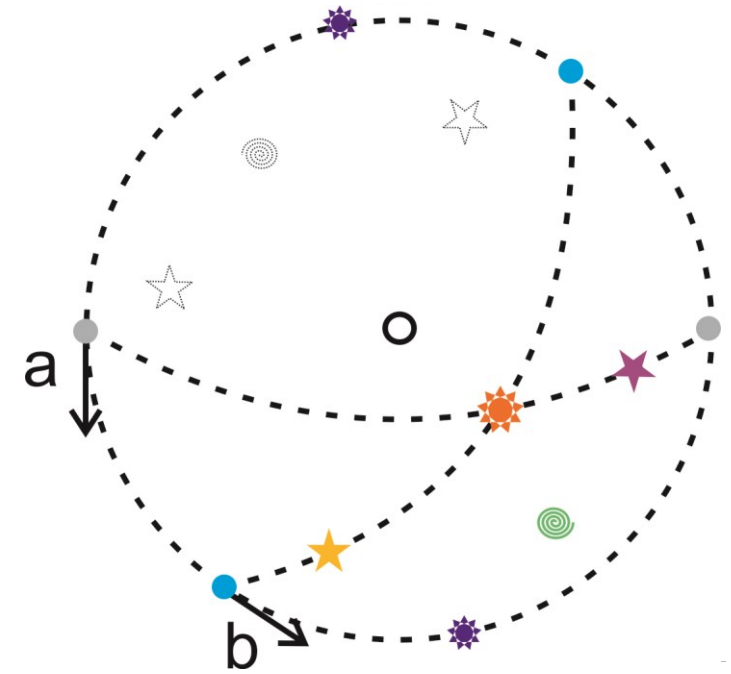
$$\alpha \neq \beta \neq \gamma (\neq 90^\circ)$$



Holoedrija triklinskog sustava ($\bar{1}$) – forme

PINAKOID = otvorena forma od 2 paralelne plohe:

- • **prednji** – plohe sijeku samo os a , $\{100\}$
- • **bočni** – plohe sijeku samo os b , $\{010\}$
- ☀ • **bazni** – plohe sijeku samo os c , $\{001\}$
- ★ • **I. položaj** – plohe ne sijeku os a (paralelan s a); siječe osi b i c , $\{0kl\}$
- ★ • **II. položaj** – plohe ne sijeku os b (paralelan s b); siječe osi a i c , $\{h0l\}$
- ☀ • **III. položaj** – plohe ne sijeku os c (paralelan s c); siječe osi a i b , $\{hk0\}$
- 🌀 • **IV. (opći) položaj** – plohe sijeku sve 3 osi, $\{hkl\}$



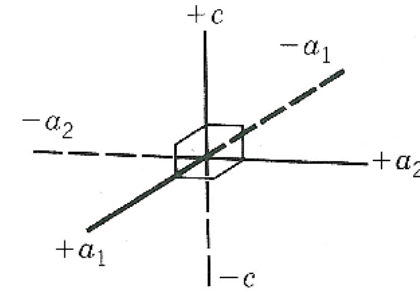
Tetragonski sustav

Hermann-Mauguin-ov simbol	smjer na koji se odnosi simbol na odgovarajućem mjestu u Hermann-Mauguin-ovom simbolu i broj ekvivalentnih smjerova			Schönflies-ov simbol
	1	2	3	
1) $\frac{4}{m} \frac{2}{m} \frac{2}{m}$	$\langle 001 \rangle$ 1	$\langle 100 \rangle$ 2	$\langle 110 \rangle$ 2	D_{4h}
2) $\bar{4} 2 m$				D_{2d}
3) $4 m m$				C_{4v}
4) $\frac{4}{m}$				C_{4h}
5) $4 2 2$				D_4
6) $\bar{4}$				S_4
7) 4	kristalografska os c	kristalografske osi a_1, a_2	simetrane između kristalografskih osi a_1, a_2	C_4

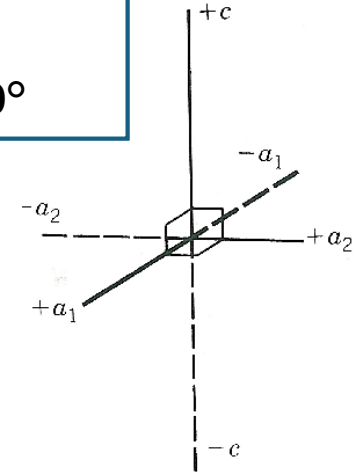
Karakteristike sustava:

$$a_1 = a_2 \neq c$$

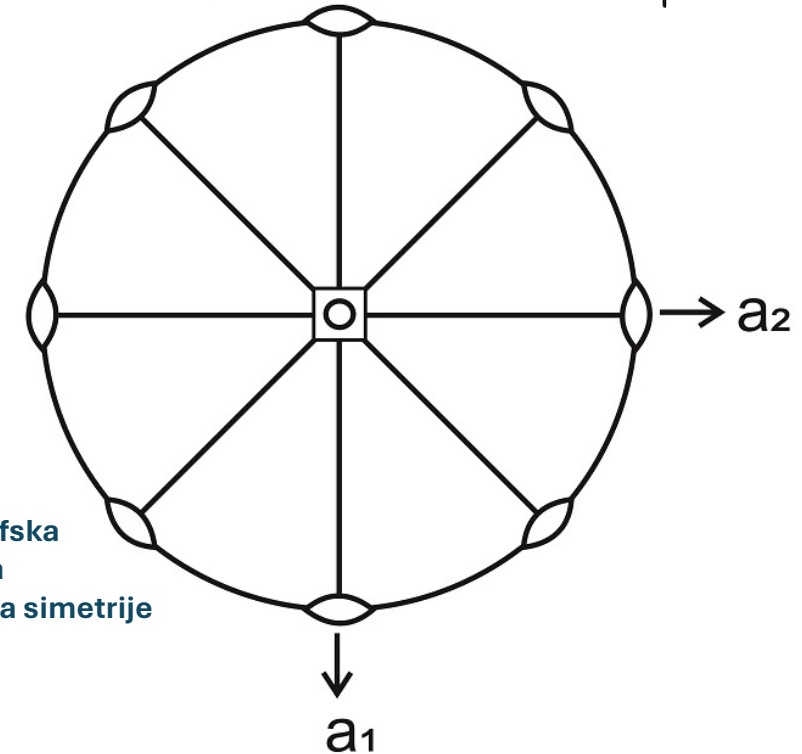
$$\alpha_1 = \alpha_2 = \gamma = 90^\circ$$



osni križ



stereografska projekcija elemenata simetrije



Forme

PRIZMA = otvorena forma od 3 ili više (4, 6, 8, 12) paralelnih plohe koje se sijeku u međusobno paralelnim bridovima, tj. paralelne su s nekim pravcem

→ naziv prema **kristalnom sustavu** (presjeku) i **položaju**

! U **tetragonskom** i **heksagonskom** sustavu:

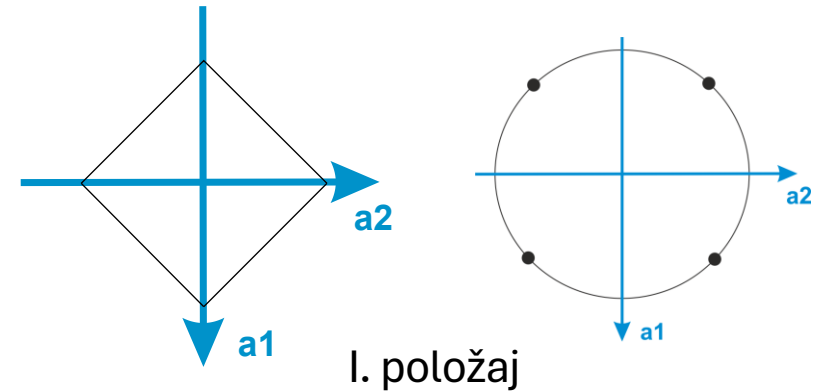
→ uvijek paralelne sa osi **c**!

I. položaj – stereografska projekcija ploha nalazi se na simetralama između osi a_1 i a_2 (i/ili a_3)

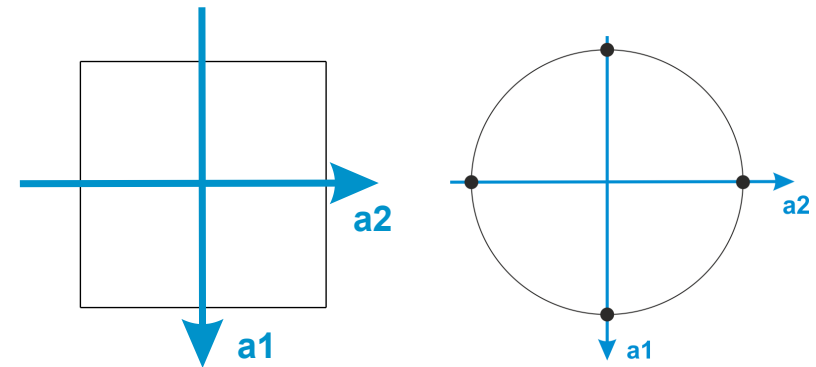
$\{110\}$ tj. $\{2\bar{1}\bar{1}0\}$

II. položaj – stereografska projekcija ploha nalazi se na osima a_1 i a_2 (i a_3)

$\{100\}$ tj. $\{10\bar{1}0\}$



I. položaj



II. položaj

poprečni presjek
prizme

stereografska
projekcija ploha
prizme

Forme

DIPIRAMIDA (BIPIRAMIDA) = zatvorena forma od 6 ili više (8, 12, 16 ili 24) ploha koje su pod jednakim kutom *nagnute* u odnosu na neki pravac

→ naziv prema **kristalnom sustavu** (presjeku) i **položaju**

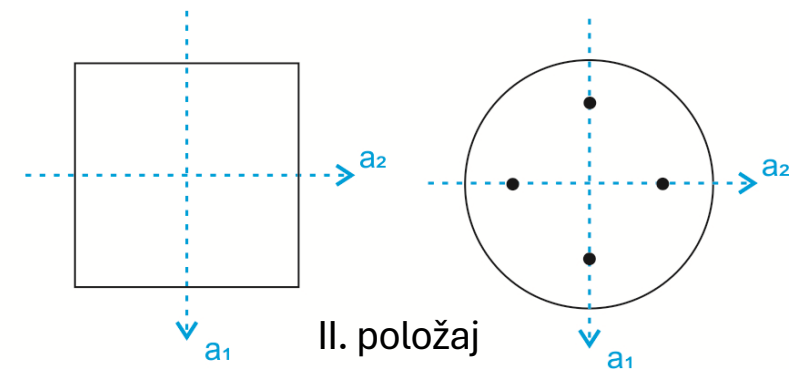
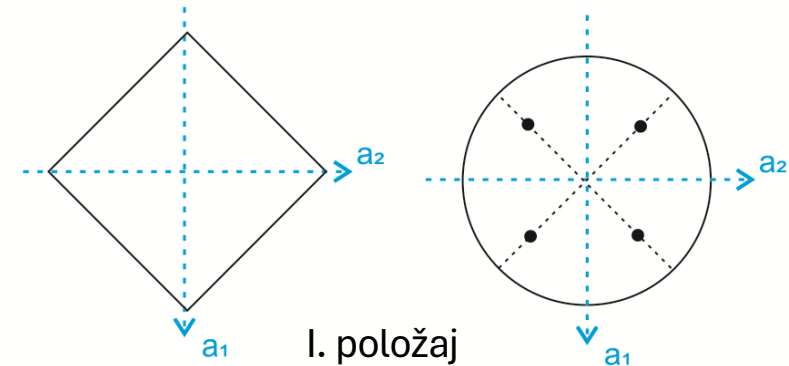
! U **tetragonskom** i **heksagonskom** sustavu:

I. položaj – stereografska projekcija ploha nalazi se na simetralama između osi a_1 i a_2 (i/ili a_3)

$$\{110\} \text{ tj. } \{2\bar{1}\bar{1}0\}$$

II. položaj – stereografska projekcija ploha nalazi se na osima a_1 i a_2 (i a_3)

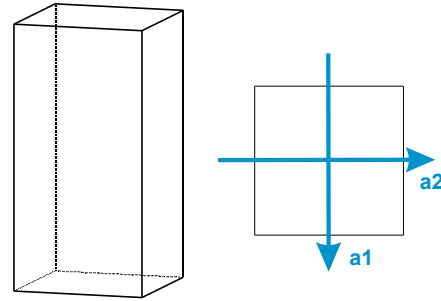
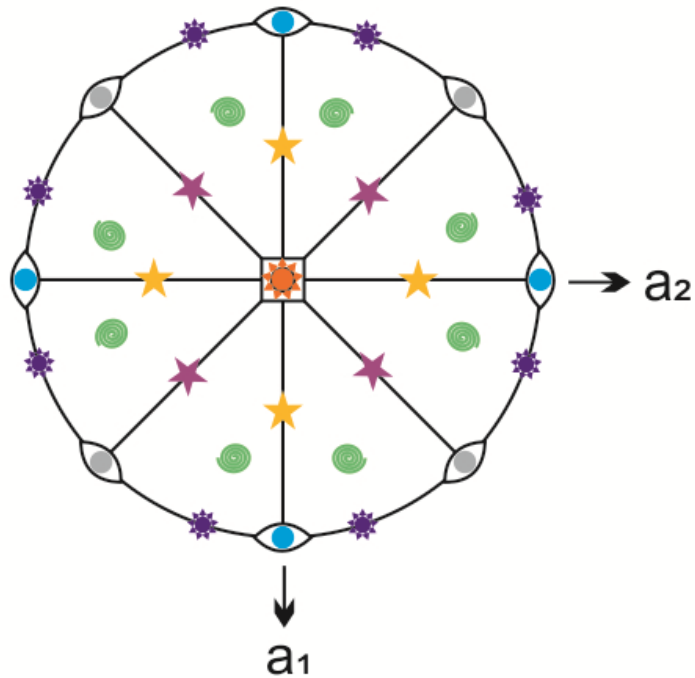
$$\{100\} \text{ tj. } \{10\bar{1}0\}$$



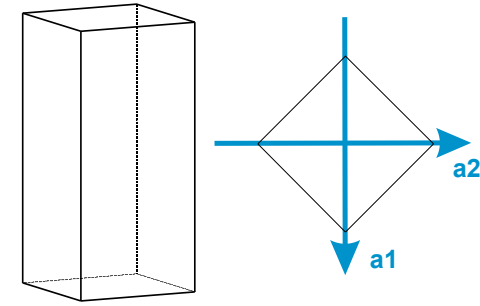
poprečni presjek
dipiramide

stereografska
projekcija ploha
dipiramide

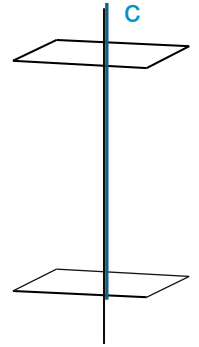
Holoedrija tetragonskog sustava $\left(\frac{4}{m} \frac{2}{m} \frac{2}{m}\right)$ - forme



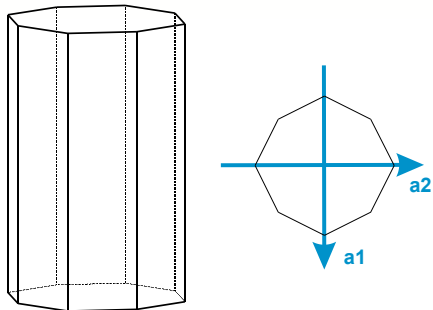
● **tetragonska prizma II. položaja**
 $\{100\}$
 4 plohe



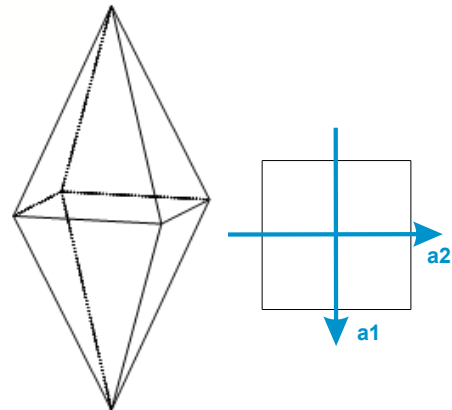
● **tetragonska prizma I. položaja**
 $\{110\}$
 4 plohe



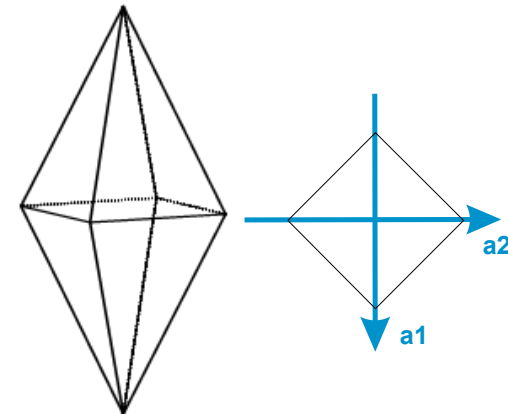
☀ **bazni pinakoid**
 $\{001\}$
 2 plohe



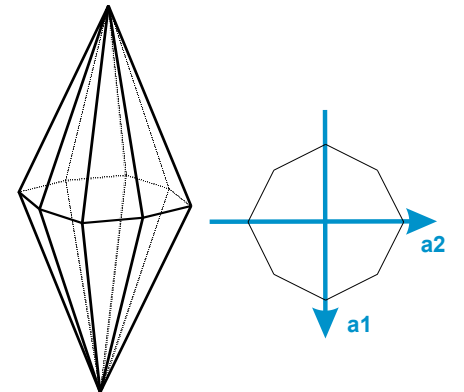
☼ **ditetragonska prizma**
 $\{hk0\}$ pr. $\{210\}$
 8 ploha



★ **tetragonska dipiramida II. položaja**
 $\{h0l\}$ pr. $\{101\}$
 8 ploha



★ **tetragonska dipiramida I. položaja**
 $\{hhl\}$ pr. $\{111\}$
 8 ploha



☼ **ditetragonska dipiramida**
 $\{hkl\}$ pr. $\{211\}$
 16 ploha

Heksagonski sustav (dio I.)

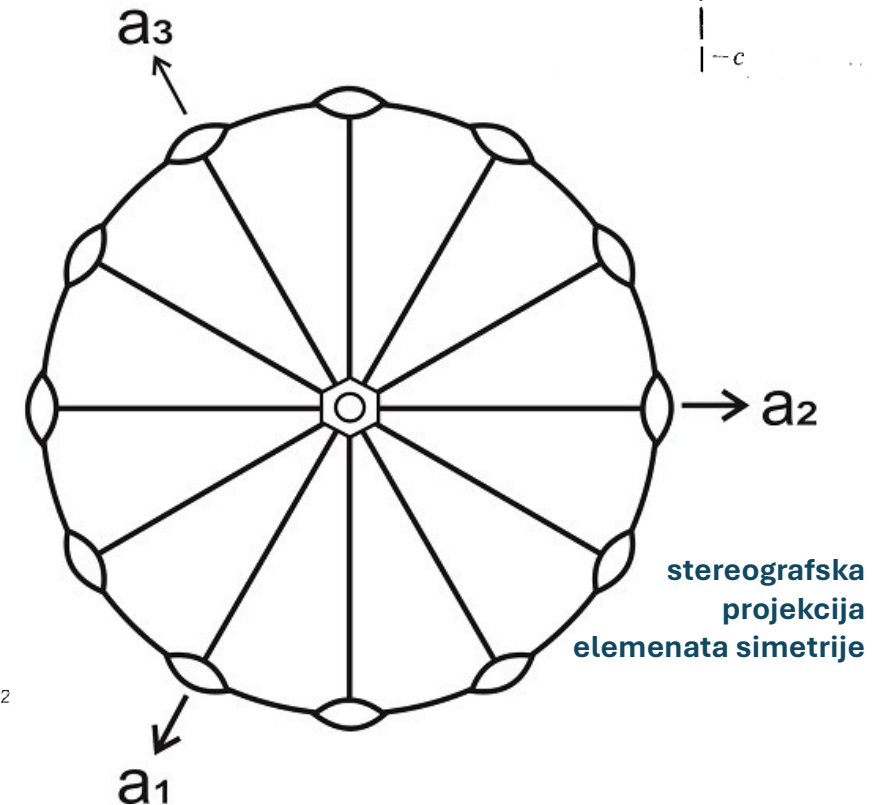
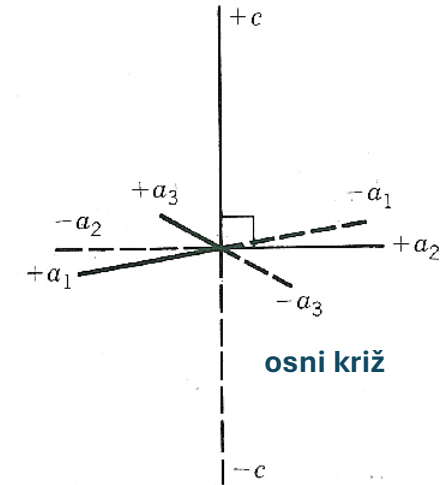
Hermann-Mauguin-ov simbol	smjer na koji se odnosi simbol na odgovarajućem mjestu u Hermann-Mauguin-ovom simbolu i broj ekvivalentnih smjerova			Schönflies-ov simbol
	1	2	3	
1) $\frac{6}{m} \frac{2}{m} \frac{2}{m}$	$\langle 001 \rangle$	$\langle 100 \rangle$	$\langle 210 \rangle$	D_{6h}
2) $\bar{6} m 2$	1	3	3	D_{3h}
3) $6 m m$				C_{6v}
4) $6 2 2$				D_6
5) $\frac{6}{m}$				C_{6h}
6) $\bar{6}$				C_{3h}
7) 6	kristalografska os c	kristalografske osi a_1, a_2, a_3	simetrane između kristalografskih osi a_1, a_2, a_3	C_6

Karakteristike sustava:

$$a_1 = a_2 = a_3 \neq c$$

$$\alpha_1 = \alpha_2 = \alpha_3 = 120^\circ$$

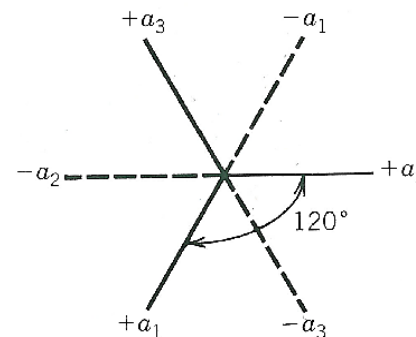
$$\delta = 90^\circ$$



Bravais-Millerovi indeksi {hkil}

$$h+k+i=0$$

*ponekad se piše samo (hkl) ili (hk.l)



Forme

PRIZMA = otvorena forma od 3 ili više (4, 6, 8, 12) paralelnih plohe koje se sijeku u međusobno paralelnim bridovima, tj. paralelne su s nekim pravcem

→ naziv prema **kristalnom sustavu** (presjeku) i **položaju**

! U tetragonskom i heksagonskom sustavu:

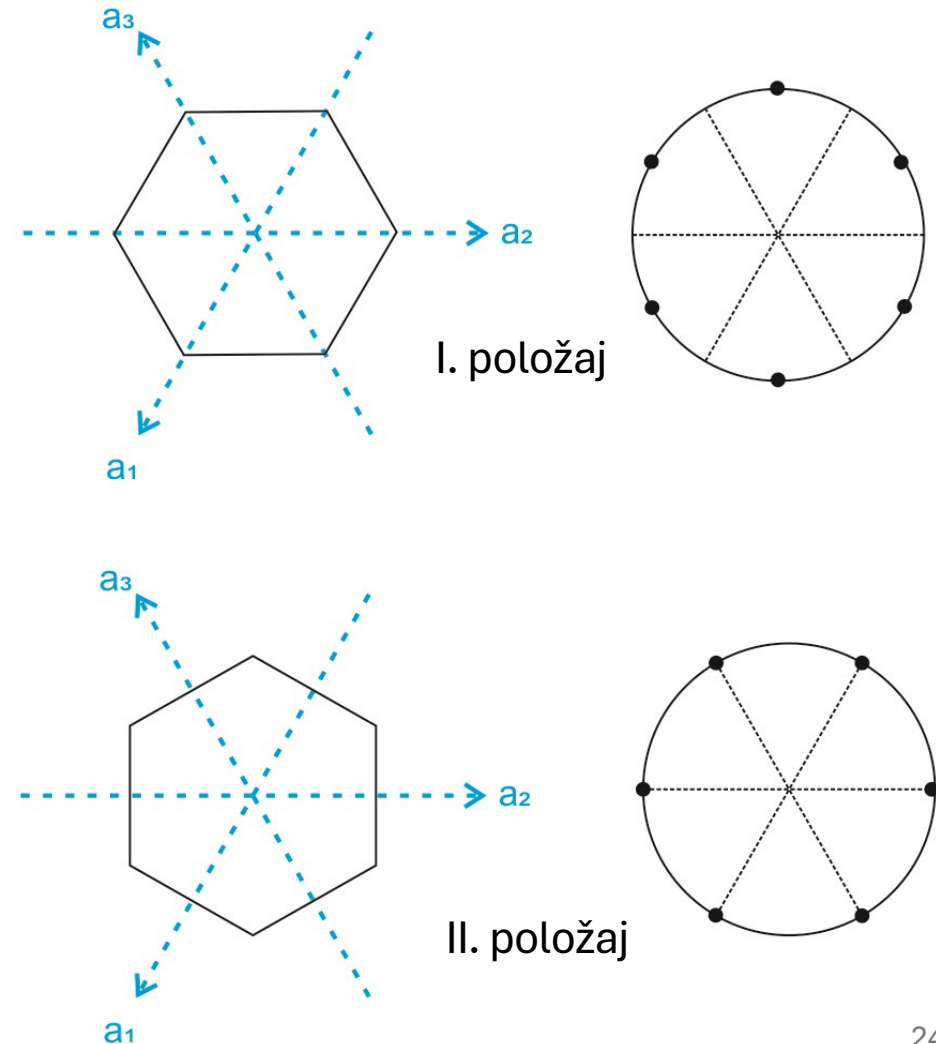
→ **uvijek paralelne sa osi c!**

I. položaj – stereografska projekcija ploha nalazi se na simetralama između osi a_1 i a_2 (i/ili a_3)

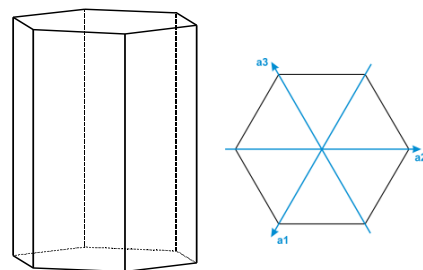
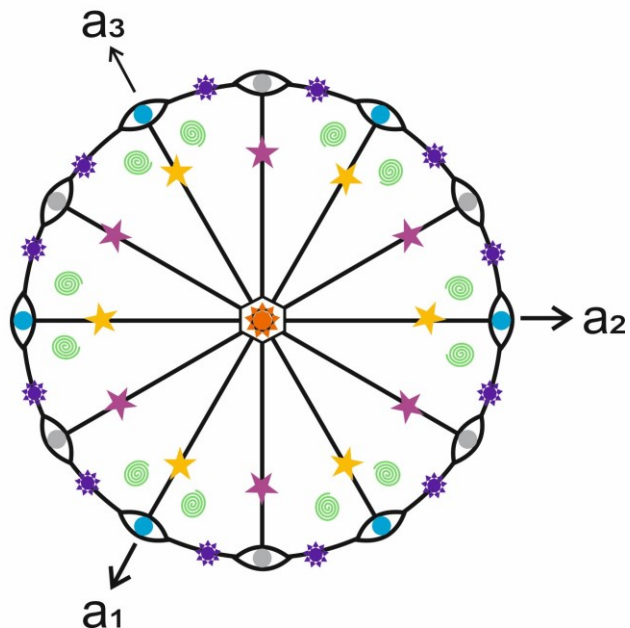
$$\{110\} \text{ tj. } \{2\bar{1}\bar{1}0\}$$

II. položaj – stereografska projekcija ploha nalazi se na osima a_1 i a_2 (i a_3)

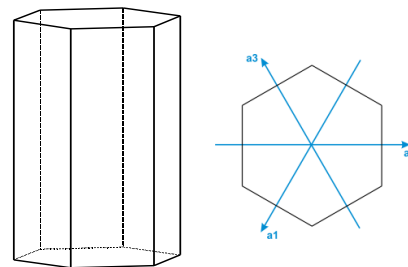
$$\{100\} \text{ tj. } \{10\bar{1}0\}$$



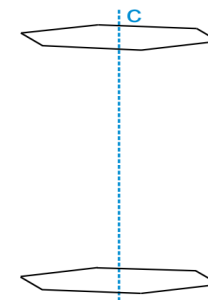
Holoedrija heksagonskog sustava $\left(\frac{6}{m} \frac{2}{m} \frac{2}{m}\right)$ - forme



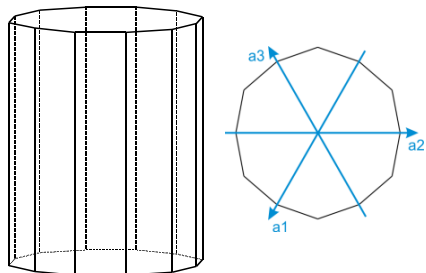
● **heksagonska prizma
I. položaja**
 $\{10\bar{1}0\}$
6 ploha



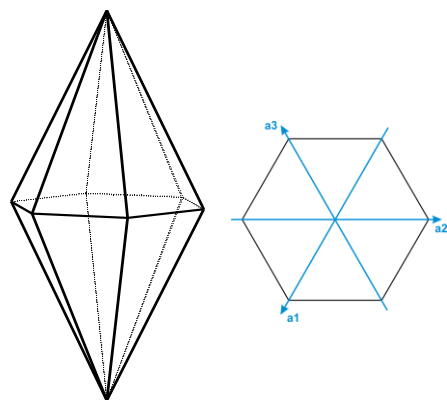
● **heksagonska prizma
II. položaja**
 $\{11\bar{2}0\}$
6 ploha



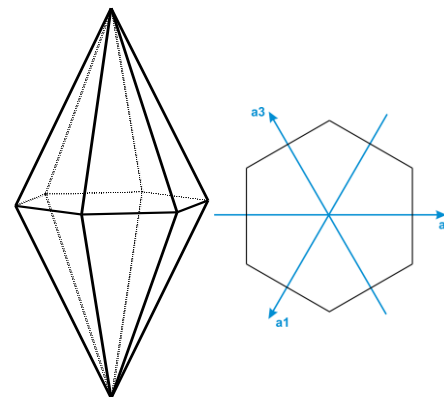
☀ **bazni pinakoid**
 $\{0001\}$
2 plohe



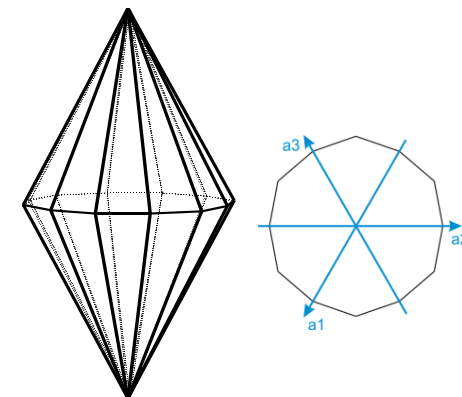
⚙ **diheksagonska prizma**
 $\{hki0\}$, pr. $\{21\bar{3}0\}$
12 ploha



★ **heksagonska dipiramida
I. položaja**
 $\{h0\bar{h}l\}$ pr. $\{10\bar{1}1\}$
12 ploha



★ **heksagonska dipiramida
II. položaja**
 $\{hh\bar{2}hl\}$ pr. $\{11\bar{2}1\}$
12 ploha



⊙ **diheksagonska
dipiramida**
 $\{hk\bar{l}l\}$ pr. $\{21\bar{3}1\}$
24 plohe

Heksagonski sustav (dio II.)

Hermann-Mauguin-ov simbol	smjer na koji se odnosi simbol na odgovarajućem mjestu u Hermann-Mauguin-ovom simbolu i broj ekvivalentnih smjerova			Schönflies-ov simbol
	1	2	3	
1) $\bar{3} \frac{2}{m}$	$\langle 001 \rangle$	$\langle 100 \rangle$	$\langle 210 \rangle$	D_{3d}
2) $3m$	1	3	3	C_{3v}
3) 32				D_3
4) $\bar{3}$				C_{3i}
5) 3	kristalografska os c	kristalografske osi a_1, a_2, a_3	simetrane između kristalografskih osi a_1, a_2, a_3	C_3

Bravais-Millerovi indeksi $\{hkil\}$

$$h+k+i=0$$

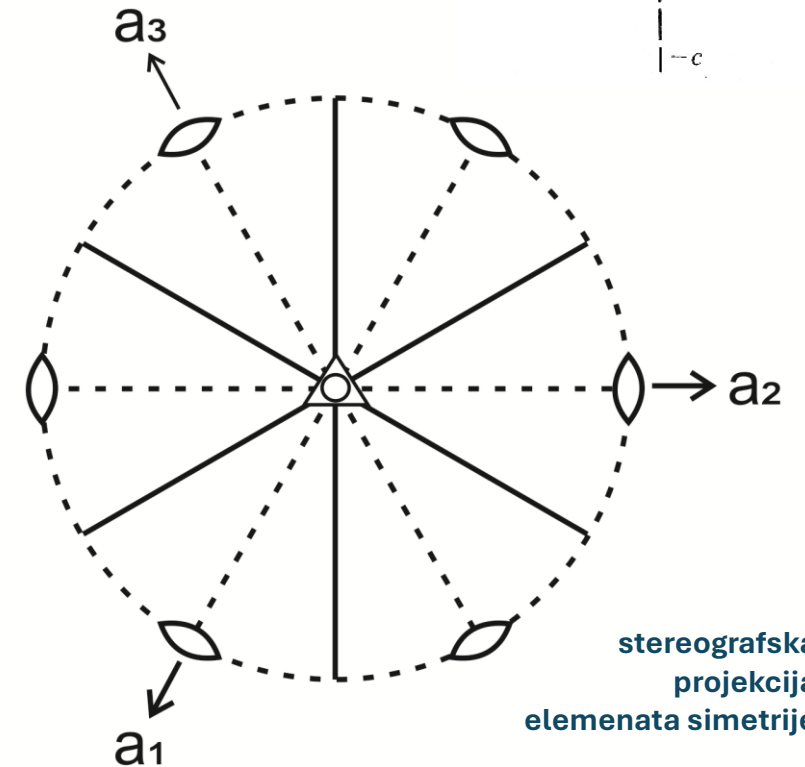
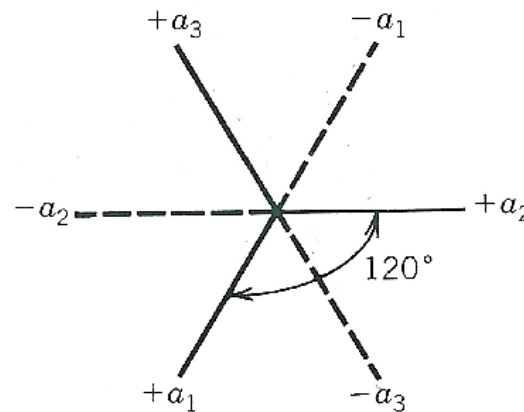
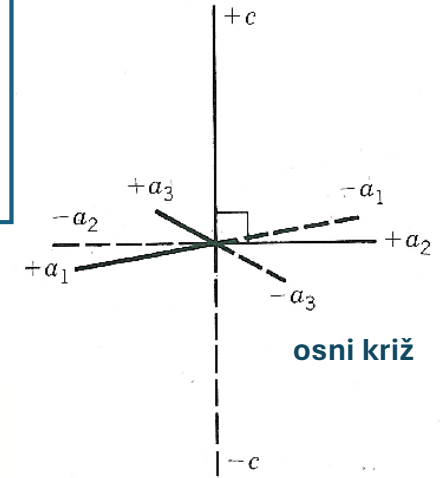
*ponekad se piše samo $\{hkl\}$ ili $\{hk.l\}$

Karakteristike sustava:

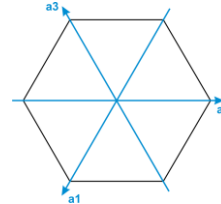
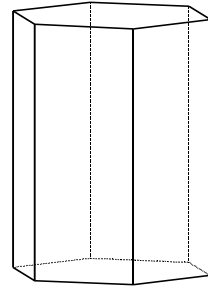
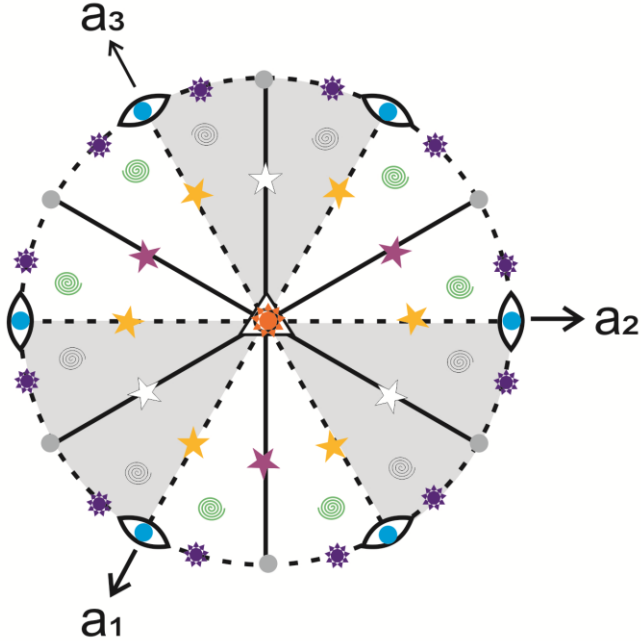
$$a_1 = a_2 = a_3 \neq c$$

$$\alpha_1 = \alpha_2 = \alpha_3 = 120^\circ$$

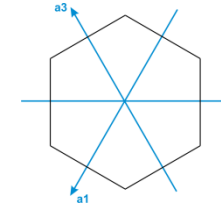
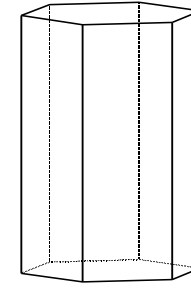
$$\delta = 90^\circ$$



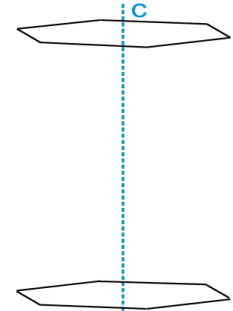
Romboedrijska hemiedrija heksagonskog sustava $\left(\bar{3} \frac{2}{m}\right)$ - forme



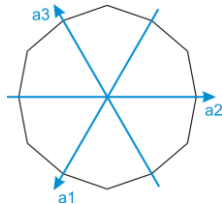
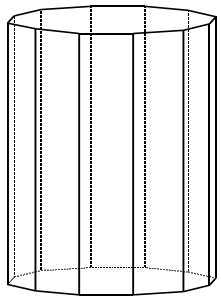
● **heksagonska prizma
I. položaja**
 $\{10\bar{1}0\}$
6 ploha



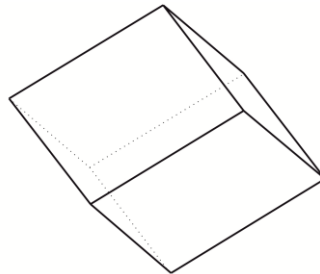
● **heksagonska prizma
II. položaja**
 $\{11\bar{2}0\}$
6 ploha



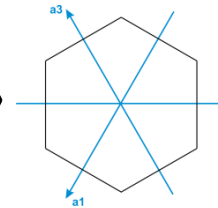
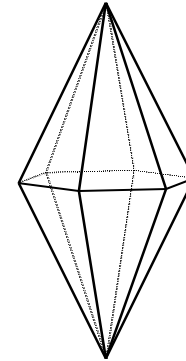
★ **bazni pinakoid**
 $\{0001\}$
2 plohe



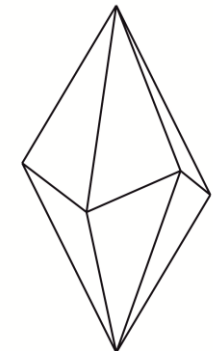
★ **diheksagonska prizma**
 $\{hki0\}$, pr. $\{21\bar{3}0\}$
12 ploha



★ **romboedar (+)**
 $\{h0\bar{h}l\}$ pr. $\{10\bar{1}1\}$
6 ploha



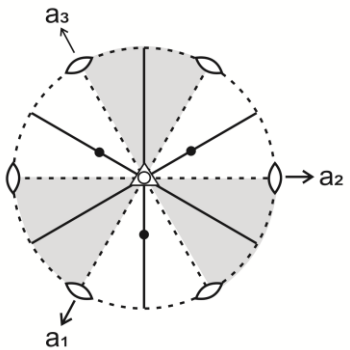
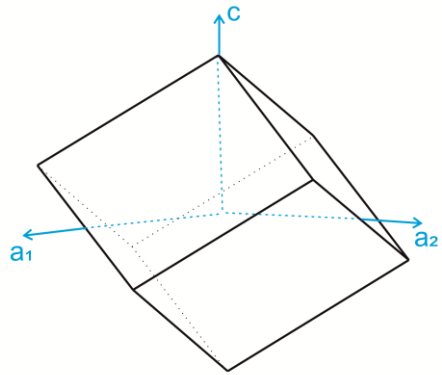
★ **heksagonska dipiramida
II. položaja**
 $\{hh\bar{2}hl\}$ pr. $\{11\bar{2}1\}$
12 ploha



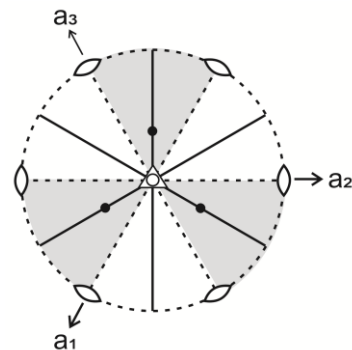
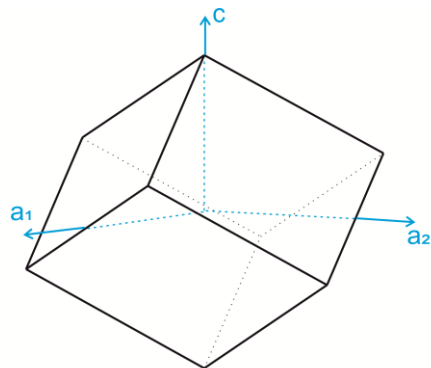
★ **ditrigonski skalenoedar (+)**
 $\{hkil\}$ pr. $\{21\bar{3}1\}$
12 ploha

Romboedrijska hemiedrija heksagonskog sustava ($\bar{3} \frac{2}{m}$)

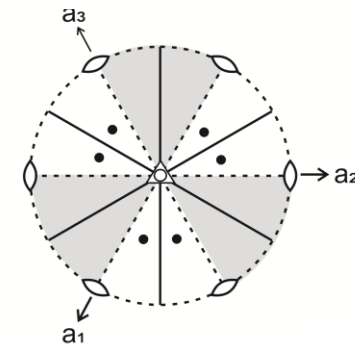
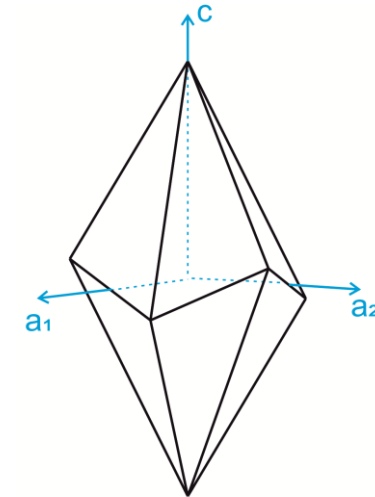
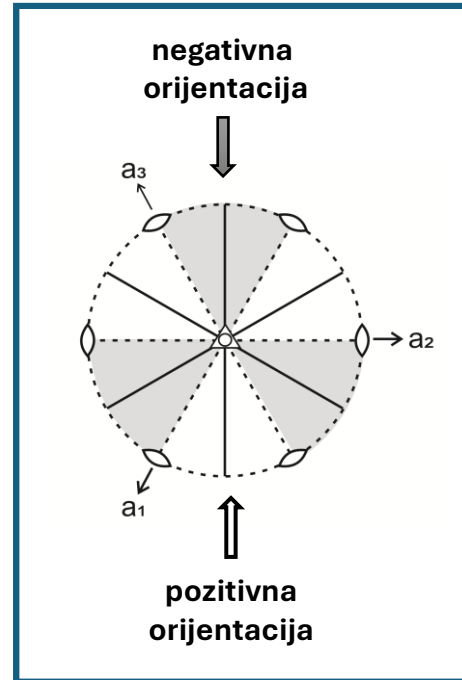
- pozitivne (+) i negativne (-) orijentacije formi



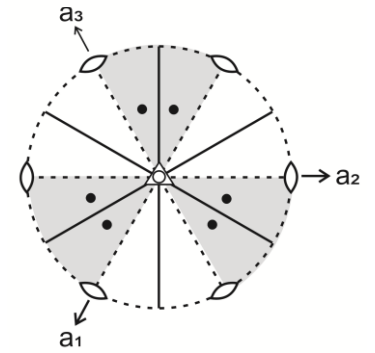
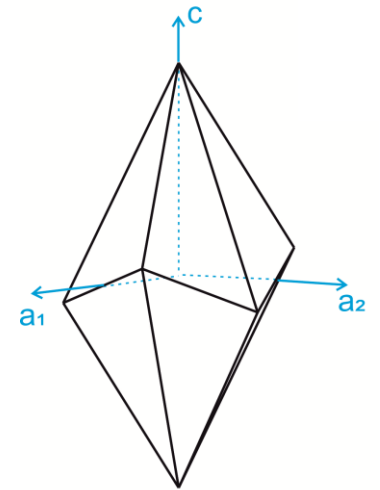
romboedar (+)
 $\{h0\bar{h}l\}$ pr. $\{10\bar{1}1\}$
6 ploha



romboedar (-)
 $\{0h\bar{h}l\}$ pr. $\{01\bar{1}1\}$
6 ploha



**ditrigonski
sklenoedar (+)**
 $\{hkil\}$ pr. $\{21\bar{3}1\}$
12 ploha



**ditrigonski
sklenoedar (-)**
 $\{hkil\}$ pr. $\{12\bar{3}1\}$
12 ploha

Heksagonski sustav - forme

	6/m 2/m 2/m		$\bar{3}$ 2/m	
	Ime forme	Indeks forme	Ime forme	Indeks forme
1	Bazni pinakoid	{0001}	Bazni pinakoid	{0001}
2	Heksagonska prizma I. položaja	{10 $\bar{1}$ 0}	Heksagonska prizma I. položaja	{10 $\bar{1}$ 0}
3	Heksagonska prizma II. položaja	{11 $\bar{2}$ 0}	Heksagonska prizma II. položaja	{11 $\bar{2}$ 0}
4	Diheksagonska prizma	{hki0}	Diheksagonska prizma	{hki0}
5	Heksagonska dipiramida I. položaja	{h0 $\bar{h}$ l}	Romboedar +/-	{h0 $\bar{h}$ l} {0h $\bar{h}$ l}
6	Heksagonska dipiramida II. položaja	{hh $\bar{2}$ h}l}	Heksagonska dipiramida II. položaja	{hh $\bar{2}$ h}l}
7	Diheksagonska dipiramida	{hkil}	Ditrigonski skalenoedar +/-	{hkil}

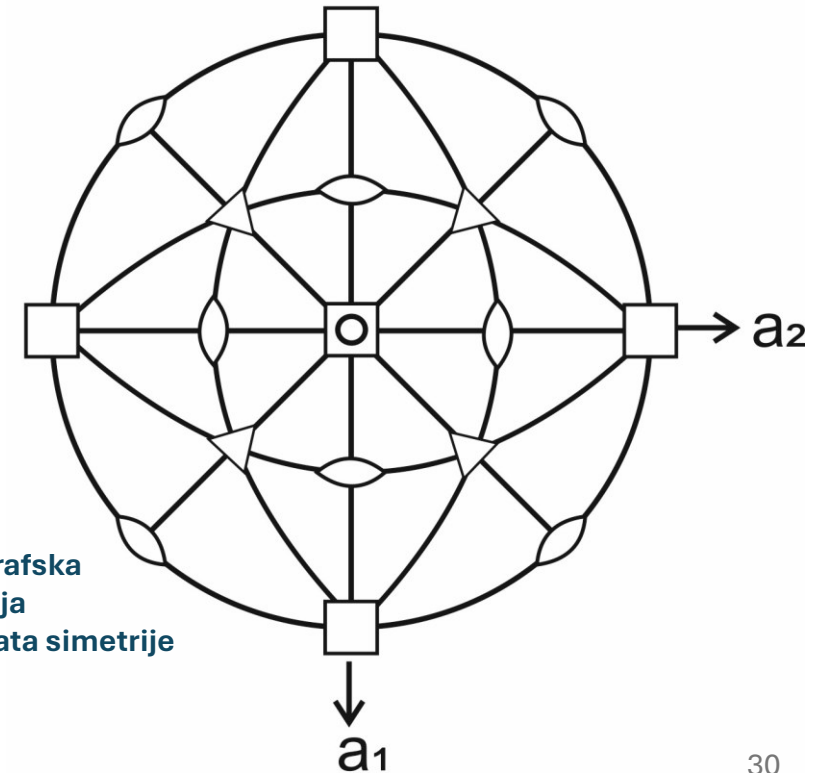
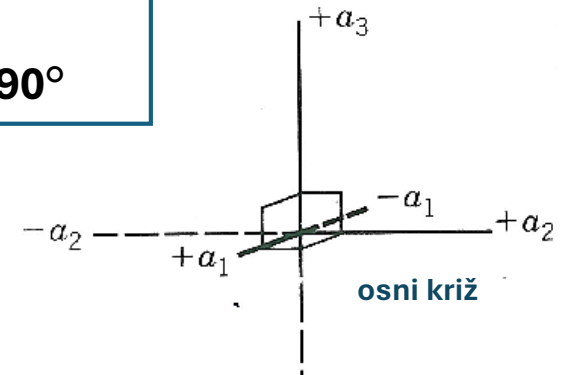
Kubični sustav

Hermann-Mauguin-ov simbol	smjer na koji se odnosi simbol na odgovarajućem mjestu u Hermann-Mauguin-ovom simbolu i broj ekvivalentnih smjerova			Schönflies-ov simbol
	1	2	3	
1) $\frac{4}{m} \bar{3} \frac{2}{m}$	$\langle 100 \rangle$	$\langle 111 \rangle$	$\langle 110 \rangle$	O_h
2) $\bar{4}3m$	3	4	6	T_d
3) 432				O
4) $\frac{2}{m} \bar{3}$				T_h
5) 23	kristalografske osi a_1, a_2, a_3	smjerovi prostornih dijagonala	simetrane između kristalografskih osi a_1, a_2, a_3	T

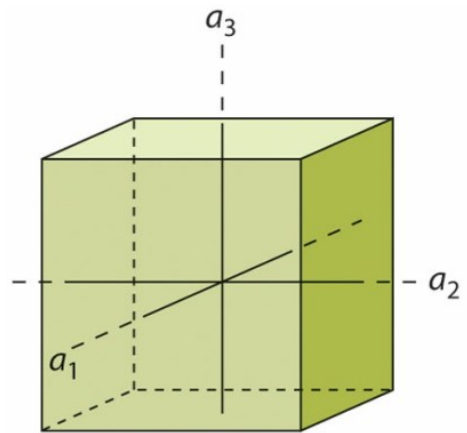
Karakteristike sustava:

$$a_1 = a_2 = a_3$$

$$\alpha_1 = \alpha_2 = \alpha_3 = 90^\circ$$

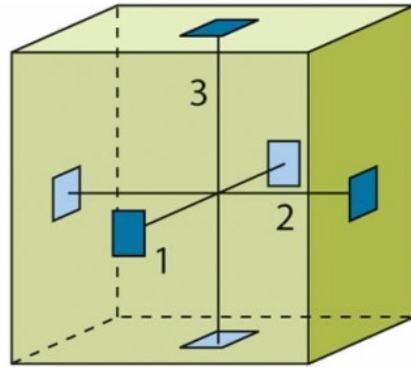


Holoedrija kubičnog sustava $\left(\frac{4}{m} \bar{3} \frac{2}{m}\right)$



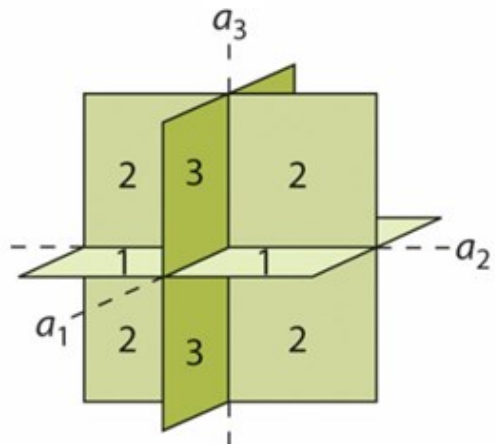
kristalografske osi

$4/m$



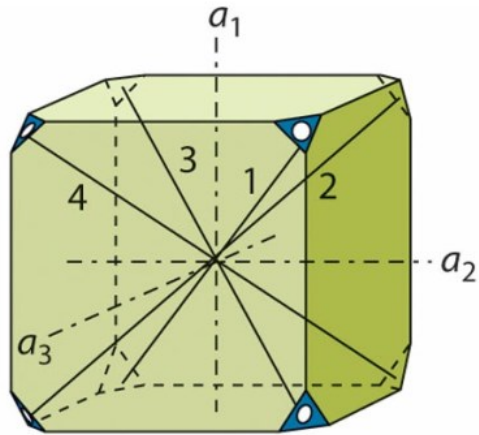
3 tetragire

+



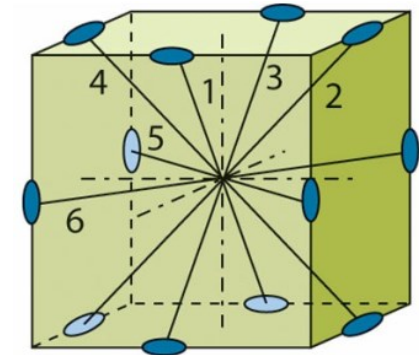
3 glavne ravnine
simetrije

$\bar{3}$



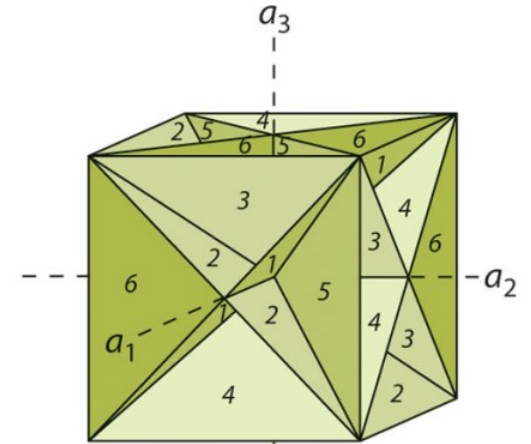
4 trigire

$2/m$



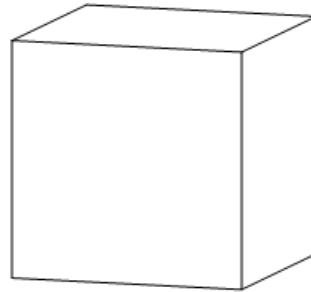
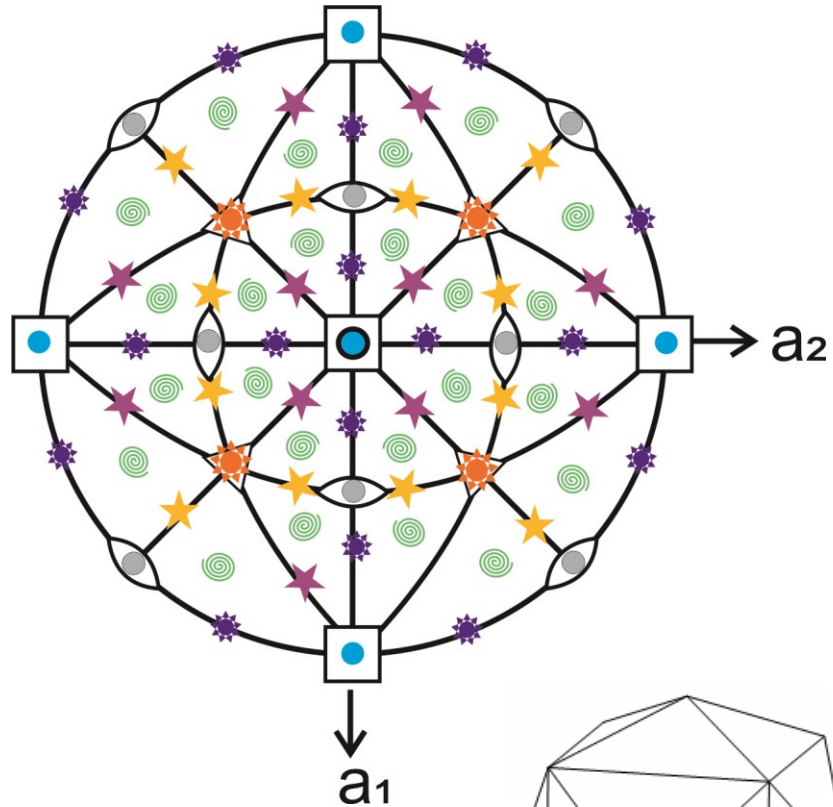
6 digira

+

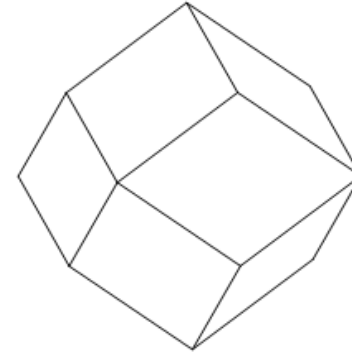


6 sporednih ravnina
simetrije

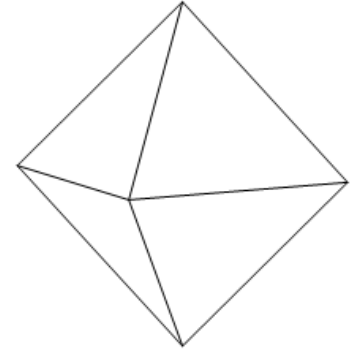
Holoedrija kubičnog sustava $\left(\frac{4}{m} \bar{3} \frac{2}{m}\right)$ - forme



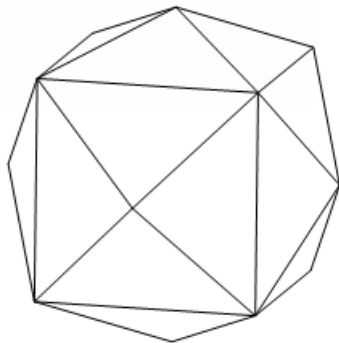
● **heksaedar**
{100}
6 ploha



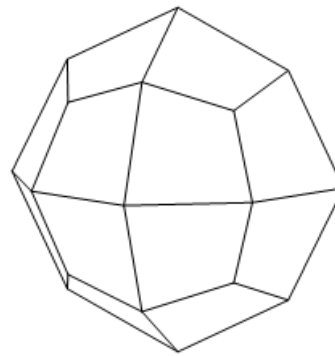
● **rompski dodekaedar**
{110}
12 ploha



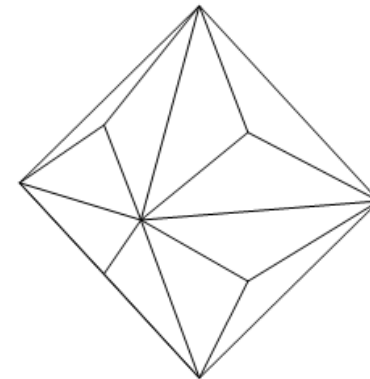
● **oktaedar**
{111}
8 ploha



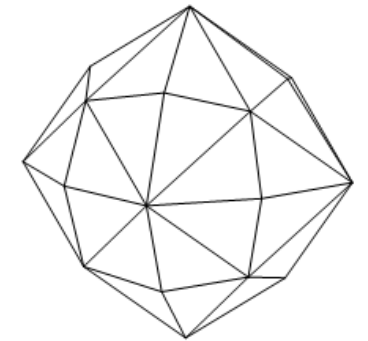
● **tetrakisheksaedar**
{hk0} pr. {210}
24 plohe



● **deltoidski ikozitetraedar**
{hll}, h>l pr. {211}
24 plohe



● **trisoktaedar**
{hhl}, h>l pr. {221}
24 plohe



● **heksakisoktaedar**
{hkl} pr. {321}
48 ploha

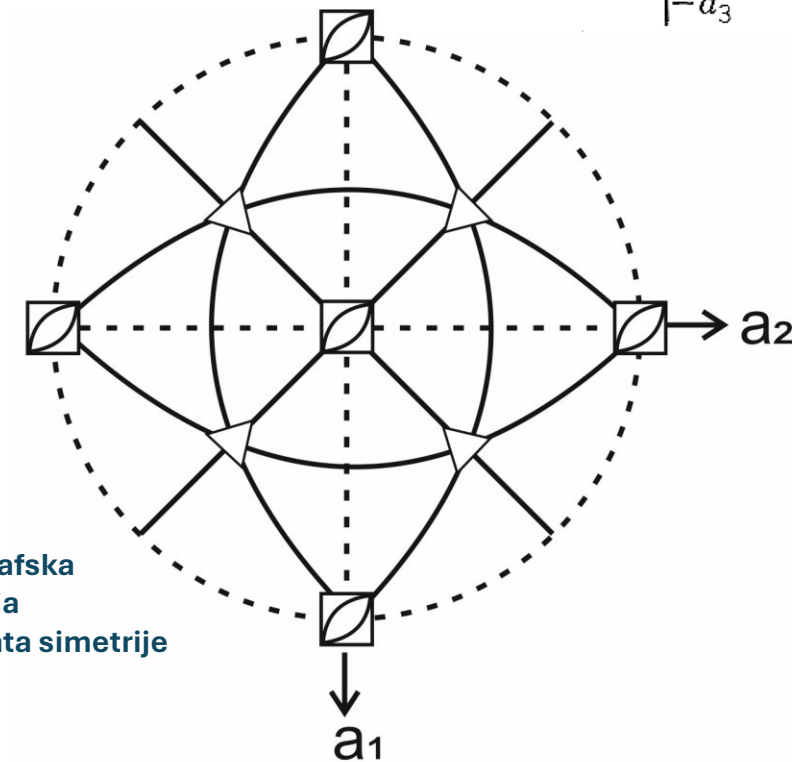
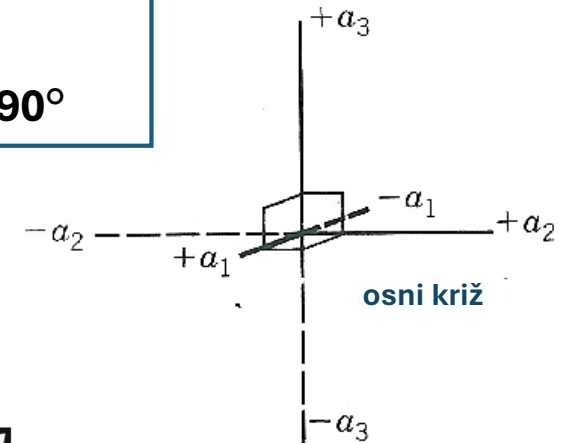
Kubični sustav

Hermann-Mauguin-ov simbol	smjer na koji se odnosi simbol na odgovarajućem mjestu u Hermann-Mauguin-ovom simbolu i broj ekvivalentnih smjerova			Schönflies-ov simbol
	1	2	3	
1) $\frac{4}{m} \bar{3} \frac{2}{m}$	$\langle 100 \rangle$	$\langle 111 \rangle$	$\langle 110 \rangle$	O_h
2) $\bar{4}3m$	3	4	6	T_d
3) 432				O
4) $\frac{2}{m} \bar{3}$				T_h
5) 23	kristalografske osi a_1, a_2, a_3	smjerovi prostornih dijagonala	simetrane između kristalografskih osi a_1, a_2, a_3	T

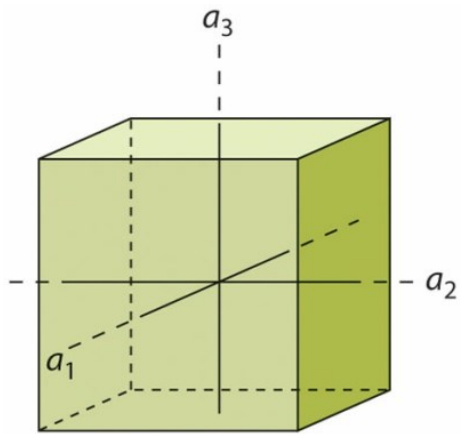
Karakteristike sustava:

$$a_1 = a_2 = a_3$$

$$\alpha_1 = \alpha_2 = \alpha_3 = 90^\circ$$

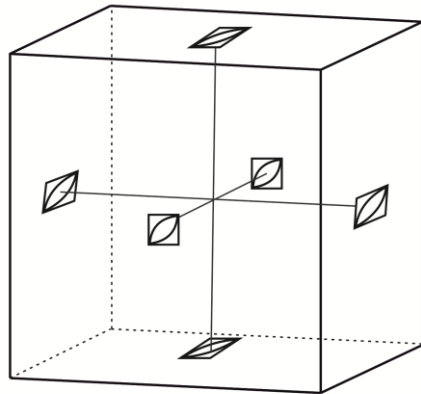


Tetraedarska hemiedrija kubičnog sustava ($\bar{4} 3 m$)



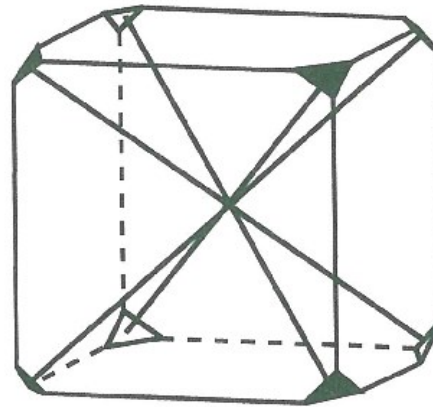
kristalografske osi

$\bar{4}$



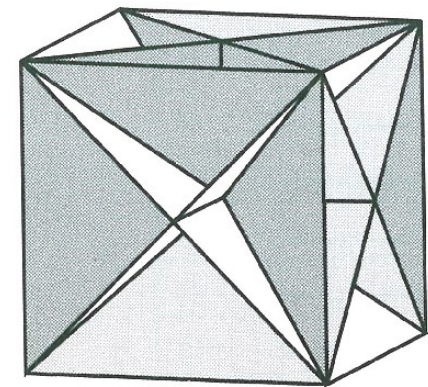
3 rotoinverzne tetragire

3



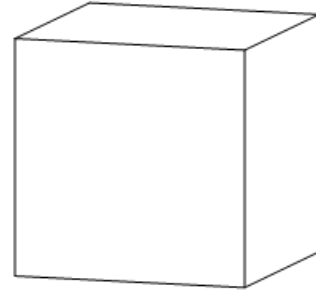
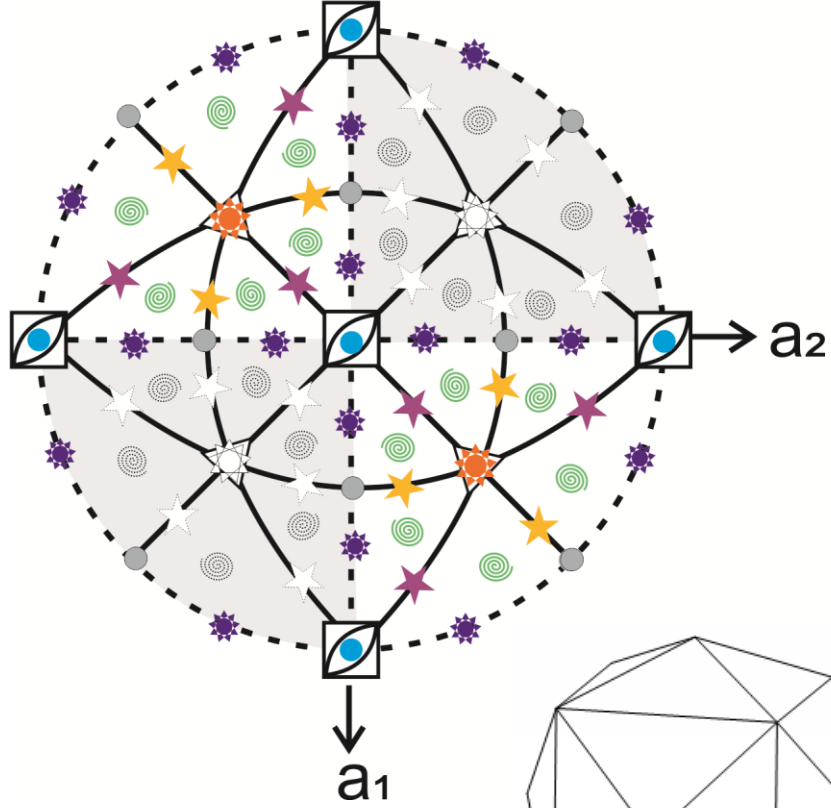
4 trigire

m

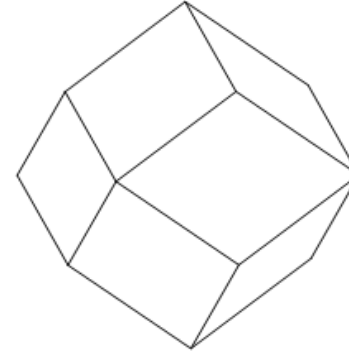


6 sporednih ravnina
simetrije

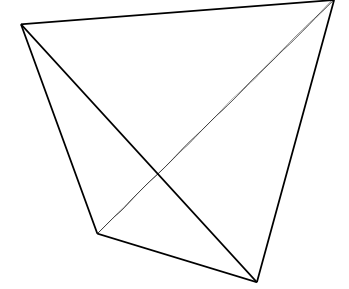
Tetraedarska hemiedrija kubičnog sustava ($\bar{4} 3 m$) - forme



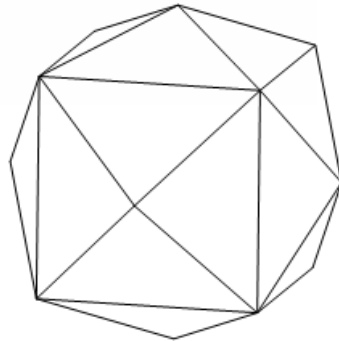
● **heksaedar**
 $\{100\}$
 6 ploha



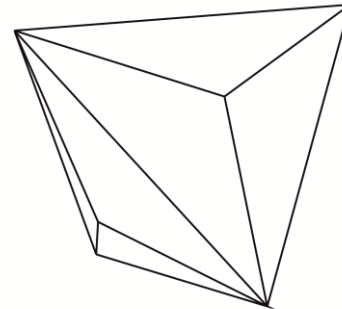
● **rompski dodekaedar**
 $\{110\}$
 12 ploha



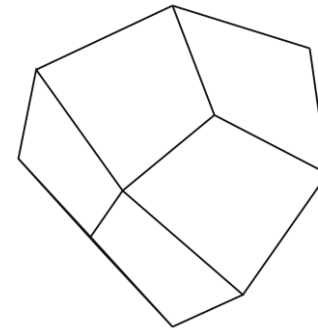
● **tetrataedar (+)**
 $\{111\}$
 4 plohe



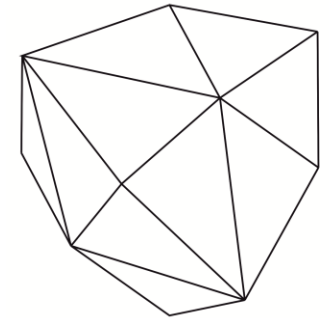
● **tetrakisheksaedar**
 $\{hk0\}$ pr. $\{210\}$
 24 plohe



★ **tristetraedar (+)**
 $\{hll\}$, $h>l$ pr. $\{211\}$
 12 ploha



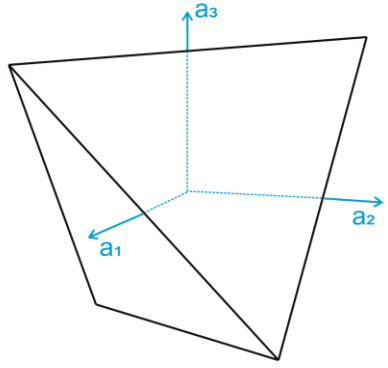
★ **deltoidski dodekaedar (+)**
 $\{hhl\}$, $h>l$ pr. $\{221\}$
 12 ploha



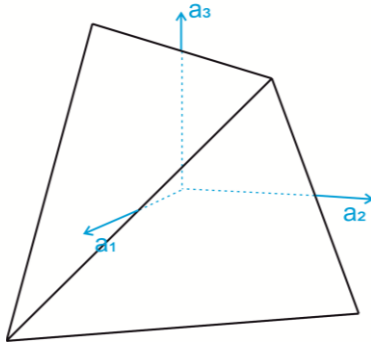
● **heksakistetraedar (+)**
 $\{hkl\}$ pr. $\{321\}$
 24 plohe

Tetraedarska hemiedrija kubičnog sustava ($\bar{4} 3 m$) - forme

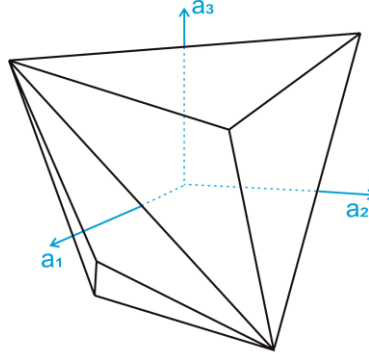
- pozitivne (+) i negativne (-) orijentacije formi



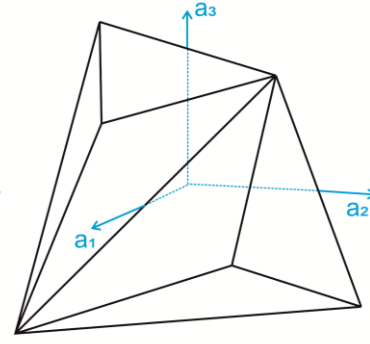
tetraedar (+)
 $\{111\}$
 4 plohe



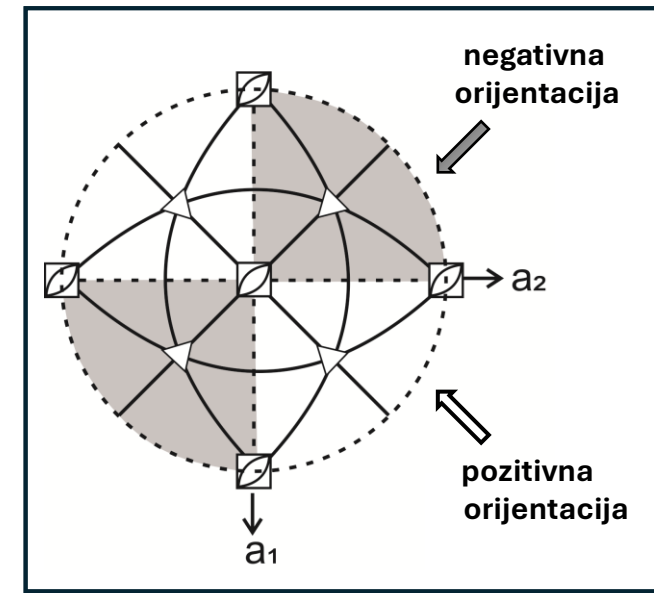
tetraedar (-)
 $\{1\bar{1}1\}$
 4 plohe



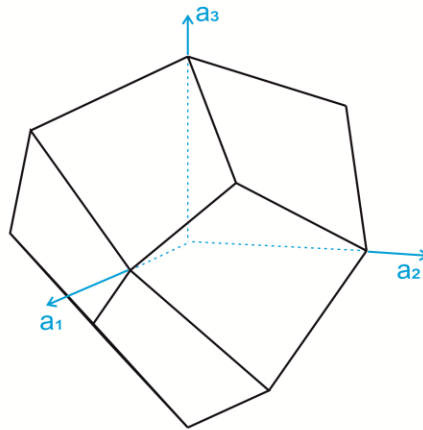
tristetrahedar (+)
 $\{hll\}$, $h>l$, pr. $\{211\}$
 12 ploha



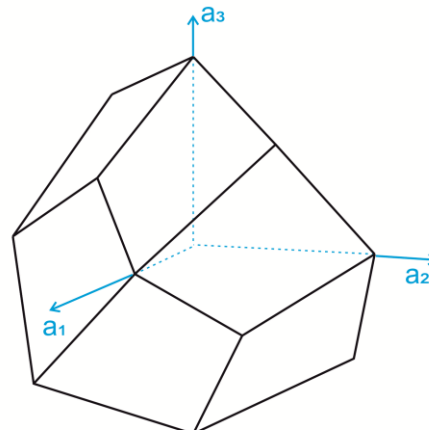
tristetrahedar (-)
 $\{hll\}$, $h>l$, pr. $\{2\bar{1}1\}$
 12 ploha



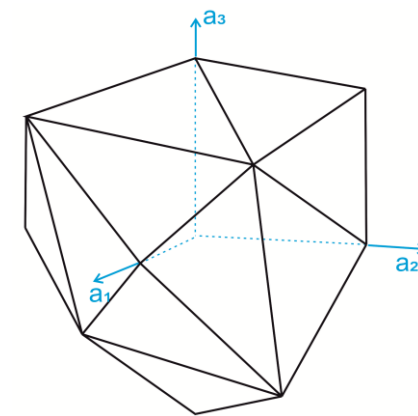
! polarna trigira



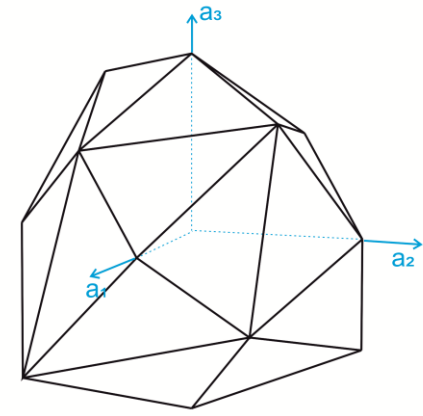
deltoidski dodekaedar (+)
 $\{hhl\}$, $h>l$, pr. $\{221\}$
 12 ploha



deltoidski dodekaedar (-)
 $\{hhl\}$, $h>l$, pr. $\{2\bar{2}1\}$
 12 ploha



heksakistetrahedar (+)
 $\{hkl\}$ pr. $\{321\}$
 24 plohe



heksakistetrahedar (-)
 $\{hkl\}$ pr. $\{3\bar{2}1\}$
 24 plohe

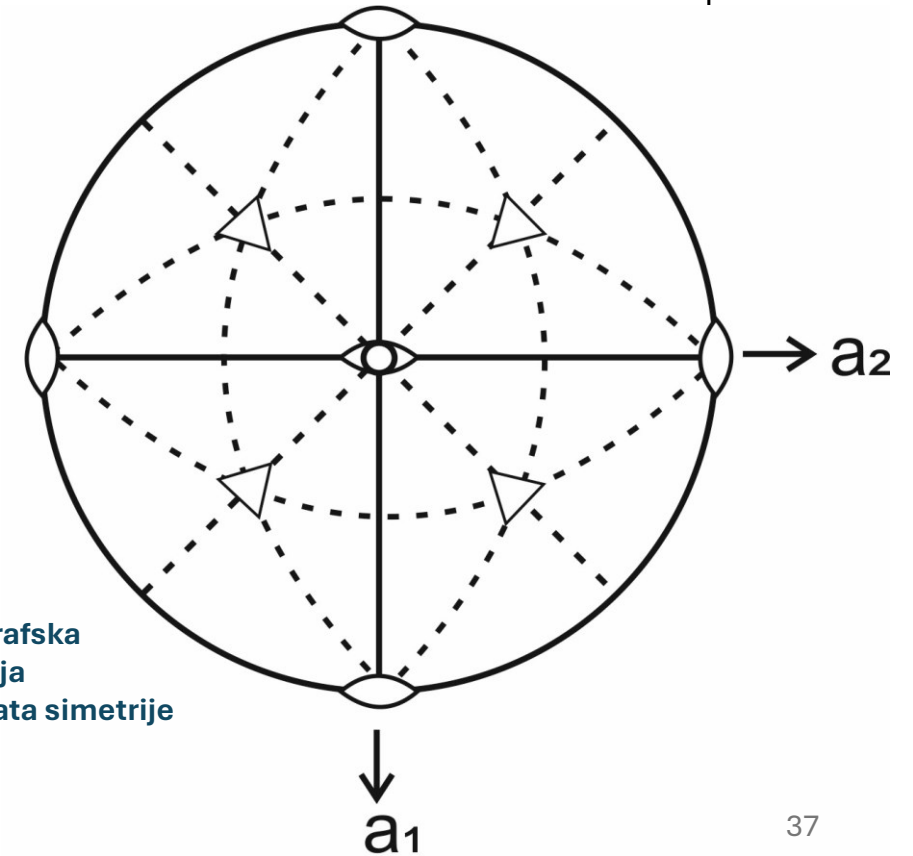
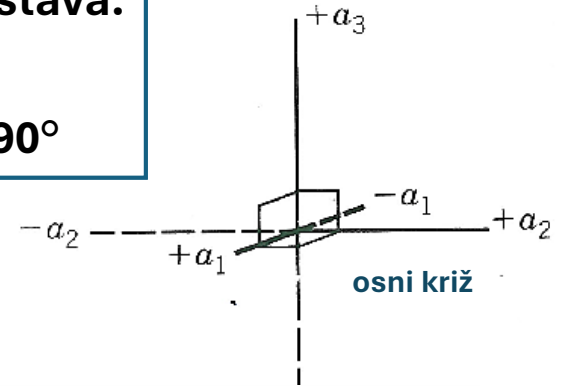
Kubični sustav

Hermann-Mauguin-ov simbol	smjer na koji se odnosi simbol na odgovarajućem mjestu u Hermann-Mauguin-ovom simbolu i broj ekvivalentnih smjerova			Schönflies-ov simbol
	1	2	3	
1) $\frac{4}{m} \bar{3} \frac{2}{m}$	$\langle 100 \rangle$	$\langle 111 \rangle$	$\langle 110 \rangle$	O_h
2) $\bar{4}3m$	3	4	6	T_d
3) 432				O
4) $\frac{2}{m} \bar{3}$		smjerovi prostornih dijagonala	simetrane između kristalografskih osi a_1, a_2, a_3	T_h
5) 23	kristalografske osi a_1, a_2, a_3			T

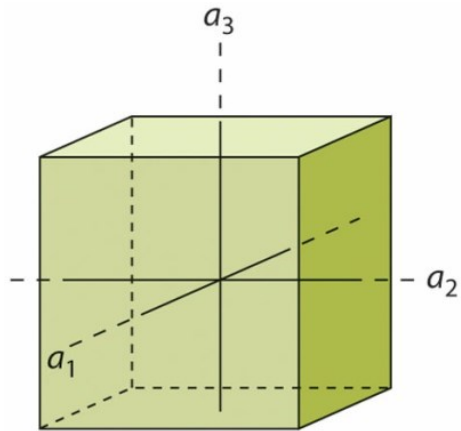
Karakteristike sustava:

$$a_1 = a_2 = a_3$$

$$\alpha_1 = \alpha_2 = \alpha_3 = 90^\circ$$

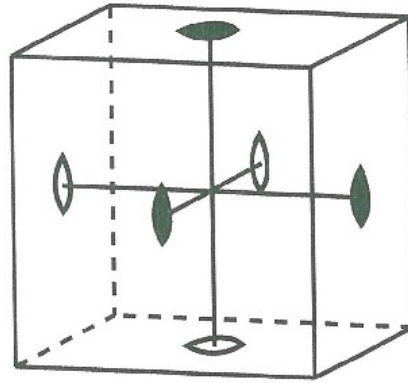


Pentagonska hemiedrija tetragonskog sustava ($\frac{2}{m} \bar{3}$)



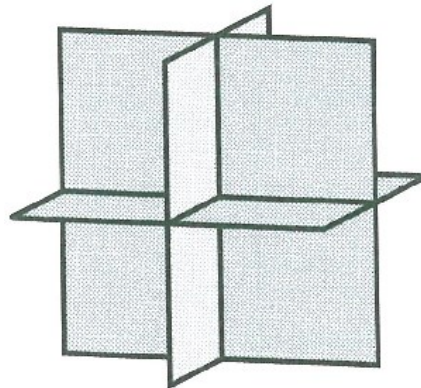
kristalografske osi

$$\frac{2}{m}$$



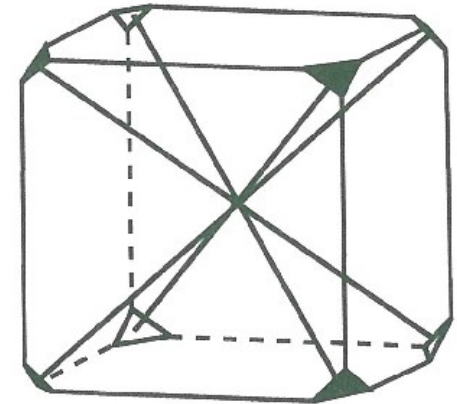
3 digire

+



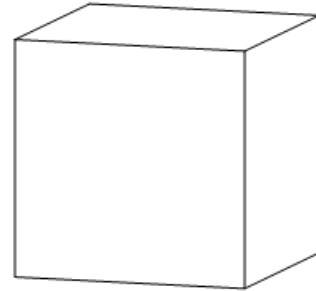
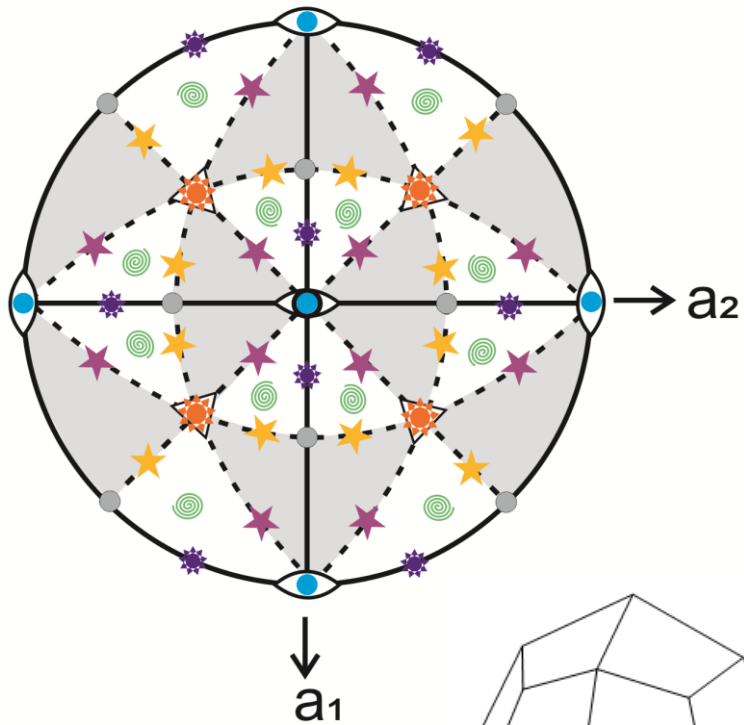
3 glavne ravnine simetrije

$$\bar{3}$$

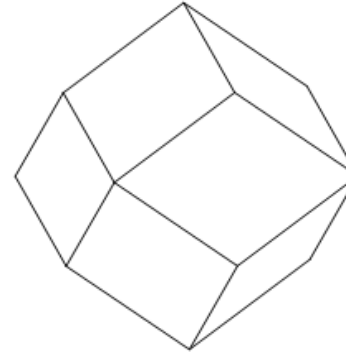


4 trigire

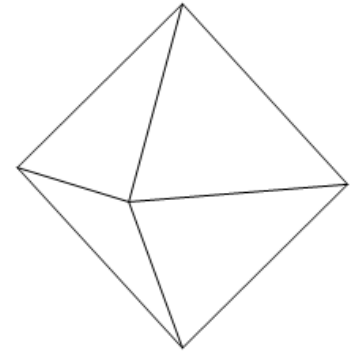
Pentagonska hemiedrija kubičnog sustava $\left(\frac{2}{m}\bar{3}\right)$ - forme



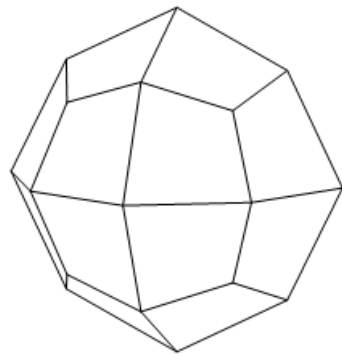
● **heksaedar**
{100}
6 ploha



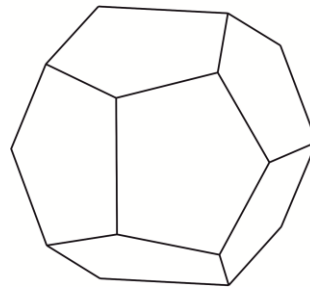
● **rompski dodekaedar**
{110}
12 ploha



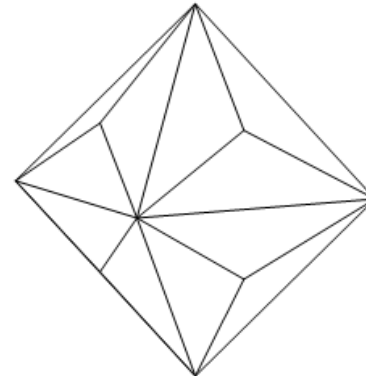
● **oktaedar**
{111}
8 ploha



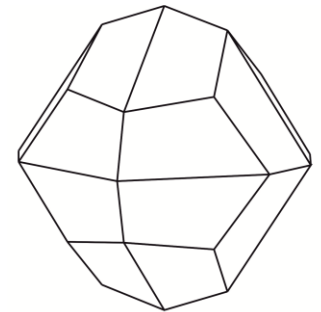
★ **deltoidski
ikozitetraedar**
{hll}, h>l pr. {211}
24 plohe



★ **pentagonski
dodekaedar (+)**
{hl0}, pr. {210}
12 ploha



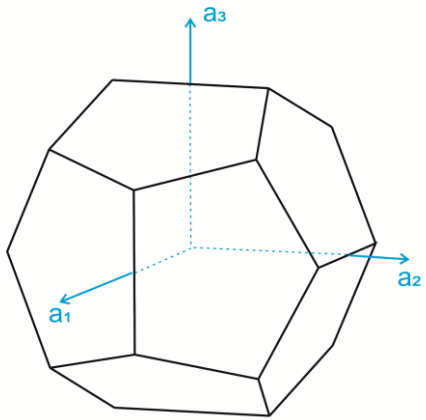
★ **trisoktaedar**
{hhl}, h>l pr. {221}
24 plohe



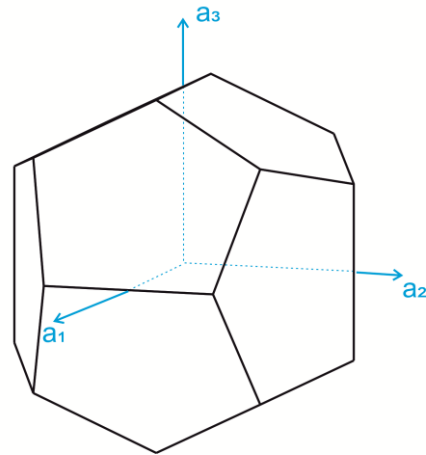
● **disdodekaedar (-)**
{hkl}, pr. {312}
24 plohe

Pentagonska hemiedrija kubičnog sustava $\left(\frac{2}{m}\bar{3}\right)$ - forme

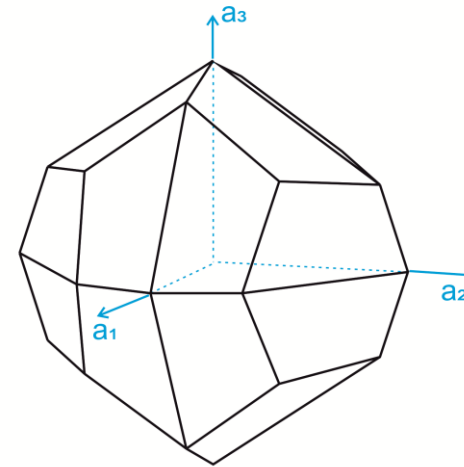
- pozitivne (+) i negativne (-) orijentacije formi



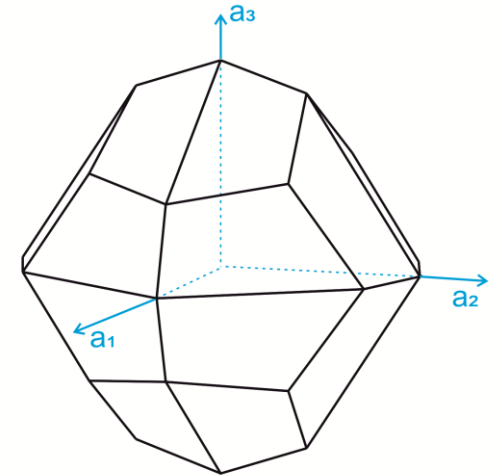
pentagonski dodekaedar (+)
 $\{hl0\}$ pr. $\{210\}$
12 ploha



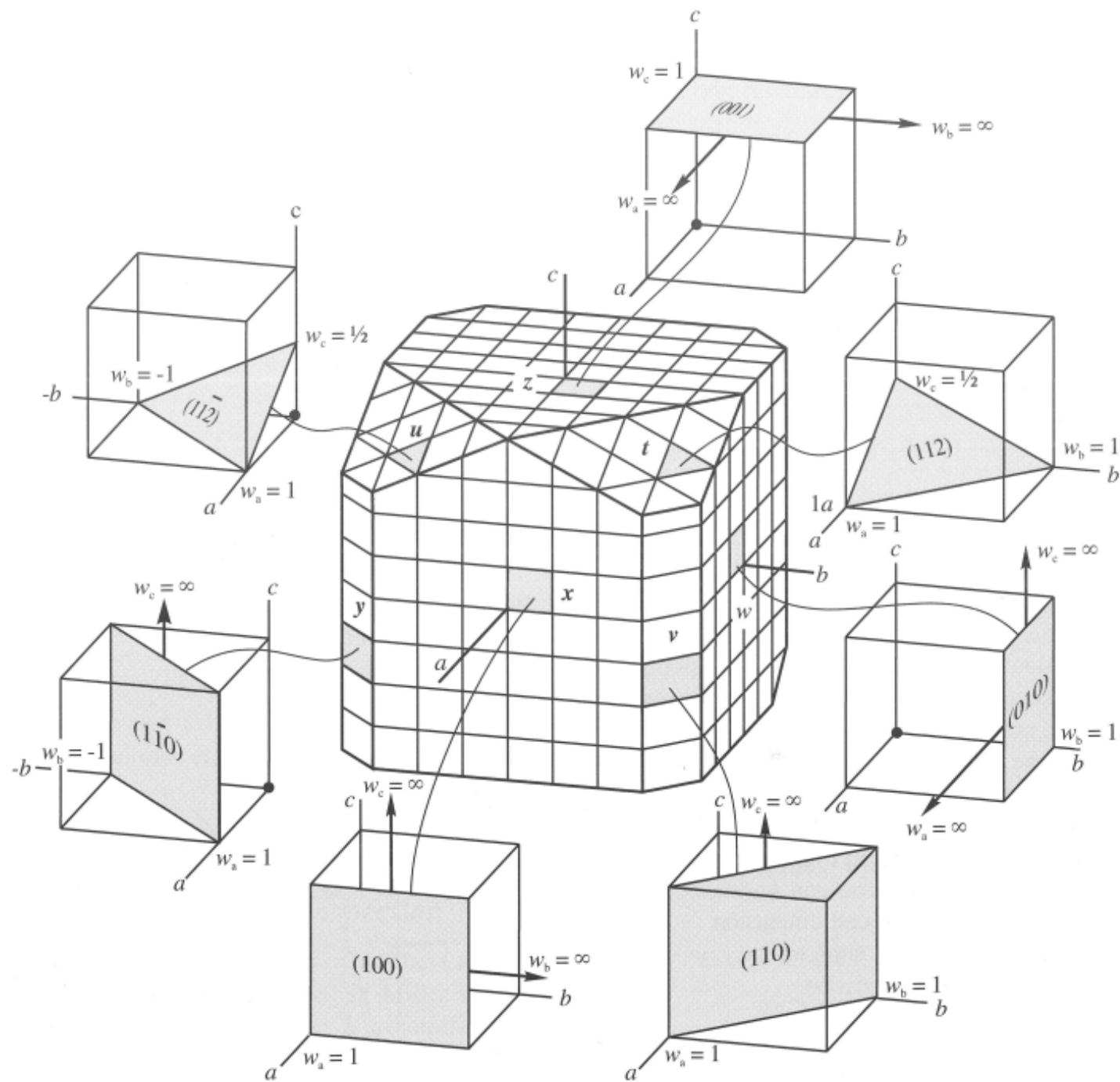
pentagonski dodekaedar (-)
 $\{hl0\}$ pr. $\{120\}$
12 ploha



disdodekaedar (+)
 $\{hkl\}$ pr. $\{312\}$
24 plohe



disdodekaedar (-)
 $\{hkl\}$ pr. $\{321\}$
24 plohe



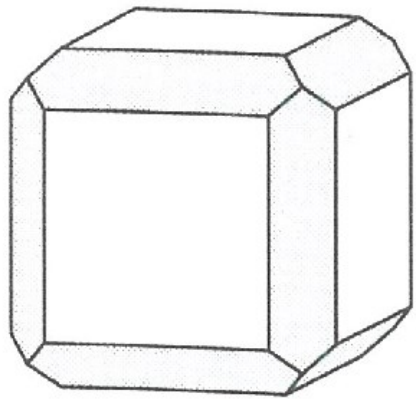
Kubični sustav - forme

	$4/m \bar{3} 2/m$		$\bar{4} 3 m$		$2/m \bar{3}$	
	Ime forme	Indeks forme	Ime forme	Indeks forme	Ime forme	Indeks forme
1	Heksaedar (6)	{100}	Heksaedar (6)	{100}	Heksaedar (6)	{100}
2	Rompski dodekaedar (12)	{110}	Rompski dodekaedar (12)	{110}	Rompski dodekaedar (12)	{110}
3	Oktaedar (8)	{111}	Tetraedar +/- (4)	$\begin{Bmatrix} 111 \\ 1\bar{1}1 \end{Bmatrix}$	Oktaedar (8)	{111}
4	Tetrakisheksaedar (24)	{hk0}	Tetrakisheksaedar (24)	{hk0}	Pentagonski dodekaedar +/- (12)	$\begin{Bmatrix} hk0 \\ kh0 \end{Bmatrix}$
5	Deltoidski ikozitetraedar (24)	{hll}	Tristetraedar +/- (12)	$\begin{Bmatrix} hll \\ h\bar{l}l \end{Bmatrix}$	Deltoidski ikozitetraedar (24)	{hll}
6	Trisoktaedar (24)	{hhl}	Deltoidski dodekaedar +/- (12)	$\begin{Bmatrix} hhl \\ h\bar{h}l \end{Bmatrix}$	Trisoktaedar (24)	{hhl}
7	Heksakisoktaedar (48)	{hkl}	Heksakistetraedar (24)	$\begin{Bmatrix} hkl \\ h\bar{k}l \end{Bmatrix}$	Disdodekaedar +/- (24)	$\begin{Bmatrix} hkl \\ khl \end{Bmatrix}$

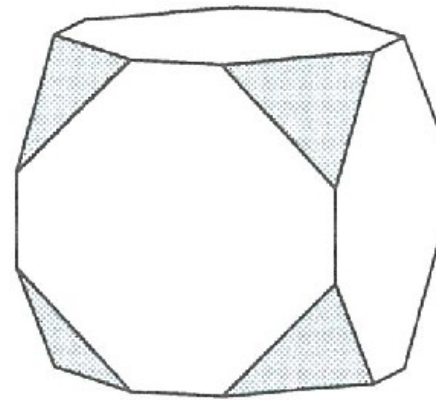
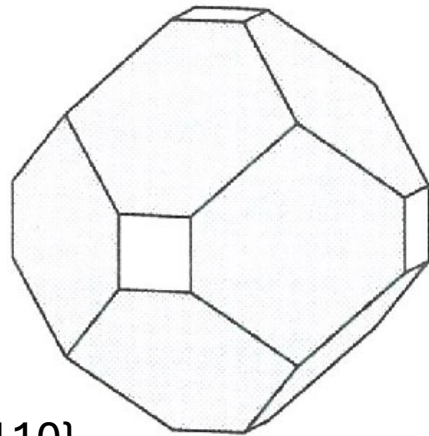
$h > k > l$

*u zagradi označen broj ploha svake forme

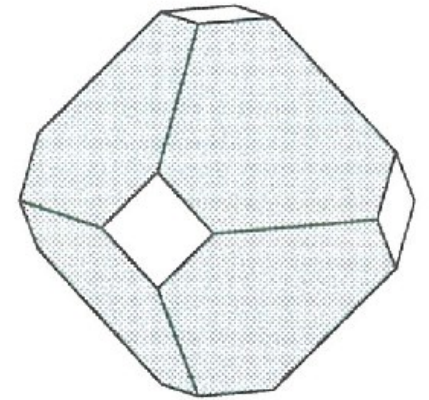
Razvoj formi



$\{100\} + \{110\}$



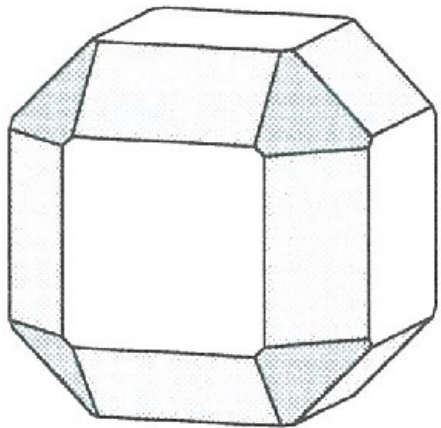
$\{100\} + \{111\}$



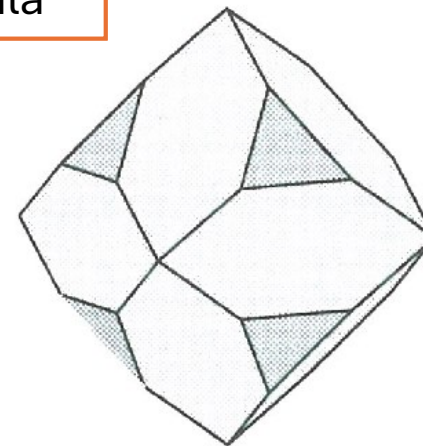
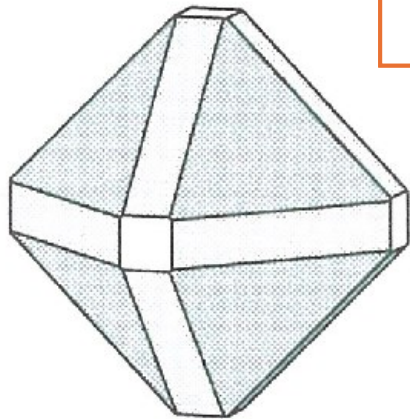
iste forme, ali različito razvijene



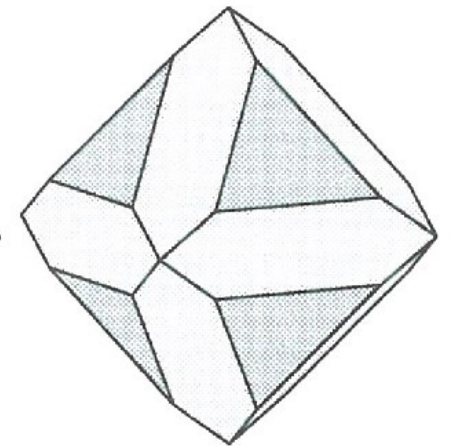
različita morfologija kristala



$\{100\} + \{110\} + \{111\}$



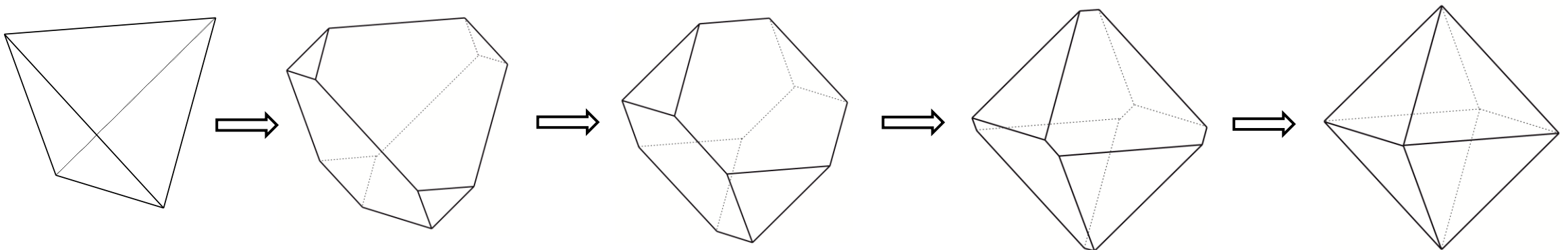
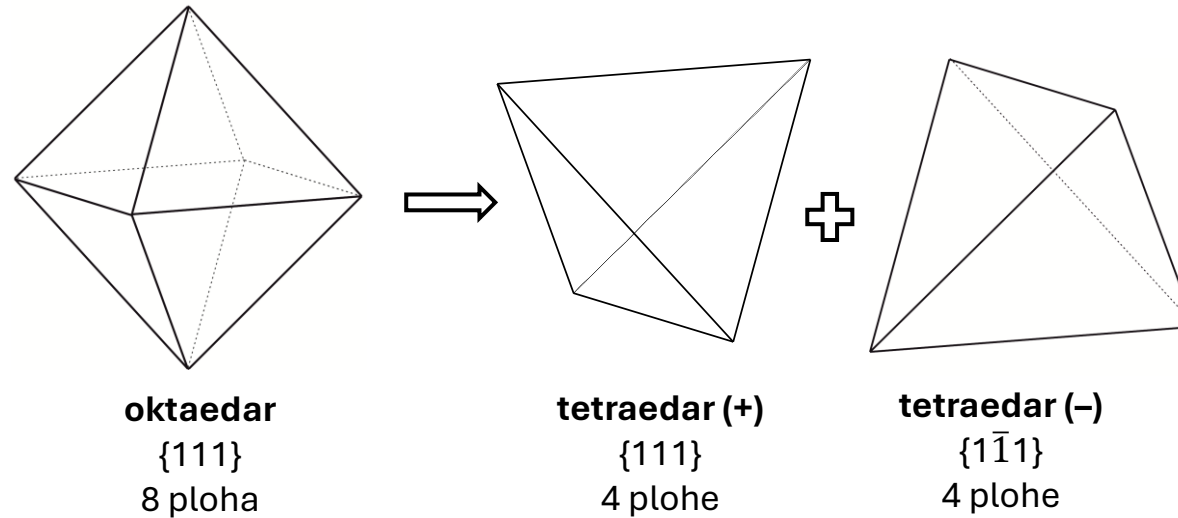
$\{110\} + \{111\}$



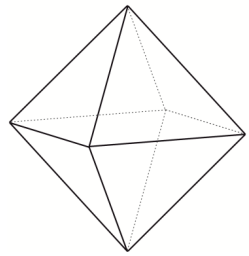
Komplementarne forme

! Gubitak elemenata simetrije → smanjivanje broja ekvivalentnih ploha.

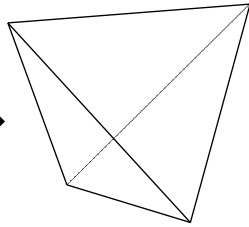
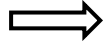
→ Umjesto forme iz klase s višim stupnjem simetrije moguće su dvije forme, koje se dopunjuju u formu iz koje su nastale = **komplementarne forme**



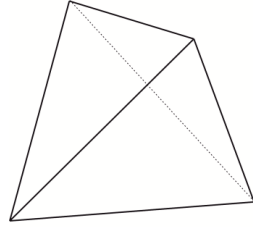
Komplementarne forme (kubični sustav)



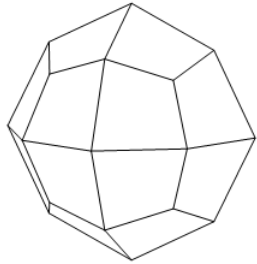
oktaedar
 $\{111\}$
8 ploha



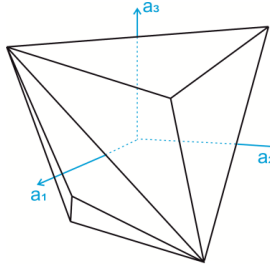
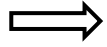
tetraedar (+)
 $\{111\}$
4 plohe



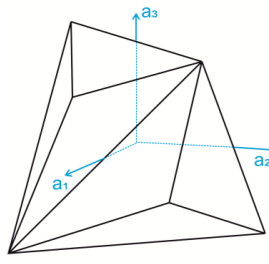
tetraedar (-)
 $\{1\bar{1}1\}$
4 plohe



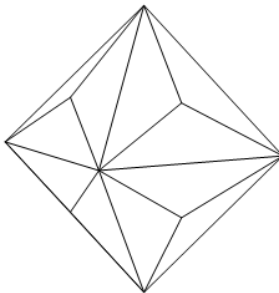
deltoidski ikozitetraedar
 $\{211\}$
24 plohe



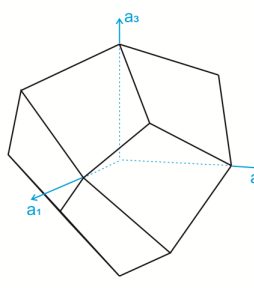
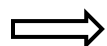
tristetraedar (+)
 $\{211\}$
12 ploha



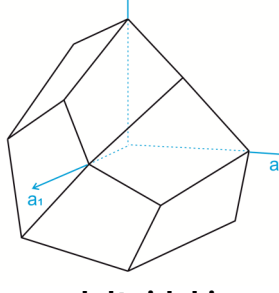
tristetraedar (-)
 $\{2\bar{1}1\}$
12 ploha



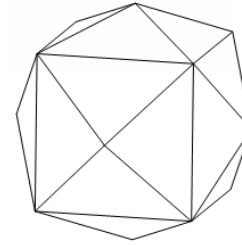
trisoktaedar
 $\{221\}$
24 plohe



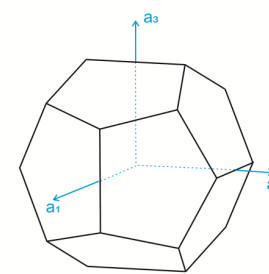
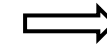
deltoidski dodekaedar (+)
 $\{221\}$
12 ploha



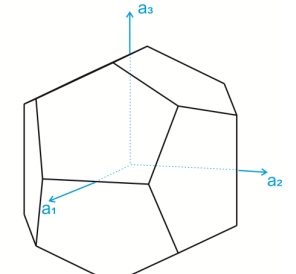
deltoidski dodekaedar (-)
 $\{2\bar{2}1\}$
12 ploha



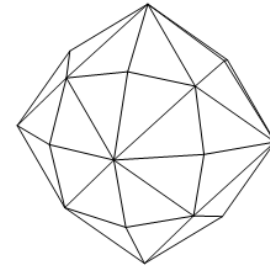
tetrakisheksaedar
 $\{210\}$
24 plohe



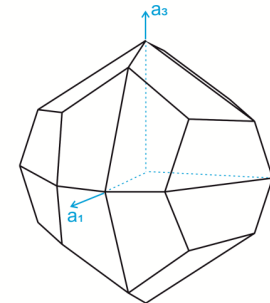
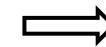
pentagonski dodekaedar (+)
 $\{210\}$
12 ploha



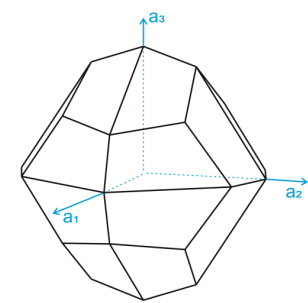
pentagonski dodekaedar (-)
 $\{120\}$
12 ploha



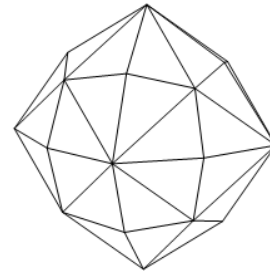
heksakisoktaedar
 $\{321\}$
48 ploha



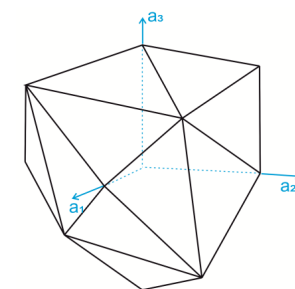
disdodekaedar (+)
 $\{321\}$
24 plohe



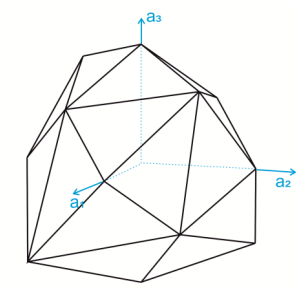
disdodekaedar (-)
 $\{231\}$
24 plohe



heksakisoktaedar
 $\{321\}$
48 ploha

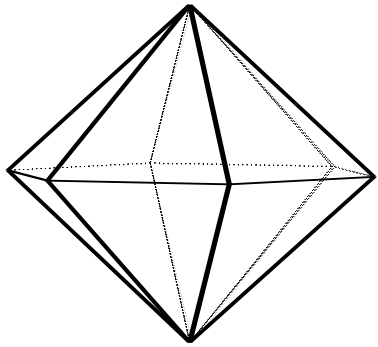


heksakistetraedar (+)
 $\{hkl\}$ pr. $\{321\}$
24 plohe

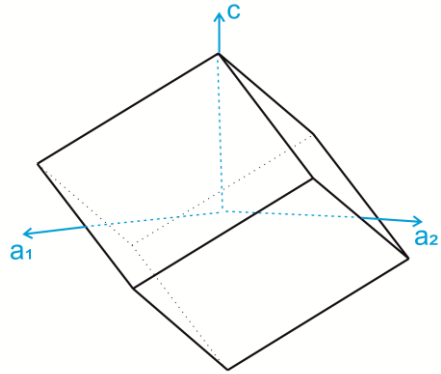
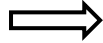


heksakistetraedar (-)
 $\{hkl\}$ pr. $\{3\bar{2}1\}$
24 plohe

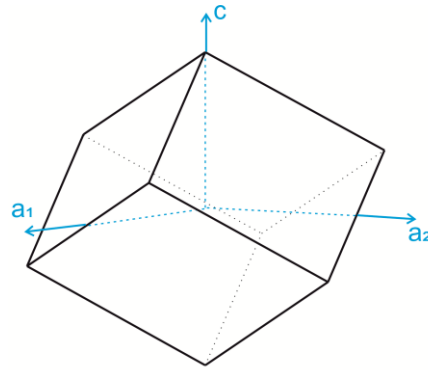
Komplementarne forme (heksagonski sustav)



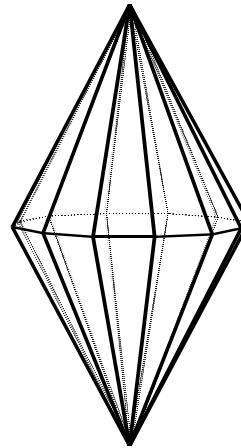
heksagonska dipiramida
I. položaja
 $\{h0\bar{h}l\}$ pr. $\{10\bar{1}1\}$
12 ploha



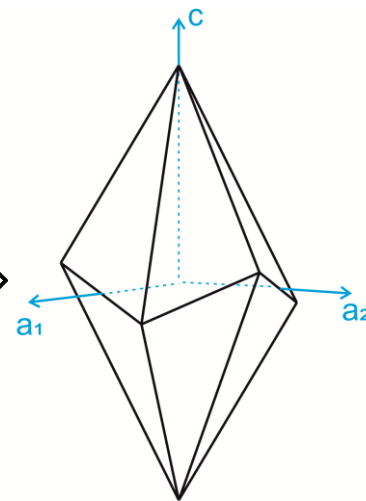
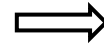
romboedar (+)
 $\{h0\bar{h}l\}$ pr. $\{10\bar{1}1\}$
6 ploha



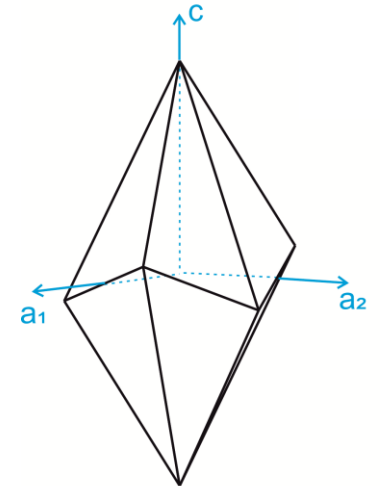
romboedar (-)
 $\{0h\bar{h}l\}$ pr. $\{01\bar{1}1\}$
6 ploha



diheksagonska dipiramida
 $\{hk\bar{l}l\}$ pr. $\{21\bar{3}1\}$
24 plohe



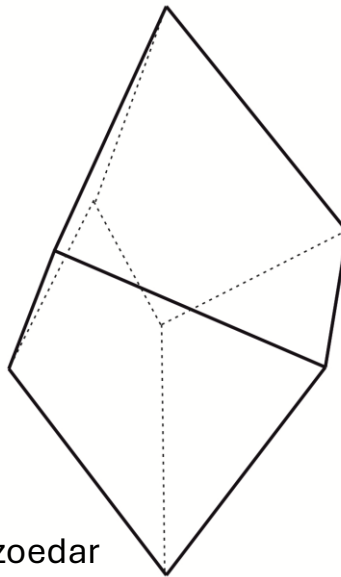
ditrigonski skalenoedar (+)
 $\{hkil\}$ pr. $\{21\bar{3}1\}$
12 ploha



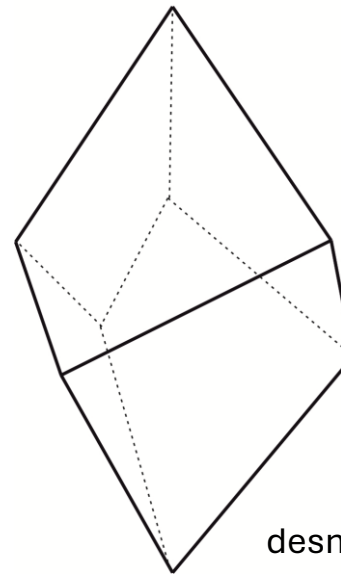
ditrigonski skalenoedar (-)
 $\{hkil\}$ pr. $\{12\bar{3}1\}$
12 ploha

Komplementarne forme

- (1) **Pozitivne i negativne** - dvije forme se zakretanjem može dovesti do potpunog preklapanja, međusobno su **potpuno jednake**, samo se razlikuju po odnosu ploha prema kristalografskim osima
- (2) **Lijeve i desne** - dvije forme se više zakretanjem ne može dovesti do preklapanja = **enantiomorfne forme**



lijevi trigonski trapezoedar



desni trigonski trapezoedar

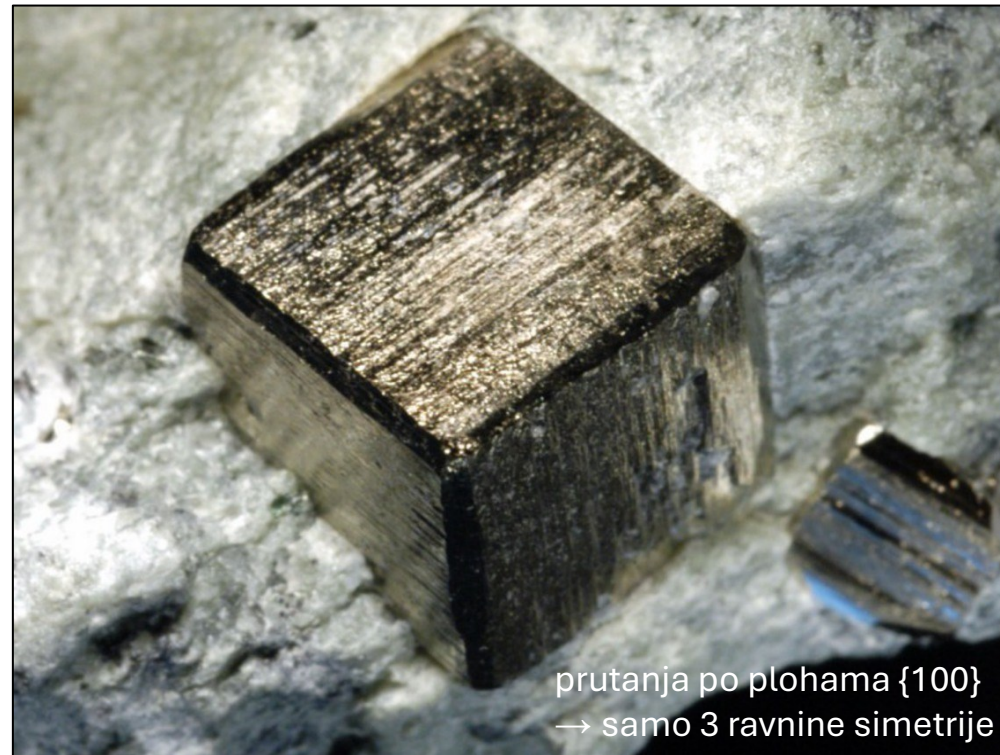
Pseudoforme

Forme koje su geometrijski iste onima iz holedrije, ali su kristalografski različite; **njihova prava simetrija je niža.**



problem određivanja simetrije

→ prepoznatljivo iz prutanja, izjedina, fizikalnih svojstava



primjer: pirit (FeS_2), klasa: $\frac{2}{m} \bar{3}$

Kubični sustav - pseudoforme

	$4/m \bar{3} 2/m$		$\bar{4} 3 m$		$2/m \bar{3}$	
	Ime forme	Indeks forme	Ime forme	Indeks forme	Ime forme	Indeks forme
1	Heksaedar (6)	{100}	Heksaedar (6)	{100}	Heksaedar (6)	{100}
2	Rompski dodekaedar (12)	{110}	Rompski dodekaedar (12)	{110}	Rompski dodekaedar (12)	{110}
3	Oktaedar (8)	{111}	Tetraedar +/- (4)	$\begin{Bmatrix} 111 \\ 1\bar{1}1 \end{Bmatrix}$	Oktaedar (8)	{111}
4	Tetrakisheksaedar (24)	{hk0}	Tetrakisheksaedar (24)	{hk0}	Pentagonski dodekaedar +/- (12)	$\begin{Bmatrix} hk0 \\ kh0 \end{Bmatrix}$
5	Deltoidski ikozitetraedar (24)	{hll}	Tristetraedar +/- (12)	$\begin{Bmatrix} hll \\ h\bar{l}l \end{Bmatrix}$	Deltoidski ikozitetraedar (24)	{hll}
6	Trisoktaedar (24)	{hhl}	Deltoidski dodekaedar +/- (12)	$\begin{Bmatrix} hhl \\ h\bar{h}l \end{Bmatrix}$	Trisoktaedar (24)	{hhl}
7	Heksakisoktaedar (48)	{hkl}	Heksakistetraedar (24)	$\begin{Bmatrix} hkl \\ h\bar{k}l \end{Bmatrix}$	Disdodekaedar +/- (24)	$\begin{Bmatrix} hkl \\ khl \end{Bmatrix}$

$h > k > l$

* u zagradi označen broj ploha svake forme

** narančasto označene pseudoforme

Heksagonski sustav - pseudoforme

	$6/m \ 2/m \ 2/m$		$\bar{3} \ 2/m$	
	Ime forme	Indeks forme	Ime forme	Indeks forme
1	Bazni pinakoid (2)	{0001}	Bazni pinakoid (2)	{0001}
2	Heksagonska prizma I. položaja (6)	{10 $\bar{1}$ 0}	Heksagonska prizma I. položaja (6)	{10 $\bar{1}$ 0}
3	Heksagonska prizma II. položaja (6)	{11 $\bar{2}$ 0}	Heksagonska prizma II. položaja (6)	{11 $\bar{2}$ 0}
4	Diheksagonska prizma (12)	{hki0}	Diheksagonska prizma (12)	{hki0}
5	Heksagonska dipiramida I. položaja (12)	{h0 $\bar{h}$ l}	Romboedar +/- (6)	{h0 $\bar{h}$ l} {0h $\bar{h}$ l}
6	Heksagonska dipiramida II. položaja (12)	{hh $\bar{2}$ hl}	Heksagonska dipiramida II. položaja (12)	{hh $\bar{2}$ hl}
7	Diheksagonska dipiramida (24)	{hkil}	Ditrigonski skalenoedar +/- (12)	{hkil}

$h > k > l$

* u zagradi označen broj ploha svake forme

** narančasto označene pseudoforme

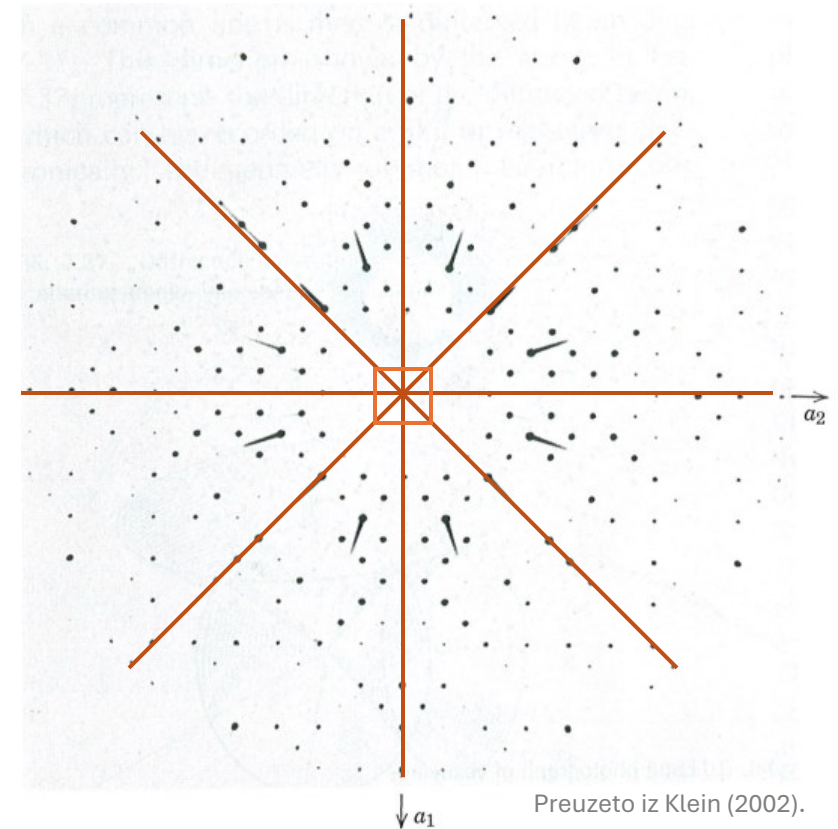
Određivanje simetrije

! Ukoliko je obasjana rendgenskim zrakama, kristalizirana materija daje pravilnu difrakcijsku sliku.

→ difrakcijska slika za određivanje kristalne strukture

!!! **Fridelov zakon:** na snimkama dobivenim primjenom difrakcije X-zraka u pravilu je prisutan centar simetrije.

→ moguće razlikovati samo 11 klasa = **Laueove grupe**



Primjer:

$$\bar{4} 3 m + \bar{1} = \frac{4}{m} \bar{3} \frac{2}{m}$$

$$4 3 2 + \bar{1} = \frac{4}{m} \bar{3} \frac{2}{m}$$

3 različite klase → ista difrakcijska slika

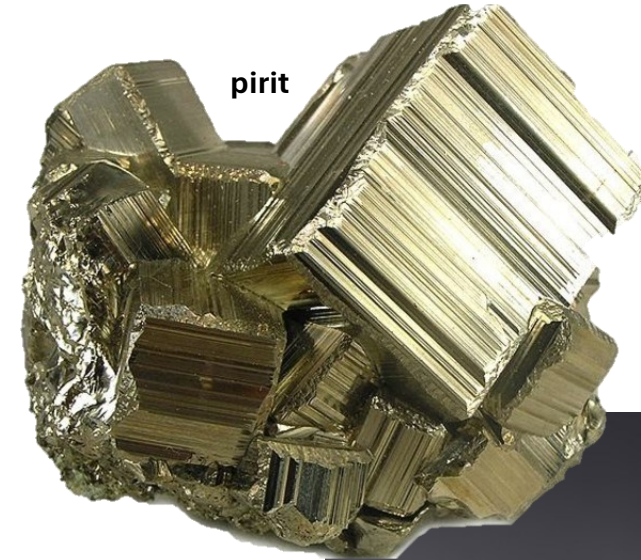
Određivanje simetrije

Laueova grupa	Kristalne klase
$\bar{1}$	$\bar{1}, 1$
$\frac{2}{m}$	$\frac{2}{m}, m, 2$
$\frac{2}{m} \frac{2}{m} \frac{2}{m}$	$\frac{2}{m} \frac{2}{m} \frac{2}{m}, mm2, 222$
$\bar{3}$	$\bar{3}, 3$
$\bar{3} 2m$	$\bar{3} \frac{2}{m}, 3m, 32$
$\frac{6}{m}$	$\frac{6}{m}, \bar{6}, 6$
$\frac{6}{m} \frac{2}{m} \frac{2}{m}$	$\frac{6}{m} \frac{2}{m} \frac{2}{m}, \bar{6}m2, 6mm, 622$
$\frac{4}{m}$	$\frac{4}{m}, \bar{4}, 4$
$\frac{4}{m} \frac{2}{m} \frac{2}{m}$	$\frac{4}{m} \frac{2}{m} \frac{2}{m}, \bar{4}2m, 4mm, 422$
$\frac{2}{m} 3$	$\frac{2}{m} 3, 23$
$\frac{4}{m} \bar{3} \frac{2}{m}$	$\frac{4}{m} \bar{3} \frac{2}{m}, \bar{4}3m, 432$

Određivanje simetrije

Svojstva uvjetovana simetrijom kristala koja mogu pomoći pri određivanju prave simetrije kristala:

- **Prutanja** = rebraste tvorbe na plohama nekih kristala



pirit



kvarc

Određivanje simetrije

Svojstva uvjetovana simetrijom kristala koja mogu pomoći pri određivanju prave simetrije kristala:

- **Prutanja** = rebraste tvorbe na plohami nekih kristala
- **Izjedine** (figure jetkanja) = nastaju tretiranjem ploha odgovarajućim otapalom



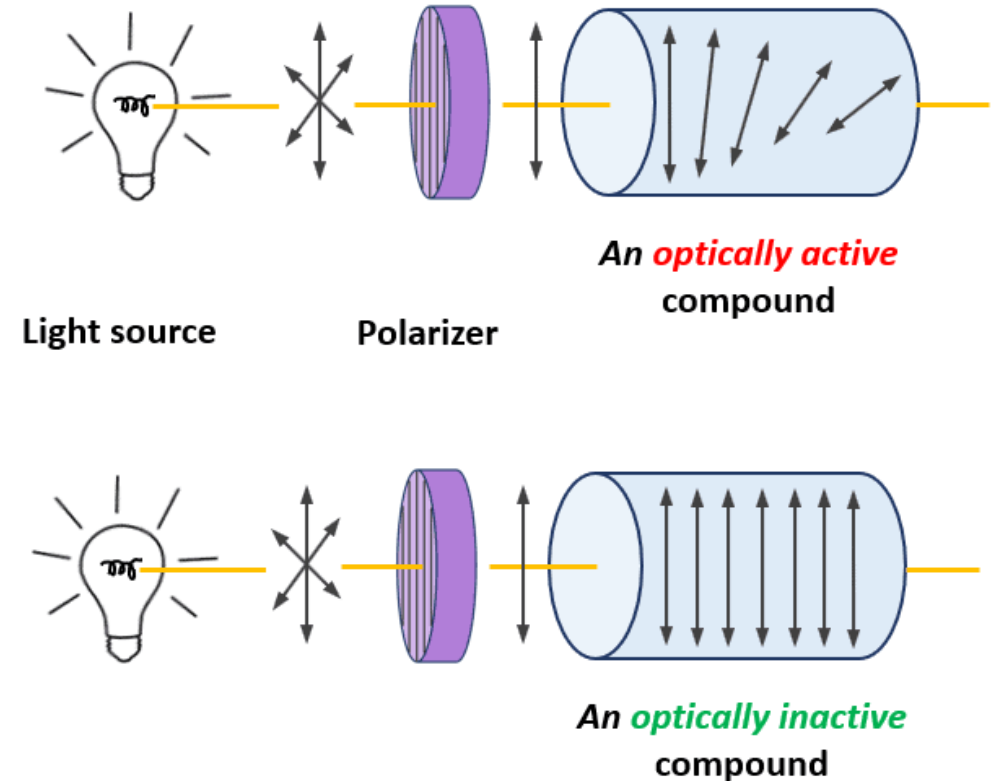
Izvor fotografije: <https://www.mindat.org>

Primjer: Widmanstättenove figure na Fe-Ni-meteoritu

Određivanje simetrije

Svojstva uvjetovana simetrijom kristala koja mogu pomoći pri određivanju prave simetrije kristala:

- **Prutanja** = rebraste tvorbe na plohama nekih kristala
- **Izjedine** (figure jetkanja) = nastaju tretiranjem ploha odgovarajućim otapalom
- **Optička aktivnost** = svojstvo kristala da zakreće ravninu polarizacije udesno ili ulijevo (samo kod klasa bez centra simetrije)
 - ovisi o valnoj duljini svjetlosti i debljini minerala (deblji mineral → veći zaokret)



Izvor fotografije: <https://www.chemistrysteps.com>

Određivanje simetrije

Svojstva uvjetovana simetrijom kristala koja mogu pomoći pri određivanju prave simetrije kristala:

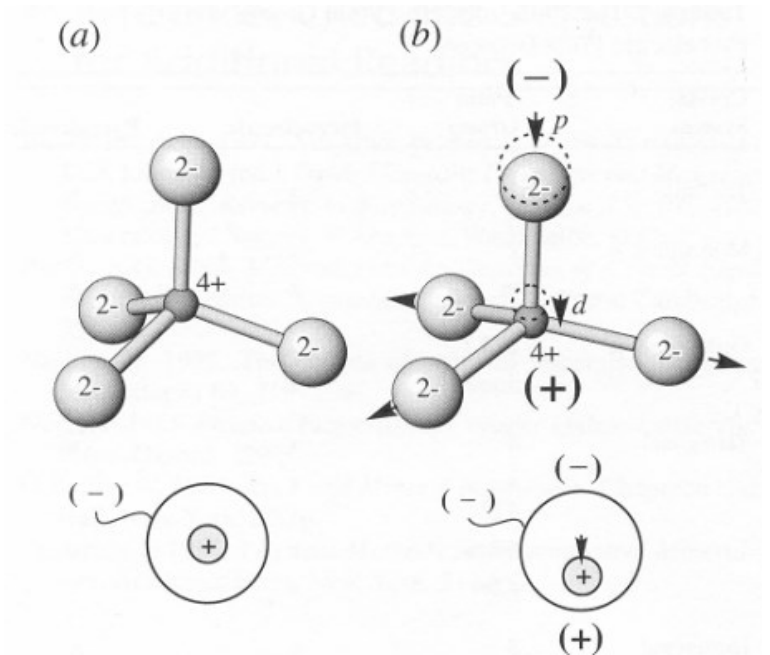
- **Prutanja** = rebraste tvorbe na plohama nekih kristala
- **Izjedine** (figure jetkanja) = nastaju tretiranjem ploha odgovarajućim otapalom
- **Optička aktivnost** = svojstvo kristala da zakreće ravninu polarizacije udesno ili ulijevo (samo kod klasa bez centra simetrije)

→ ovisi o valnoj duljini svjetlosti i debljini minerala
(deblji mineral → veći zaokret)

- **Piezelektricitet** = svojstvo kristala da se uslijed usmjerenih pritisaka **duž polarnih smjerova** polarno nabija (samo kod klasa bez centra simetrije, osim 432)

→ Takvi kristali se u električnom polju rastežu ili stežu
(obratni piezoelektrični efekt)

Primjer: kvarcni satovi



Preuzeto iz Nesse (2000)



<https://www.youtube.com/watch?app=desktop&v=3jfgQF3jX7A>

Određivanje simetrije

Svojstva uvjetovana simetrijom kristala koja mogu pomoći pri određivanju prave simetrije kristala:

- **Prutanja** = rebraste tvorbe na plohama nekih kristala
- **Izjedine** (figure jetkanja) = nastaju tretiranjem ploha odgovarajućim otapalom
- **Optička aktivnost** = svojstvo kristala da zakreće ravninu polarizacije udesno ili ulijevo (samo kod klasa bez centra simetrije)

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(deblji mineral → veći zaokret)

- **Piezeelektricitet** = svojstvo kristala da se uslijed usmjerenih pritisaka **duž polarnih smjerova** polarno nabija (samo kod klasa bez centra simetrije, osim 432)

→ Takvi kristali se u električnom polju rastežu ili stežu
(obratni piezoelektrični efekt)

Primjer: kvarcni satovi

- **Piroelektricitet** = svojstvo kristala da se električki nabije duž polarnih smjerova uslijed promjene temperature

Određivanje simetrije

Kristalna klasa	Optička aktivnost	Piroelektricitet	Piezoelektricitet
1	+	+	+
2	+	+	+
m	+	+	+
222	+		+
mm2	+	+	+
4	+	+	+
$\bar{4}$	+		+
422	+		+
4mm		+	+
$\bar{4}2m$	+		+
3	+	+	+
32	+		+
3m		+	+
6	+	+	+
$\bar{6}$			+
622	+		+
6mm		+	+
$\bar{6}2m$			+
23	+		+
432	+		
$\bar{4}3m$			+
broj klasa	15	10	20

PUNI SIMBOL	SKRAĆENI SIMBOL
$\frac{2}{m} \frac{2}{m} \frac{2}{m}$	m m m
$\frac{4}{m} \frac{2}{m} \frac{2}{m}$	$\frac{4}{m}$ m m
$\bar{3} \frac{2}{m}$	$\bar{3}$ m
$\frac{6}{m} \frac{2}{m} \frac{2}{m}$	$\frac{6}{m}$ m m
$\frac{4}{m} \bar{3} \frac{2}{m}$	m 3 m
$\frac{2}{m} \bar{3}$	m 3



! Prisutnost nekih elemenata simetrije nužno zahtijeva prisutnost dodatnih elemenata simetrije:

- presjecištem dviju međusobno okomitih ravnina simetrije ide digira ($m \perp m \rightarrow 2$)

Sažetak

Kristalni sustav	Osni sustav
Kubični	$a_1 = a_2 = a_3$ $\alpha_1 = \alpha_2 = \alpha_3 = 90^\circ$
Tetragonski	$a_1 = a_2 \neq c$ $\alpha_1 = \alpha_2 = \gamma = 90^\circ$
Heksagonski	$a_1 = a_2 = a_3 \neq c$ $\alpha_1 = \alpha_2 = \alpha_3 = 120^\circ$ $\delta = 90^\circ$
Trigonski	
Rompski	$a \neq b \neq c$ $\alpha = \beta = \gamma = 90^\circ$
Monoklinski	$a \neq b \neq c$ $\alpha = \gamma = 90^\circ; \beta > 90^\circ$
Triklinski	$a \neq b \neq c$ $\alpha \neq \beta \neq \gamma (\neq 90^\circ)$

Kristalni sustav	Broj razreda	Karakteristični elem. simetrije
Triklinski	2	c ili 1
Monoklinski	3	L^2 i/ili P duž 1 smjera
Rompski	3	$3L^2$ i/ili 3P duž tri okomita smjera
Tetragonski	7	L^4 ili $L_{(4)}^2$
Heksagonski	12	L^6 ili L^3
Kubični	5	$4L^3$

Sustav	Položaj u Hermann-Mauguinovom simbolu		
	1	2	3
Triklinski	-		
Monoklinski	-	b	-
Rompski	a	b	c
Tetragonski	c	a_1, a_2	$\langle 110 \rangle$
Heksagonski	c	a_1, a_2, a_3	$\langle 10\bar{1}0 \rangle$
Kubični	a_1, a_2, a_3	$\langle 111 \rangle$	$\langle 110 \rangle$