



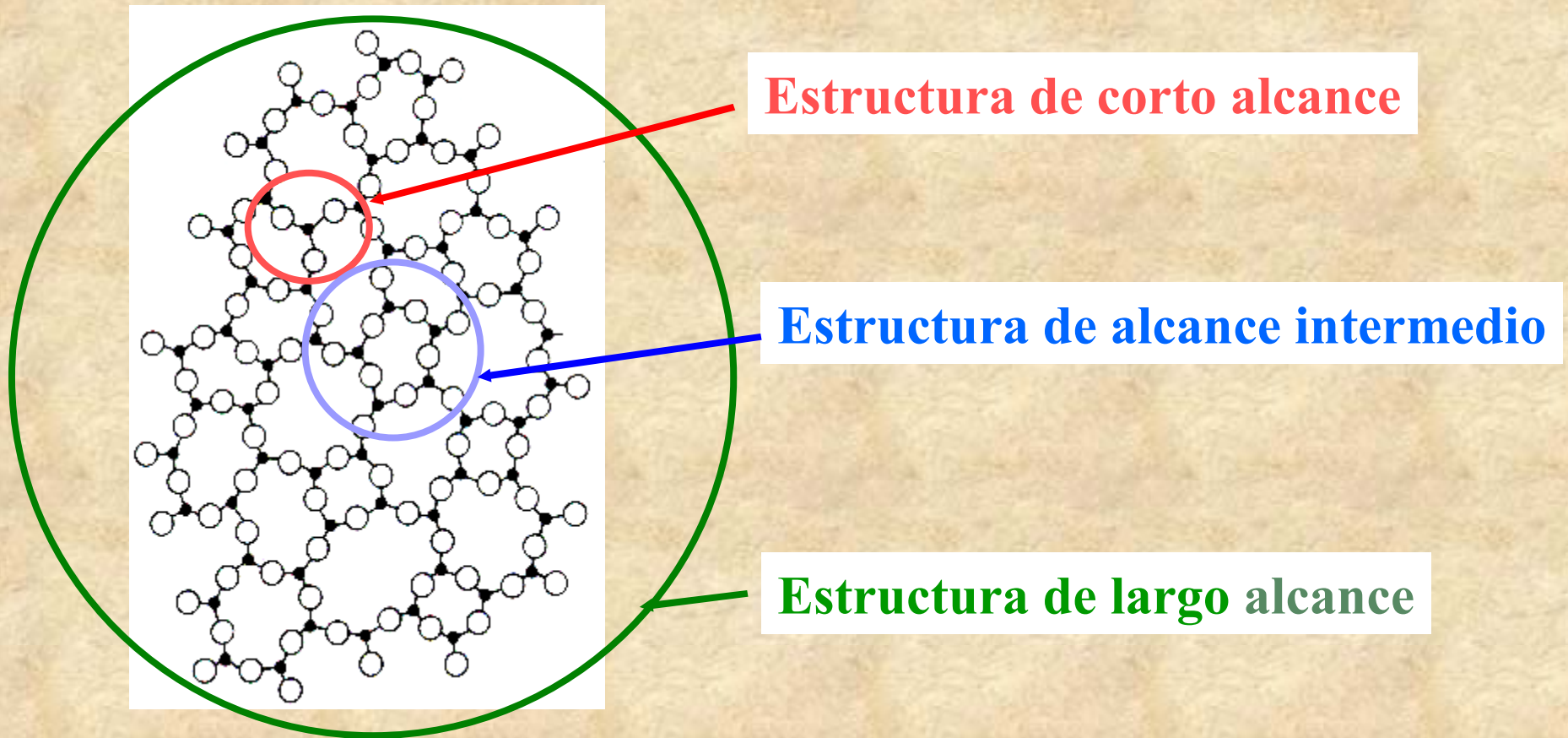
SOLIDOS

ESTRUCTURA CRISTALINA

Dr. Andres Ozols

2005

ALCANCE del ORDEN ATOMICO



TIPOS de SOLIDOS (de acuerdo al orden atómico)

AMORFOS

orden atómico o molecular de corto alcance

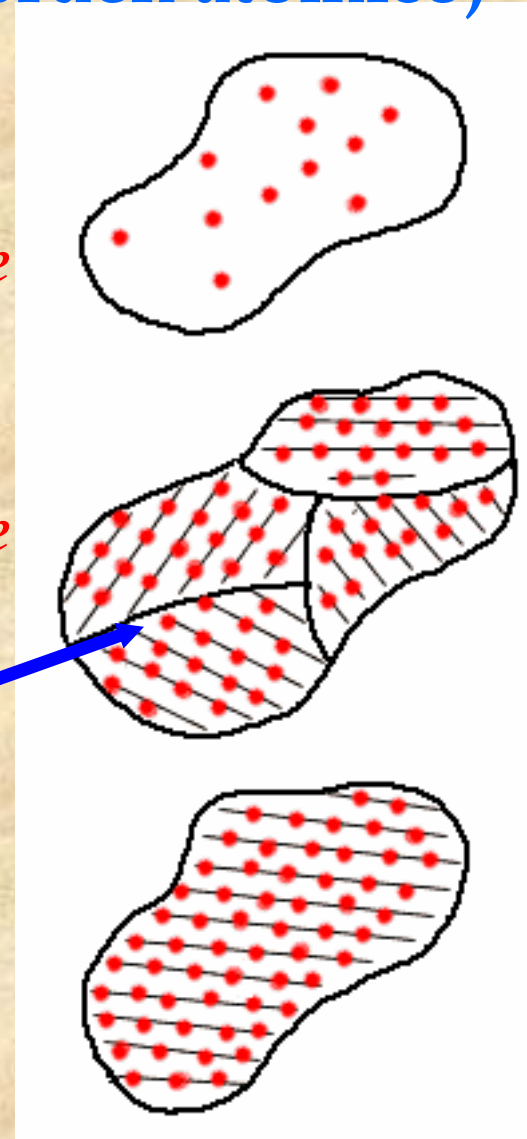
POLICRISTALINOS

orden atómico o molecular de largo alcance

forman granos o cristales separados por bordes

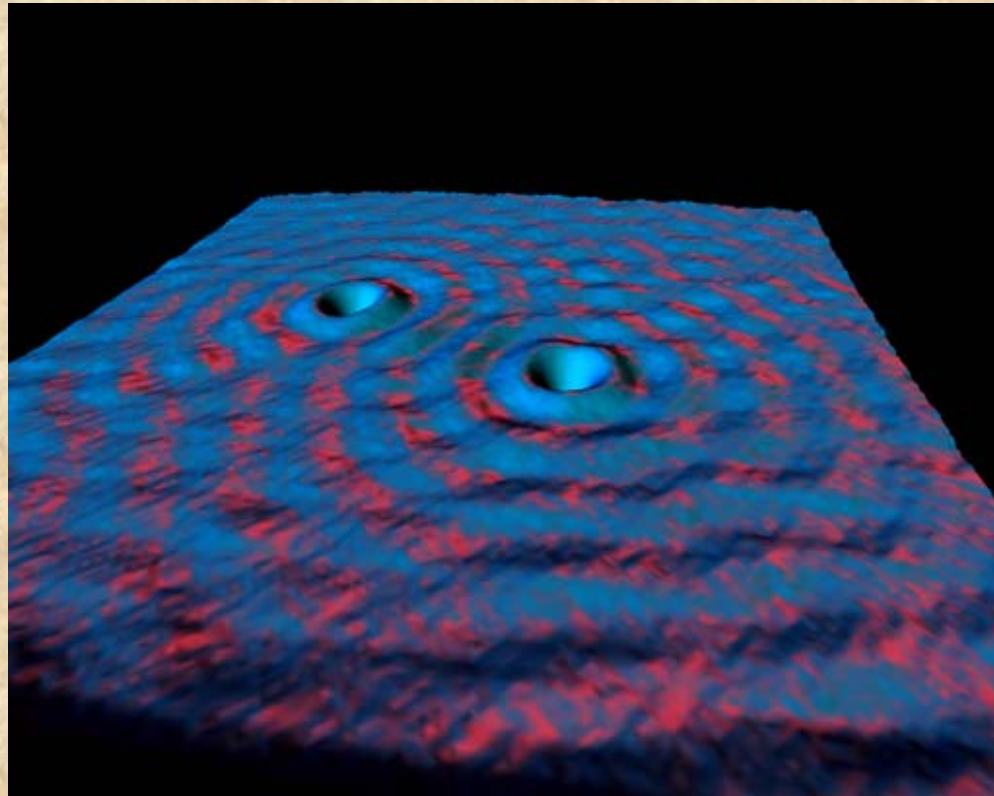
MONOCRISTALINOS

orden atómico o molecular alto en todo el cristal

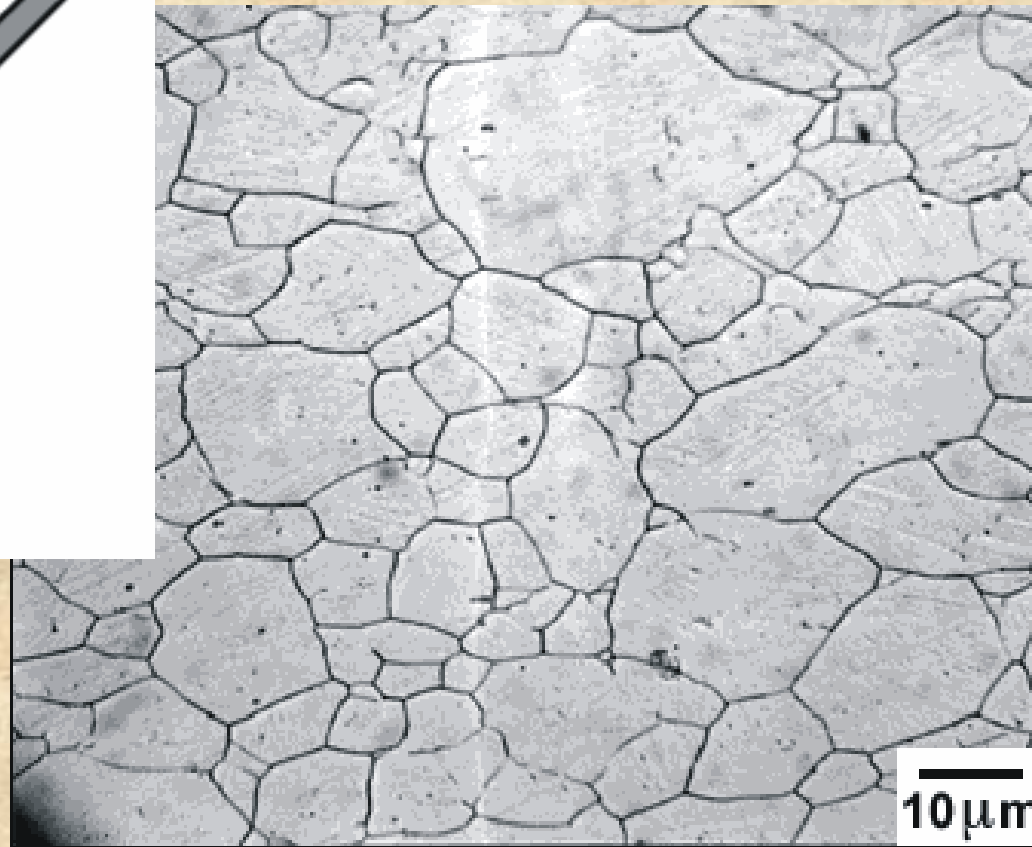
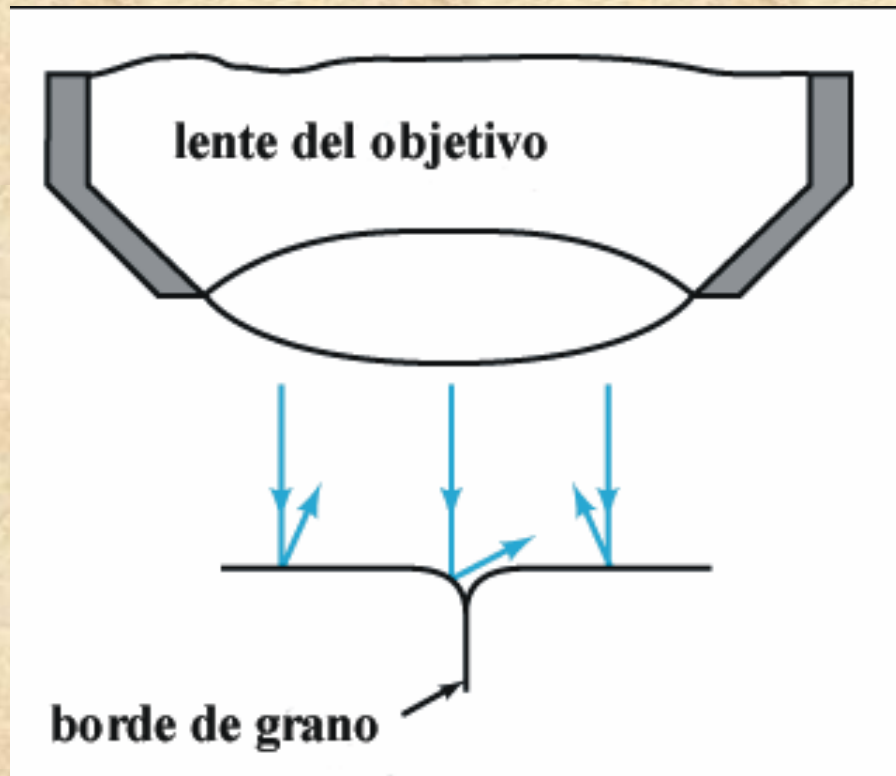


AMORFOS

orden atómico o molecular de corto alcance



ESTRUCTURA POLICRISTALINA



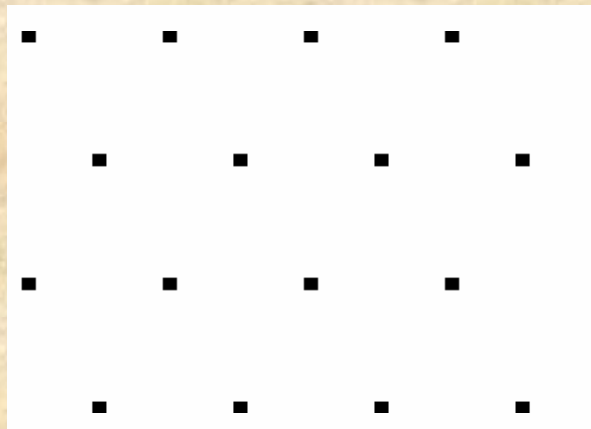
RED

+

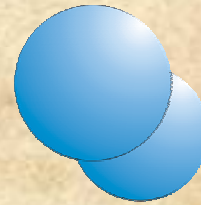
BASE

=

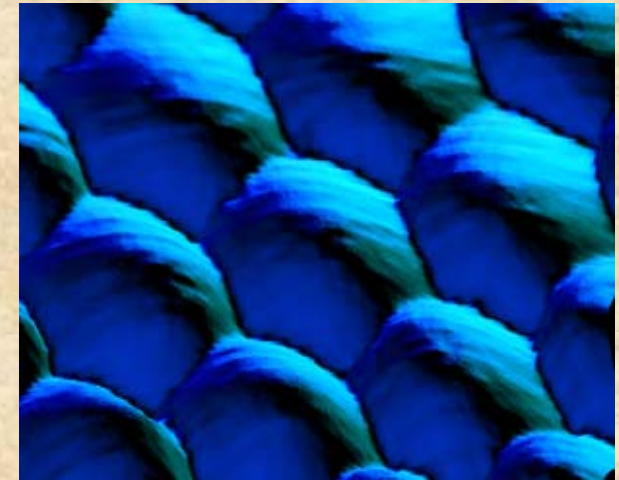
CRISTAL



+



=



Arreglo periódico de puntos + *Átomos o molécula* = *Sólido con un **arreglo periódico** de átomos o moléculas*

REDES de BRAVAIS (red matemática)

- *Conjunto de todos los puntos con posiciones definidas por*

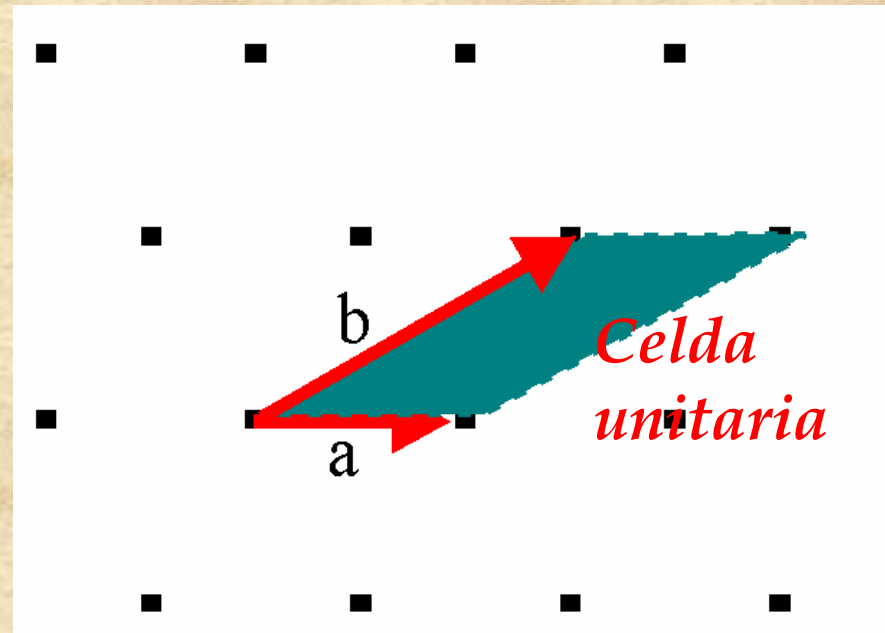
$$R = n_1 a + n_2 b + n_3 c$$

a, b y c vectores primitivos

n₁, n₂ y n₃

números enteros

- *Conjunto infinito de puntos con un arreglo y orientación que parece la misma, desde cualquier punto de observación*



- *Existen 14 redes de Bravais en 3-D*

SIMETRIA en CRISTALES

Está dada por el arreglo ordenado y periódico de átomos o grupos de átomos en varias direcciones espaciales.

Un objeto es **simétrico** \Leftrightarrow **invariante** por una transformación.

OPERACIONES de SIMETRIA

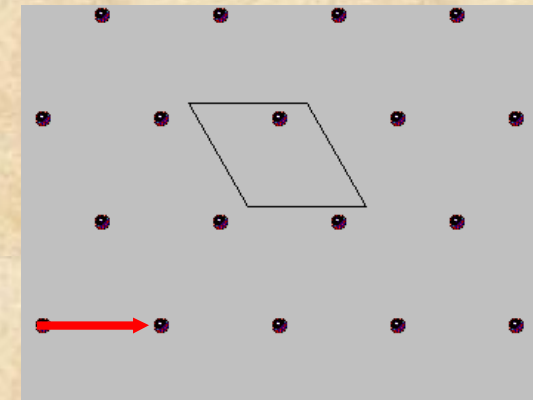
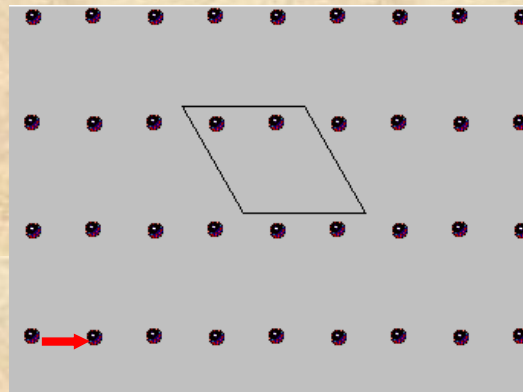
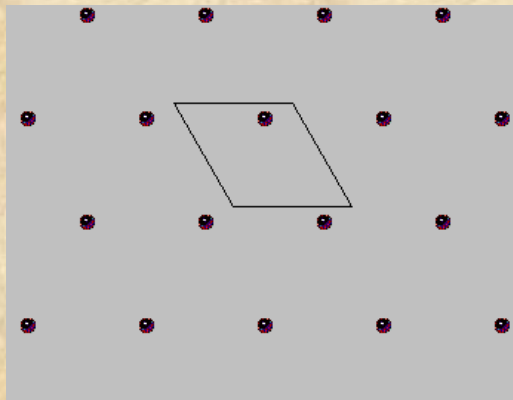
Operación matemática que lleva un átomo a otro lugar del espacio donde existe otro igual.

1. **Traslación**
2. **Reflección (simetria de espejo)**
3. **Rotación**

•Las transformaciones que dejan sin cambiar todas las distancias distancias.

•No se puede distinguir un objeto antes y despues de la transformación.

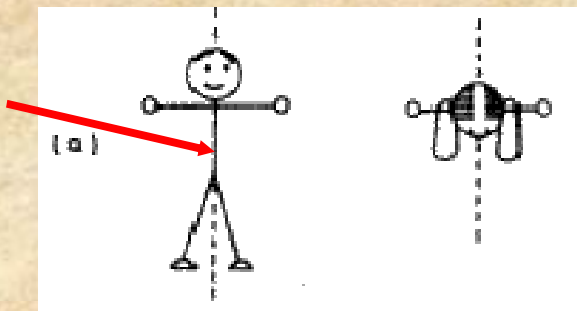
TRASLACION (*OPERACIONES de SIMETRIA*)



$$R' = R + a$$

REFLEXION (OPERACIONES de SIMETRIA)

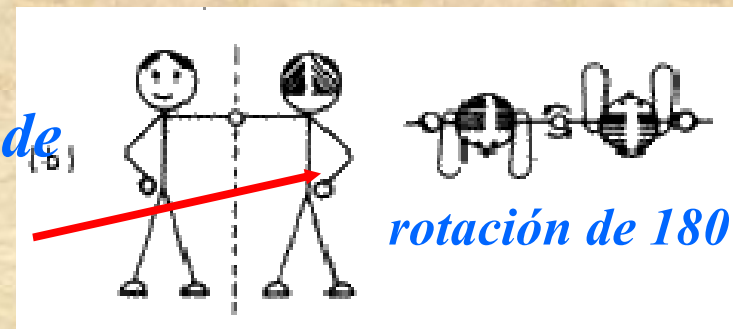
Plano de simetria



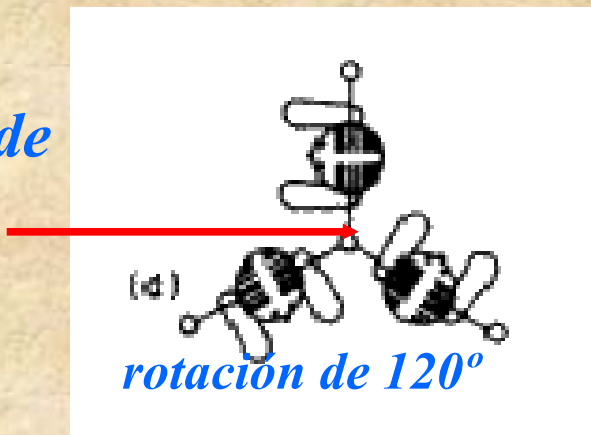
ROTACION

$(2\pi/n)$ n: orden

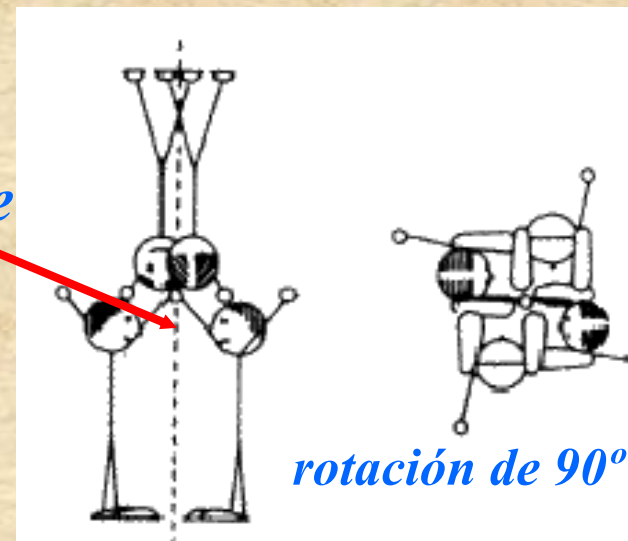
Eje de rotación de 2º orden



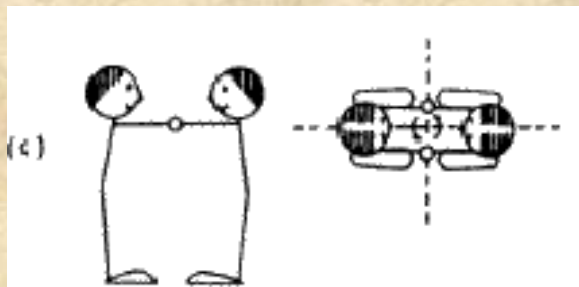
Eje de rotación de 3º orden



Eje de rotación de 4º orden



COMBINACIONES de OPERACIONES de SIMETRIA



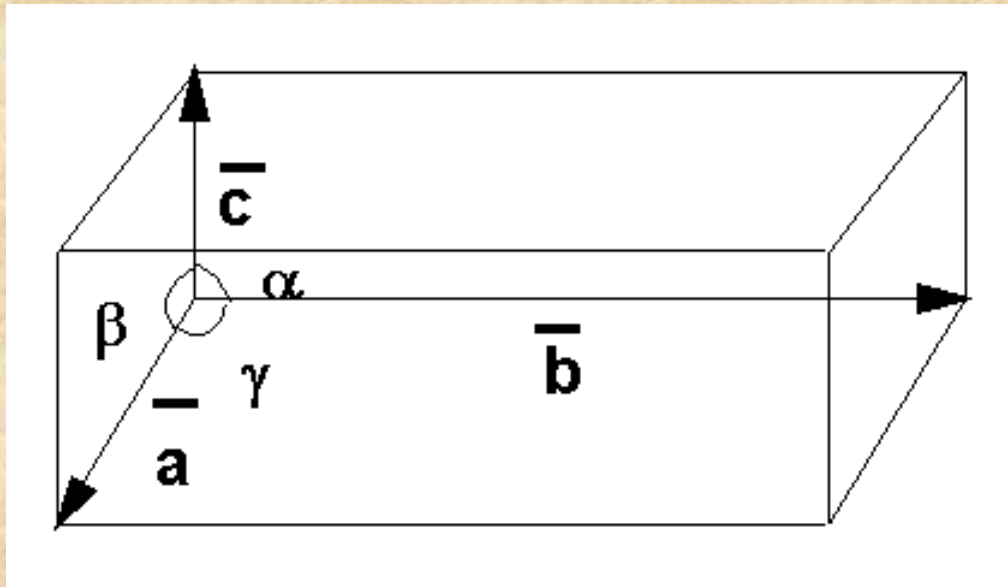
*Eje de rotación de 2°
orden+reflexión*

GRUPO PUNTUAL o CLASE de SIMETRIA

- *Conjunto de operaciones de simetría.*
- *Existen 32 grupos*

CELDA UNITARIA

Bloque fundamental repetido dentro de la red



PRIMITIVA

contiene 1 átomo

MULTIPLE

contiene más de 1 átomo

Tienen 6 parámetros característicos: 3 distancias y 3 ángulos

SISTEMAS CRISTALINOS

- *Las 14 redes de Bravais permiten 7 sistemas cristalinos.*
- *Cada sistema se caracteriza por operaciones matemáticas comunes*

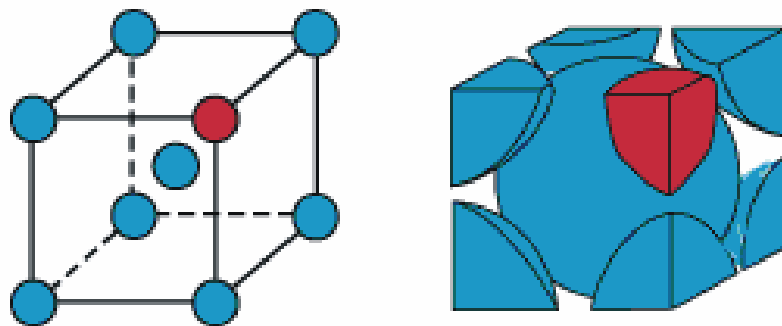
- | | |
|--------------------------|---|
| 1. SISTEMA CUBICO: | $a=b=c \quad \alpha=\beta=\chi=90^\circ$ |
| 2. SISTEMA HEXAGONAL: | $a=b \neq c \quad \alpha=\beta=90^\circ; \chi=120^\circ$ |
| 3. SISTEMA TRIGONAL: | $a=b \neq c \quad \alpha=\beta=90^\circ; \chi=120^\circ$ |
| SISTEMA TRIGONAL : | $a=b=c \quad 90^\circ \neq \alpha=\beta=\chi$ ROMBOEDRICO |
| 4. SISTEMA TETRAGONAL: | $a=b \neq c \quad \alpha=\beta=\chi=90^\circ$ |
| 5. SISTEMA ORTORROMBICO: | $a \neq b \neq c \quad \alpha=\chi=90^\circ; \beta \neq 90^\circ$ |
| 6. SISTEMA MONOCLINICO: | $a \neq b \neq c \quad \alpha \neq \beta \neq \chi \neq 90^\circ$ |
| 7. SISTEMA TRICLINICO: | $a \neq b \neq c$ |

REDES de BRAVAIS en 3D

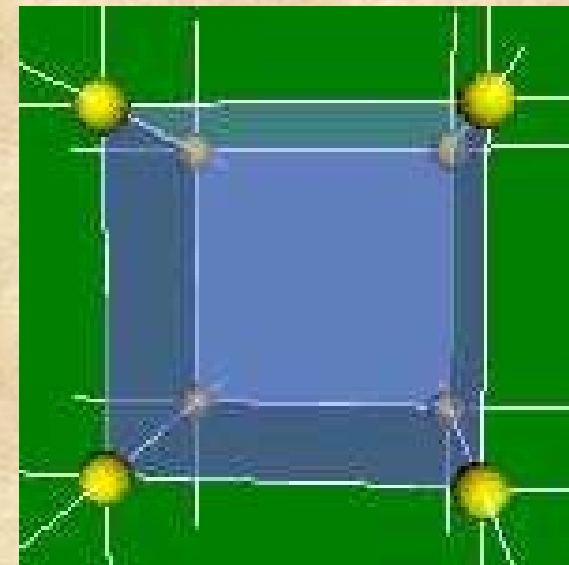
RED CUBICA (3 tipos)

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

RED CUBICA de CUERPO CENTRADO (B.C.C.)

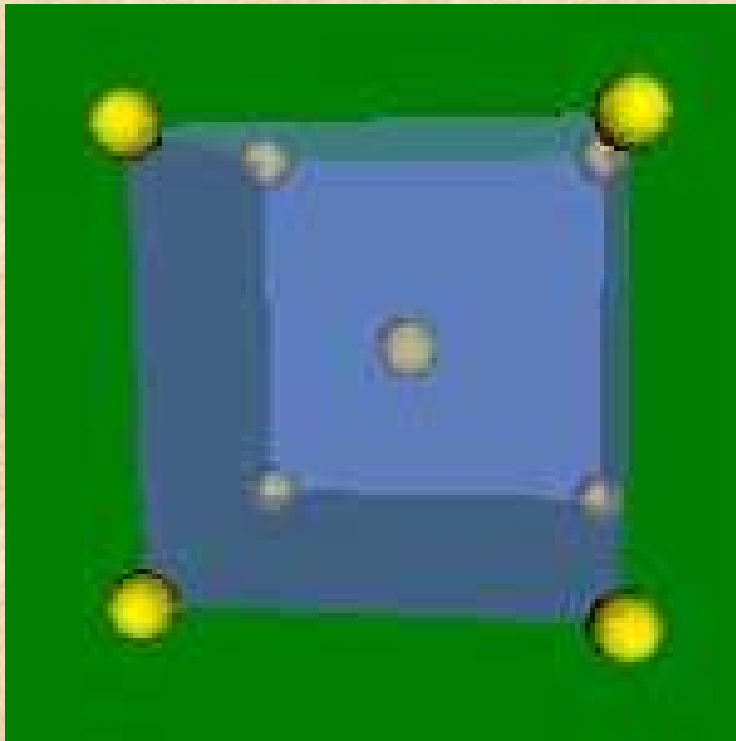


RED CUBICA SIMPLE

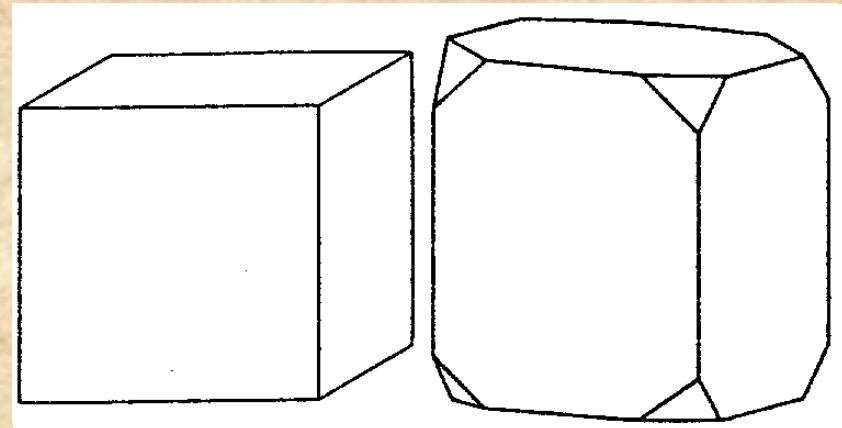


REDES de BRAVAIS en 3D

RED CUBICA de CARAS
CENTRADAS (F.C.C.)



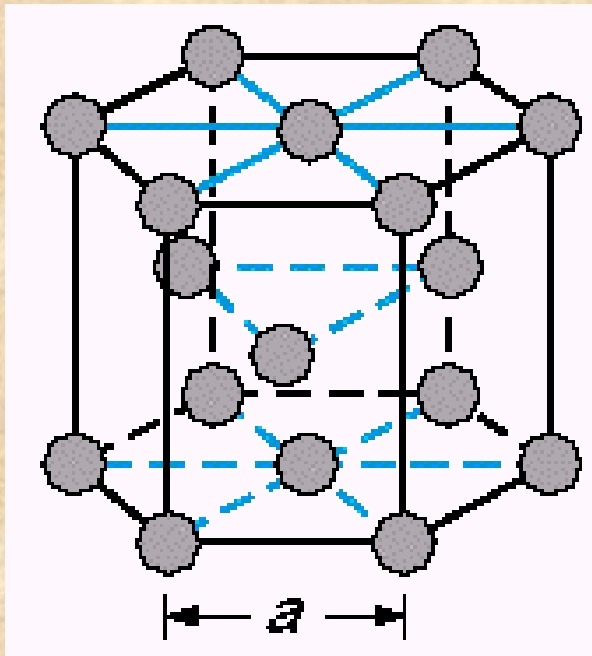
CRISTAL CUBICO



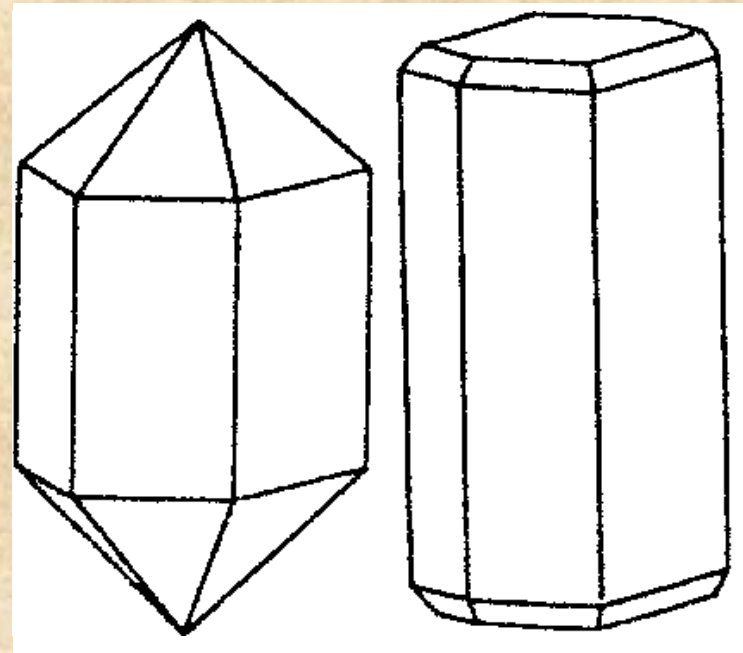
REDES de BRAVAIS en 3D

RED HEXAGONAL

$$a=b \neq c \quad \alpha=\beta=90^\circ; \gamma=120^\circ$$



CRISTAL HEXAGONAL



REDES de BRAVAIS

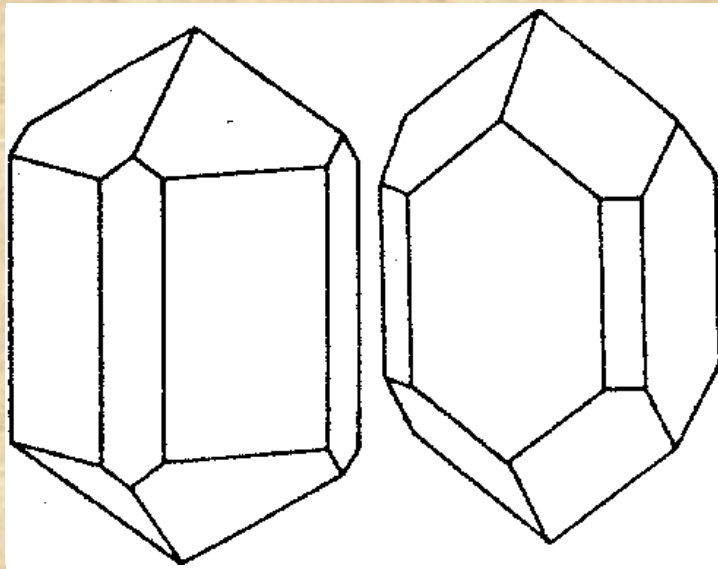
RED TRIGONAL $a=b \neq c$

$$\alpha=\beta=90^\circ; \chi=120^\circ$$

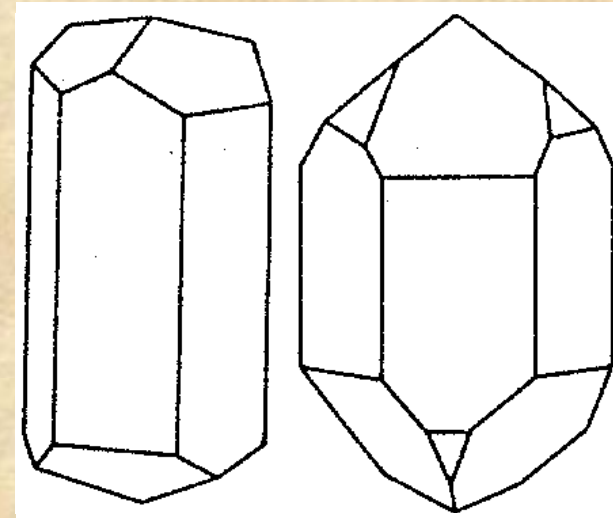
CRISTAL TRIGONAL

RED TRIGONAL ROMBOEDRICO

$$a=b=c \quad 90^\circ \neq \alpha=\beta=\chi < 120^\circ$$



CRISTAL TETRAGONAL

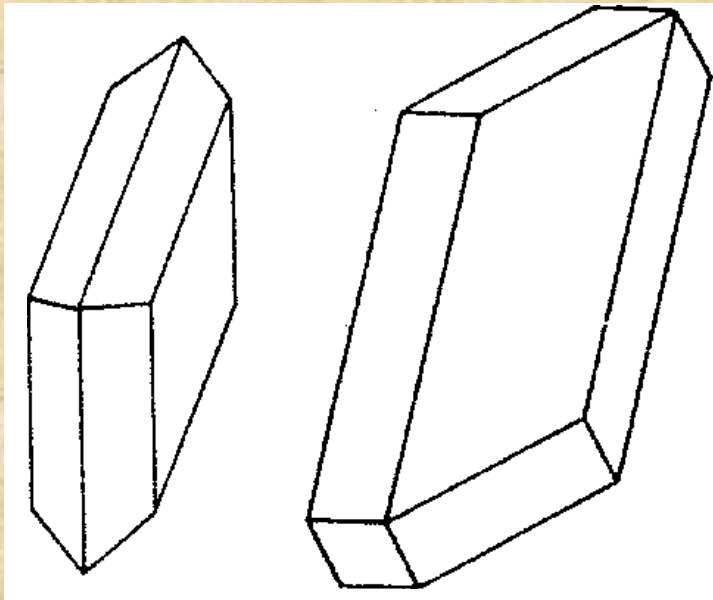


RED TETRAGONAL $a=b \neq c \quad \alpha=\beta=\chi=90^\circ$

REDES de BRAVAIS

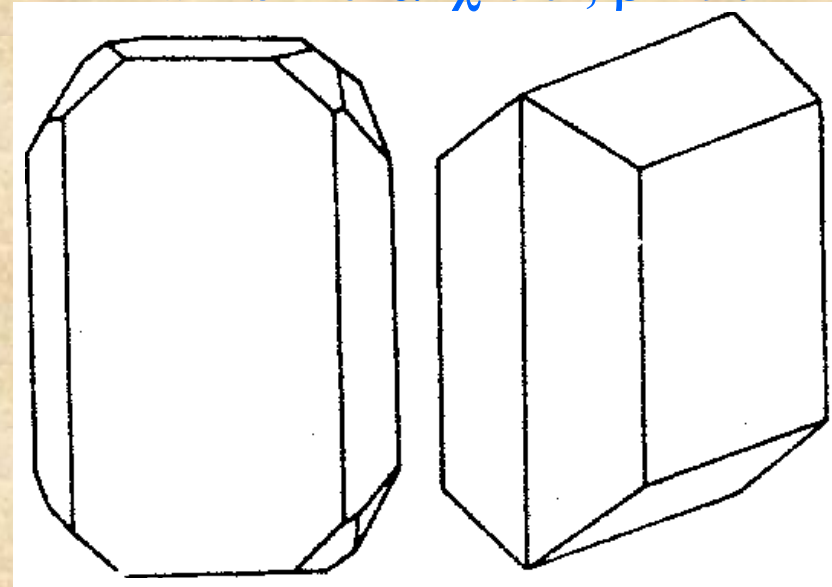
RED ORTORROMBICA

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



CRISTAL ORTORROMBICO

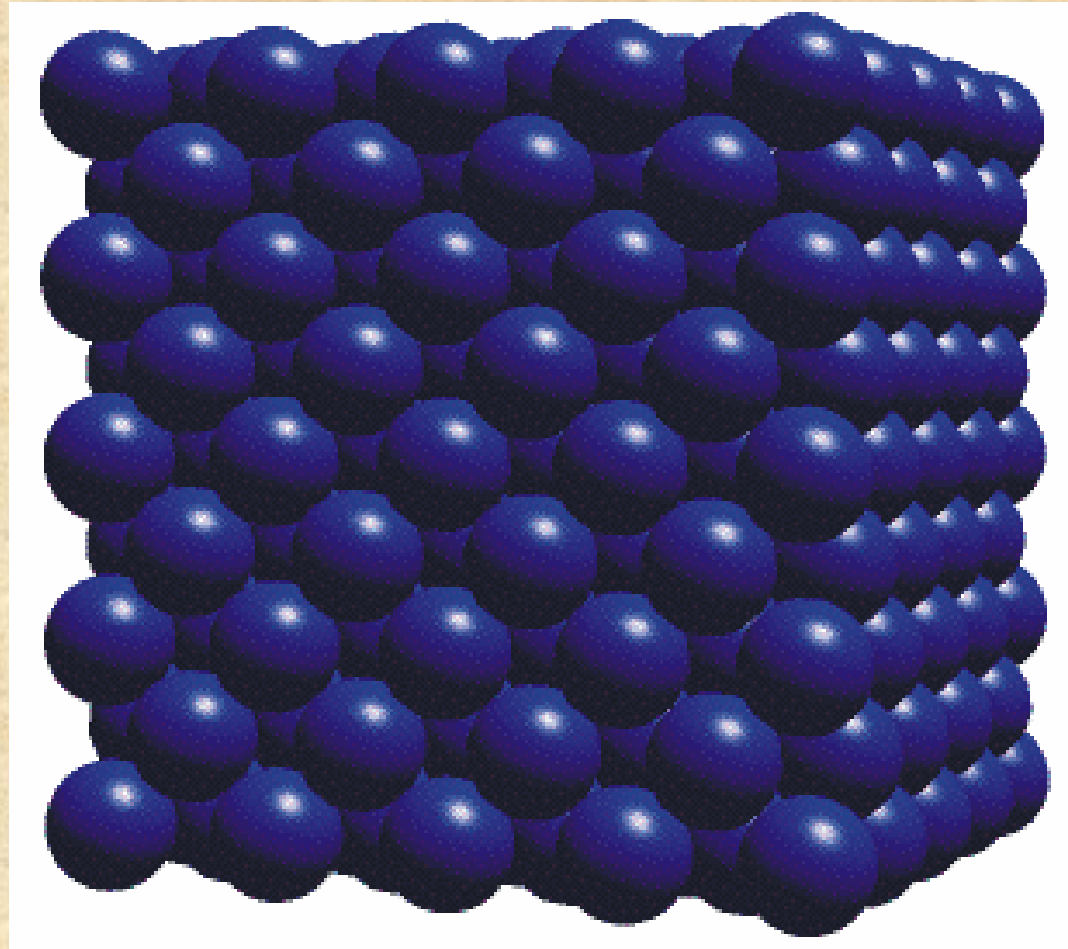
$$a \neq b \neq c \quad \alpha = \gamma = 90^\circ; \beta \neq 90^\circ$$



RED MONOCLINICA

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

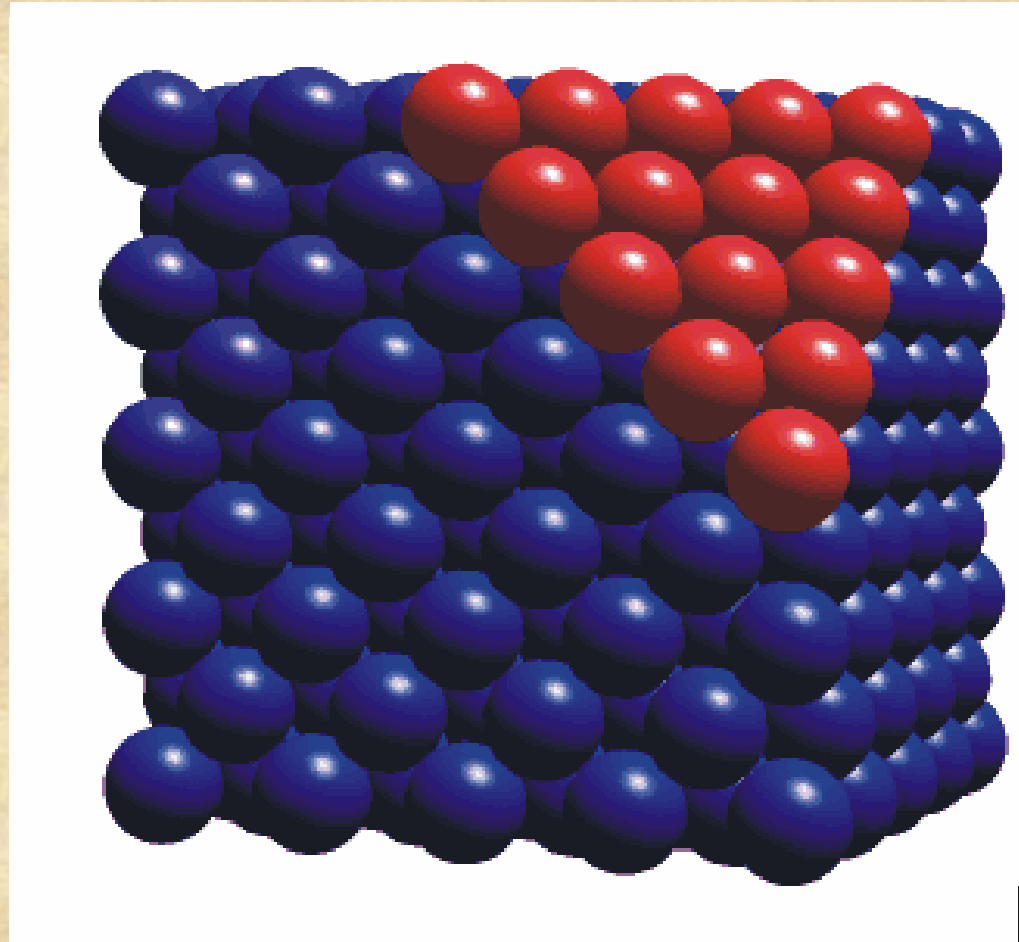
ORDENAMIENTO ATÓMICO



ORDENAMIENTO FCC

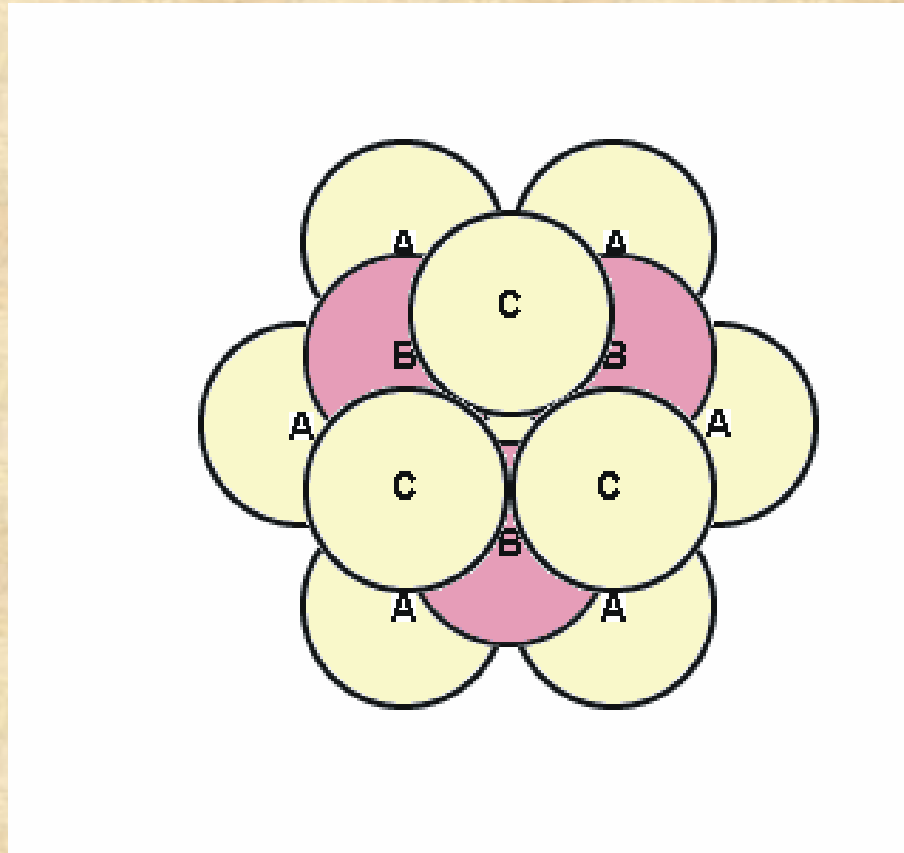
Celda unitaria

Simetría cúbica



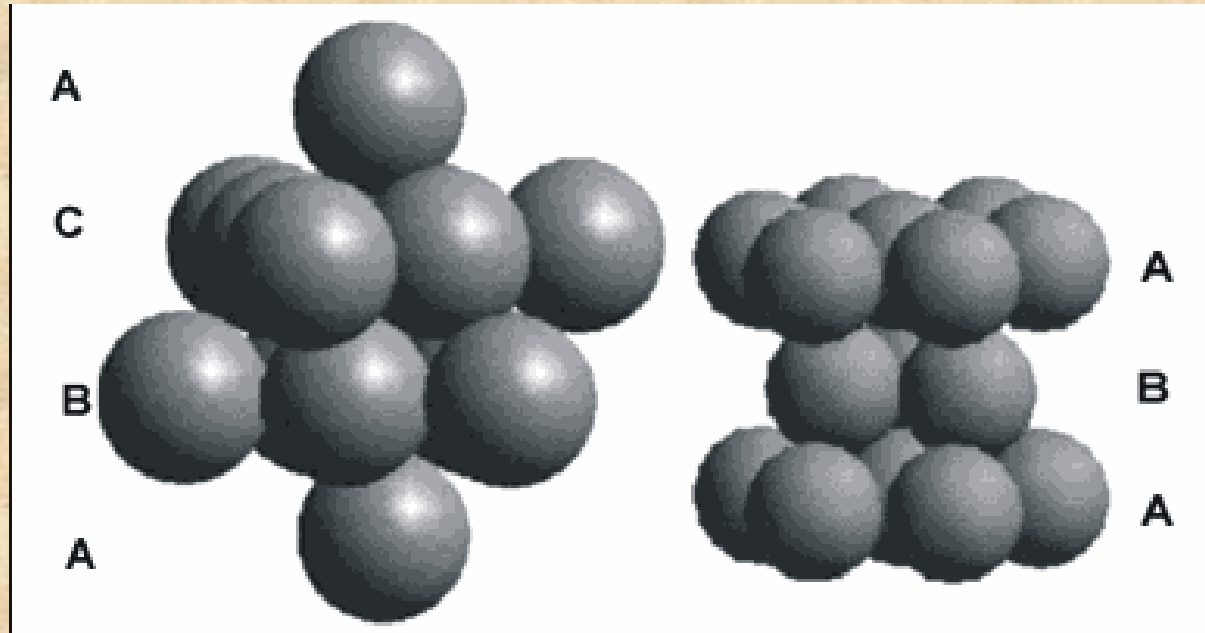
APILAMIENTO FCC

Apilamiento en capas compactas



APILAMIENTO HEXAGONAL COMPACTO HCP

ABABA..



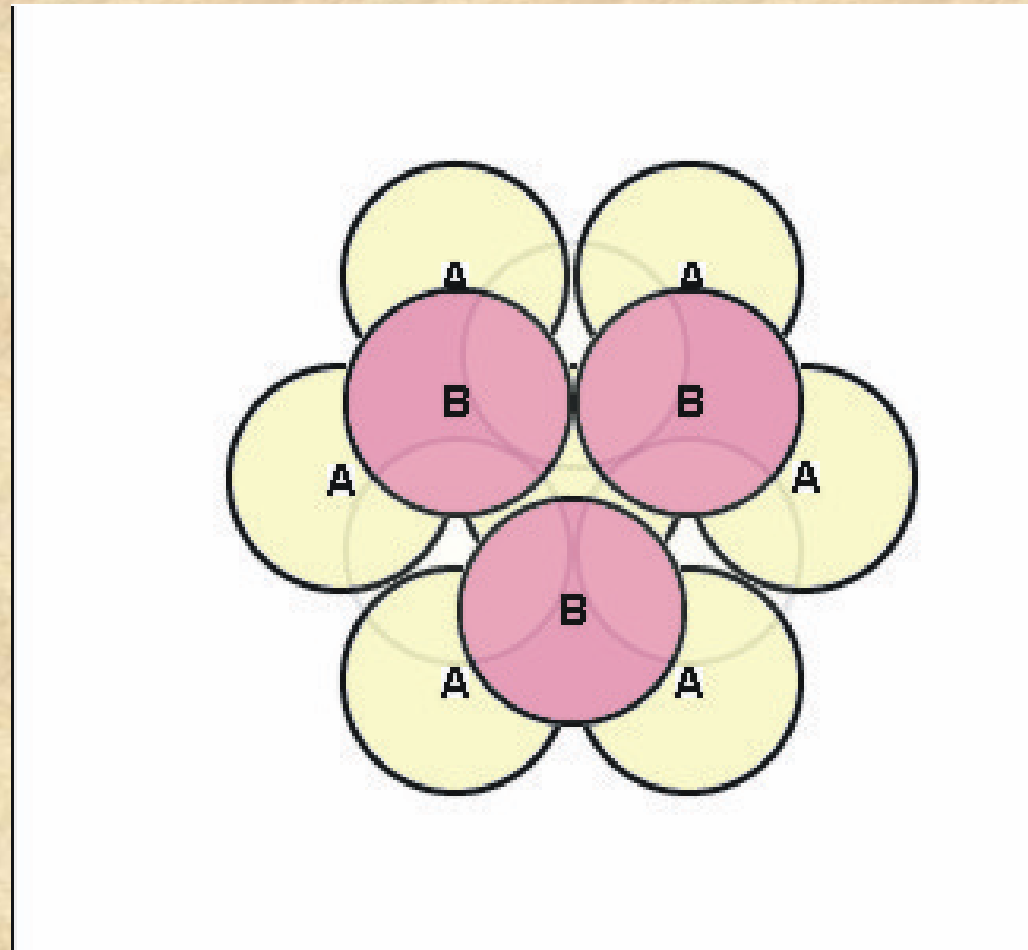
En vez de ABACABC..

Simetría hexagonal

Hexagonal compacta o HCP

ORDENAMIENTO HCP

ABABABA ...



ESTRUCTURA de los METALES

METALES FCC

Co, Fe, Ni, Cu, Ag, Au, Pt, Al,...

METALES HCP

Zn, Cd, Mg, ...

METALES BCC

Cr, Fe, V, K... Periodic Table of the Elements

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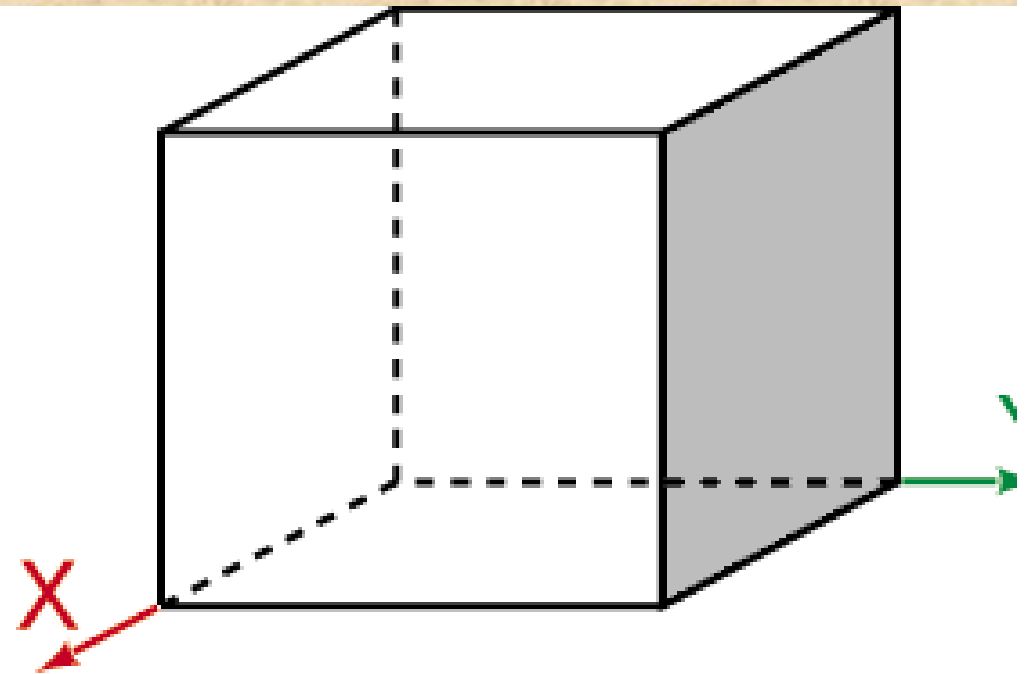
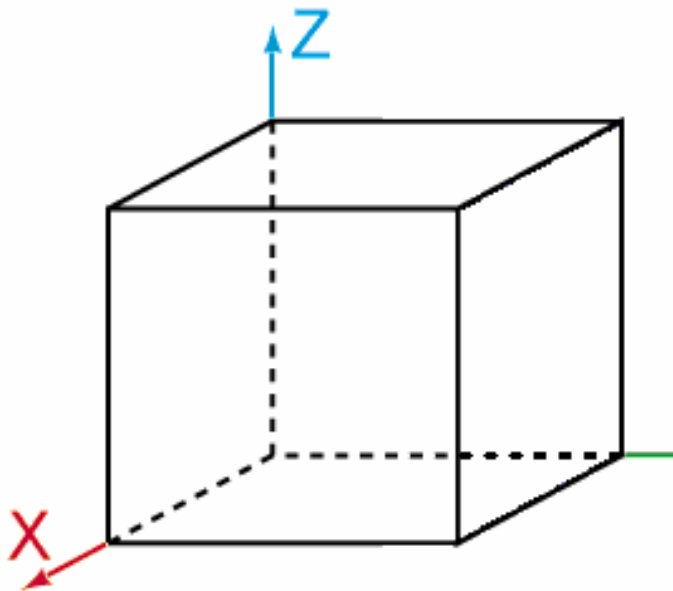
- c-cubic
- f-face-centered cubic
- b-body-centered cubic
- r-rhombohedral
- d-diamond cubic
- t-tetragonal
- m-monoclinic
- t-tetragonal

59	60	61	62	63	64	65	66	67	68	69	70	71																																																																																																																																																																																																																																																																																																																																				
Ce 140.12	Pr 140.91	Nd 144.24	Pm (147)	Sm 150.35	Eu 151.96	Gd 157.25	Tb 158.93	Dy 162.50	Ho 164.93	Er 167.26	Tm 168.93	Yb 173.04	Lu 174.97																																																																																																																																																																																																																																																																																																																																			
89	90	91	92	93	94	95	96	97	98	99	100	101	102	103	104	105	106	107	108	109	110	111	112	113	114	115	116	117	118	119	120	121	122	123	124	125	126	127	128	129	130	131	132	133	134	135	136	137	138	139	140	141	142	143	144	145	146	147	148	149	150	151	152	153	154	155	156	157	158	159	160	161	162	163	164	165	166	167	168	169	170	171	172	173	174	175	176	177	178	179	180	181	182	183	184	185	186	187	188	189	190	191	192	193	194	195	196	197	198	199	200	201	202	203	204	205	206	207	208	209	210	211	212	213	214	215	216	217	218	219	220	221	222	223	224	225	226	227	228	229	230	231	232	233	234	235	236	237	238	239	240	241	242	243	244	245	246	247	248	249	250	251	252	253	254	255	256	257	258	259	260	261	262	263	264	265	266	267	268	269	270	271	272	273	274	275	276	277	278	279	280	281	282	283	284	285	286	287	288	289	290	291	292	293	294	295	296	297	298	299	300	301	302	303	304	305	306	307	308	309	310	311	312	313	314	315	316	317	318	319	320	321	322	323	324	325	326	327	328	329	330	331	332	333	334	335	336	337	338	339	340	341	342	343	344	345	346	347	348	349	350	351	352	353	354	355	356	357	358	359	360	361	362	363	364	365	366	367	368	369	370	371	372	373	374	375	376	377	378	379	380	381	382	383	384	385	386	387	388	389	390	391	392	393	394	395	396	397	398	399	400	401	402	403	404	405	406	407	408	409	410	411	412	413	414	415	416	417	418	419	420	421	422	423	424	425

PLANOS en un CRISTAL CÚBICO

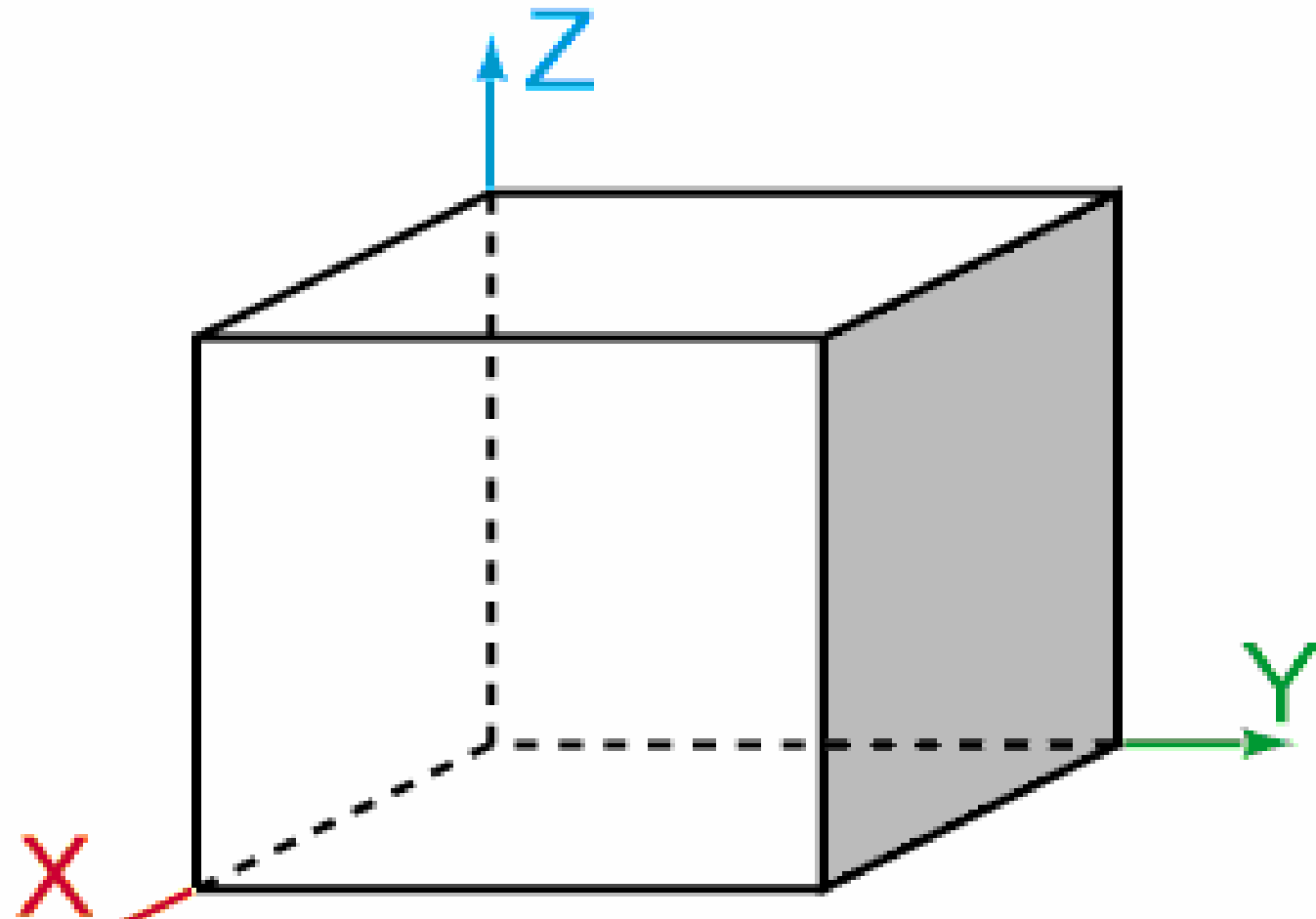
INDICES de MILLER

Ejes de coordenadas



XYZ Intersecta $\infty, 1, \infty$

INDICES de MILLER

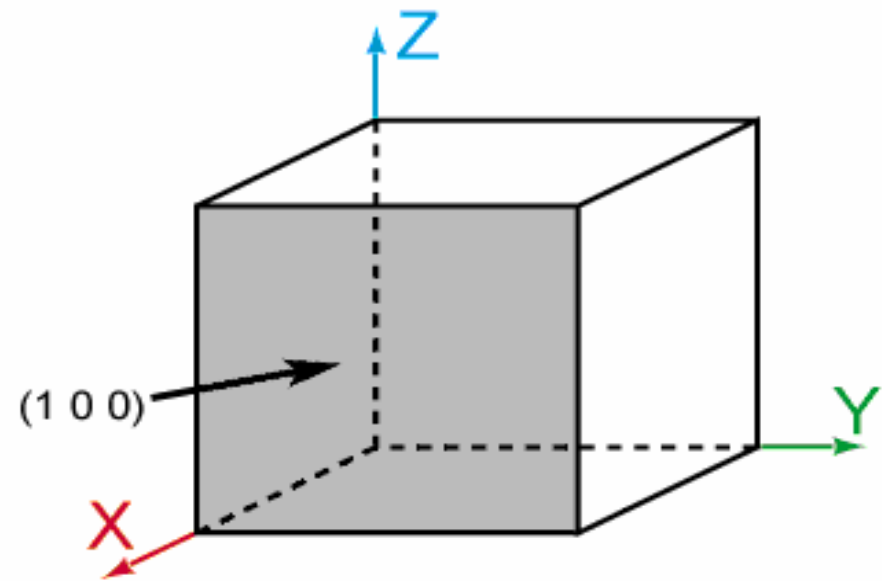
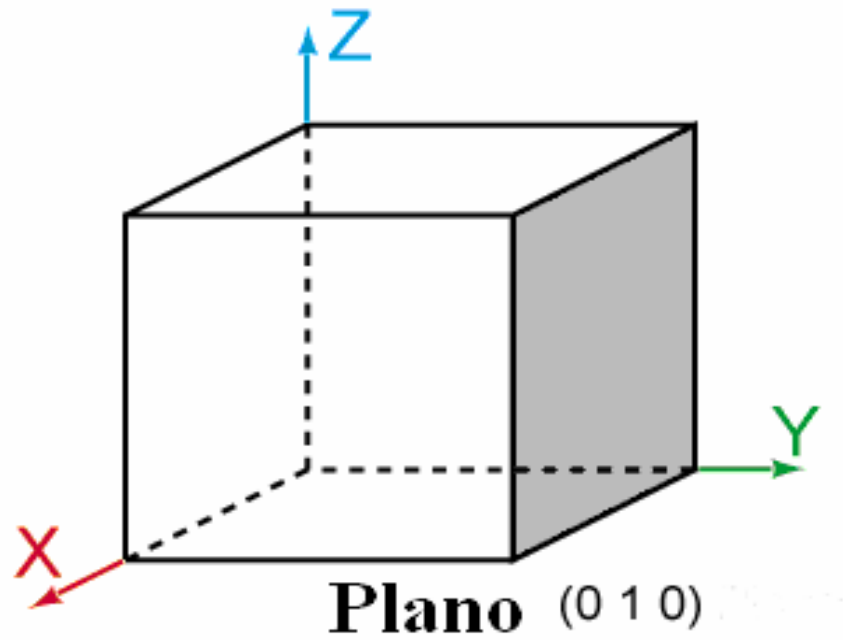


recíprocos de intersecciones

$$\frac{1}{\infty} \quad \frac{1}{1} \quad \frac{1}{\infty}$$

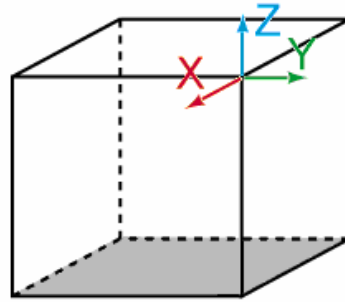
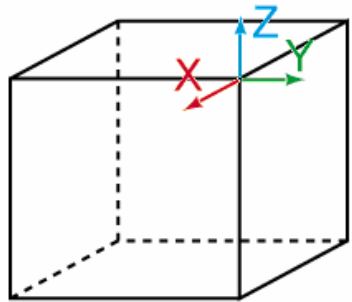


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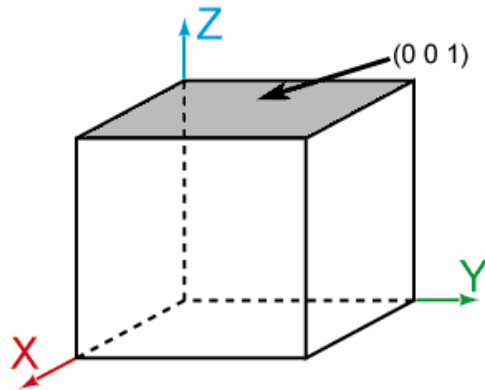


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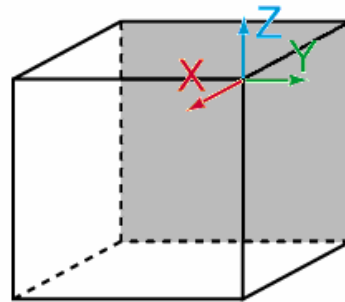
Planos de la celda cúbica



$(00\bar{1})$

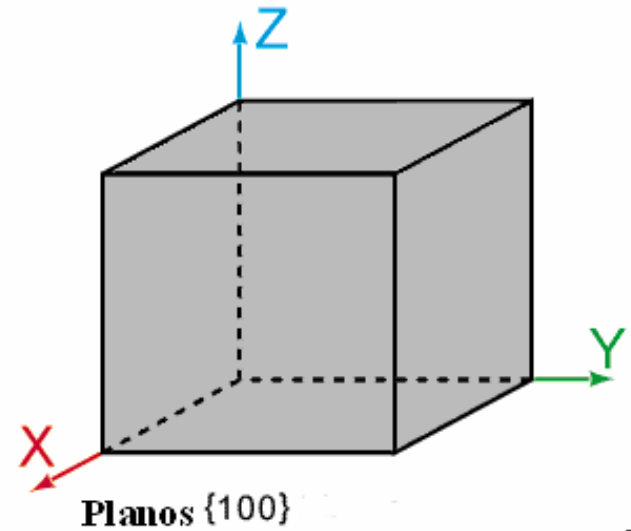


(001)



$(\bar{1}00)$

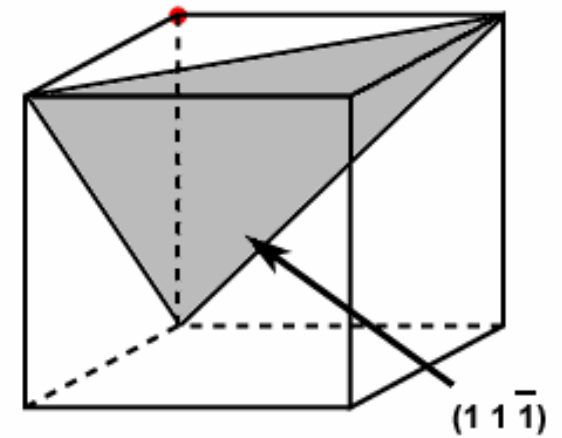
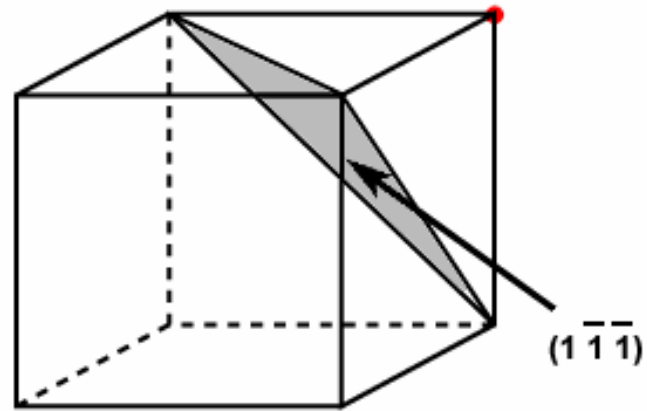
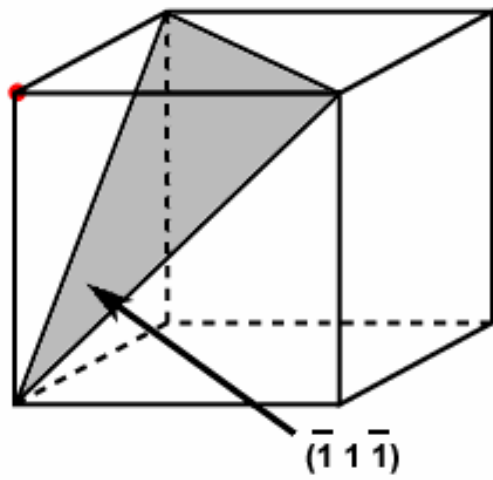
Familia de planos $\{100\}$



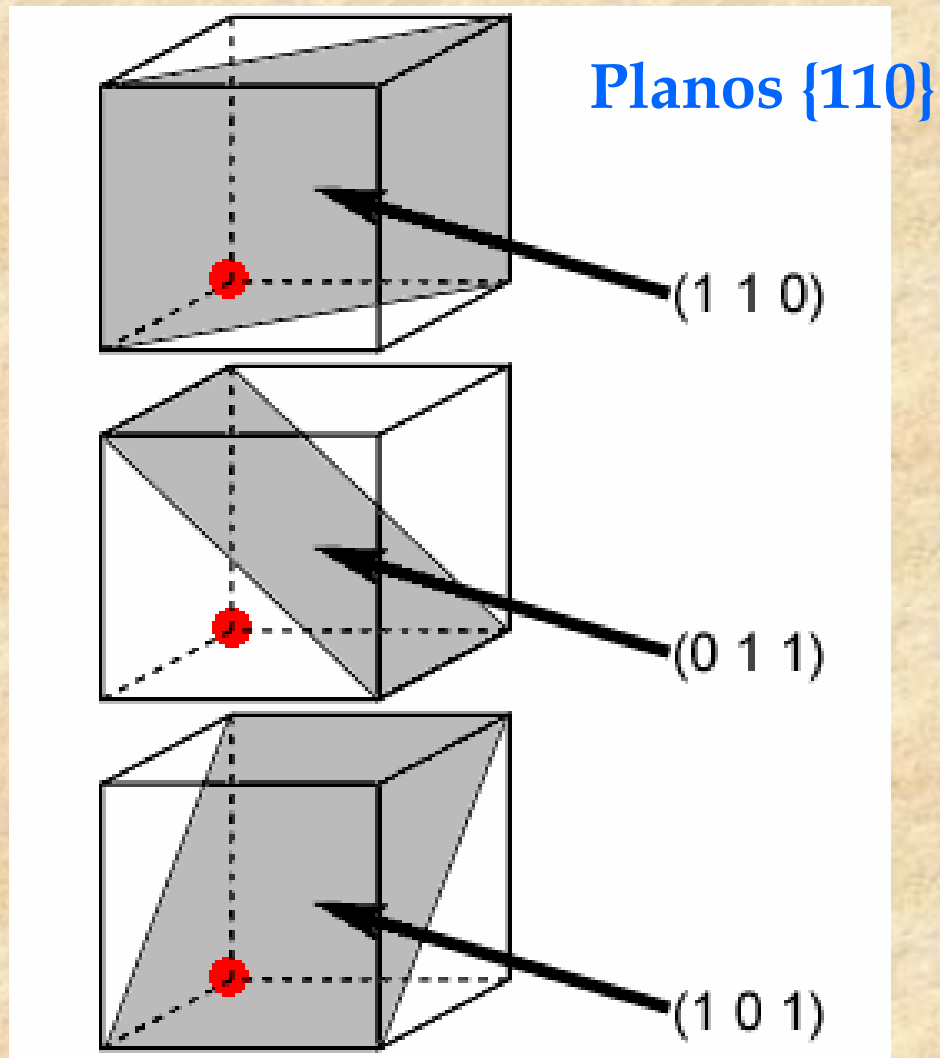
Planos $\{100\}$

INDICES de MILLER

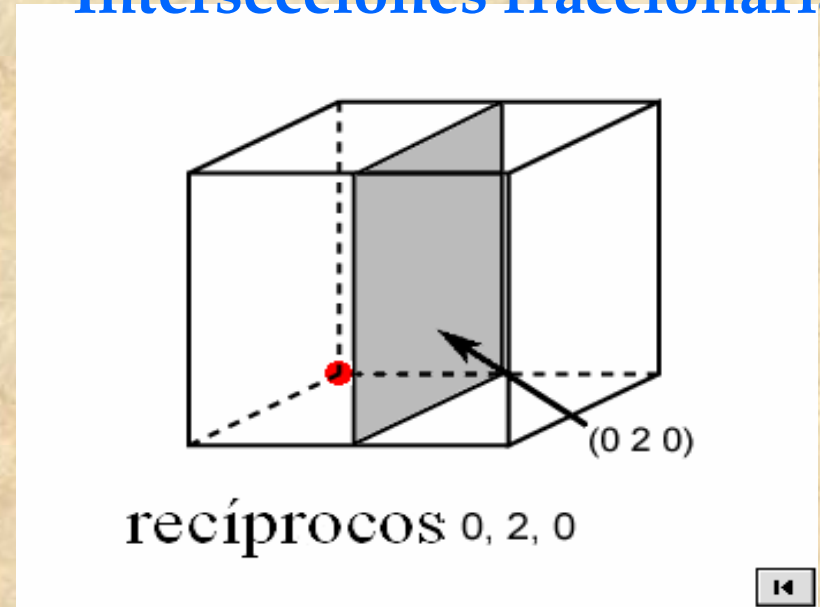
Planos {111}



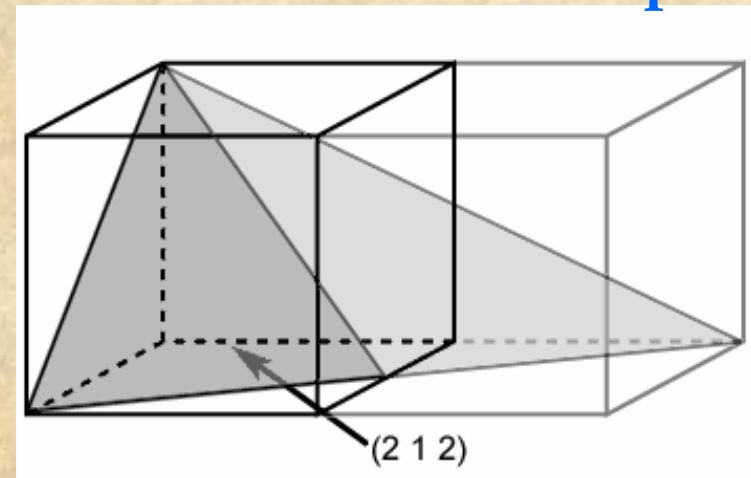
INDICES de MILLER



Intersecciones fraccionarias

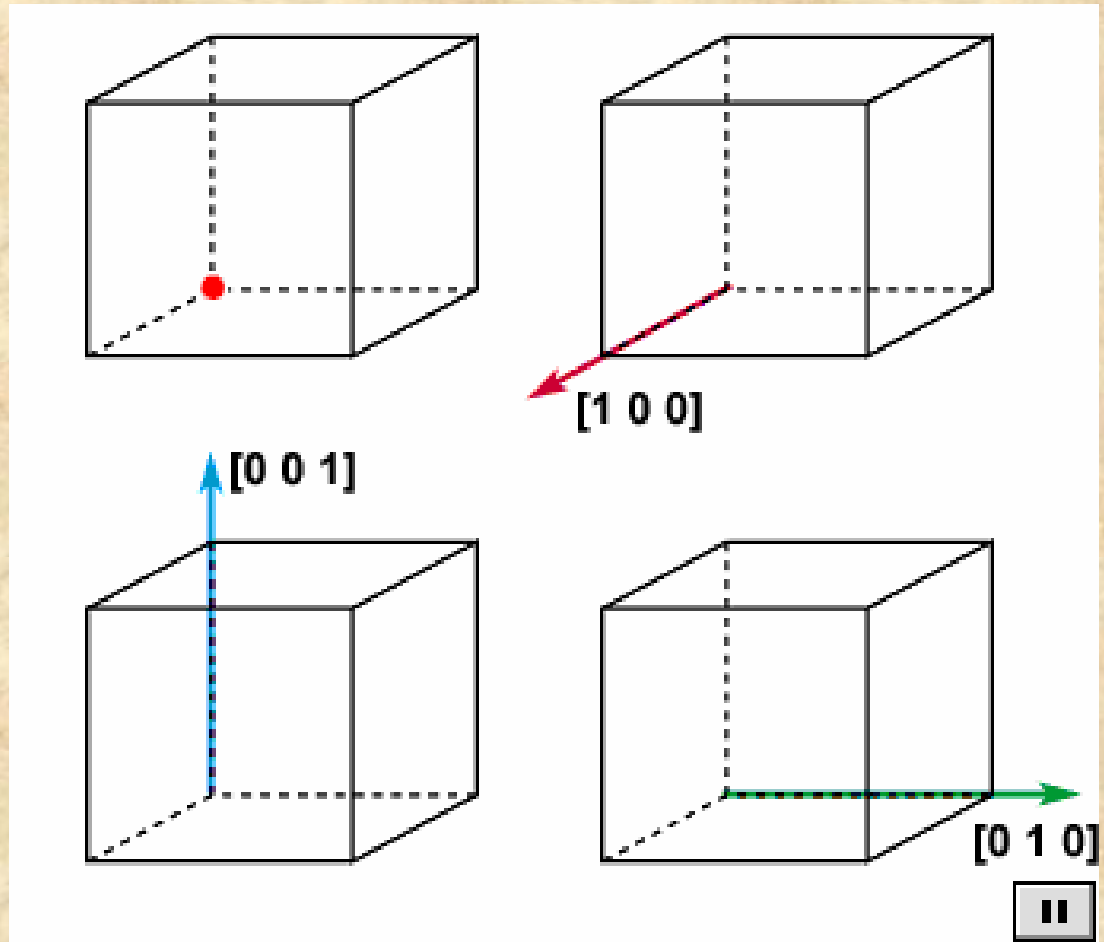


Intersecciones múltiples



INDICES de MILLER

Familia de direcciones $\langle 100 \rangle$



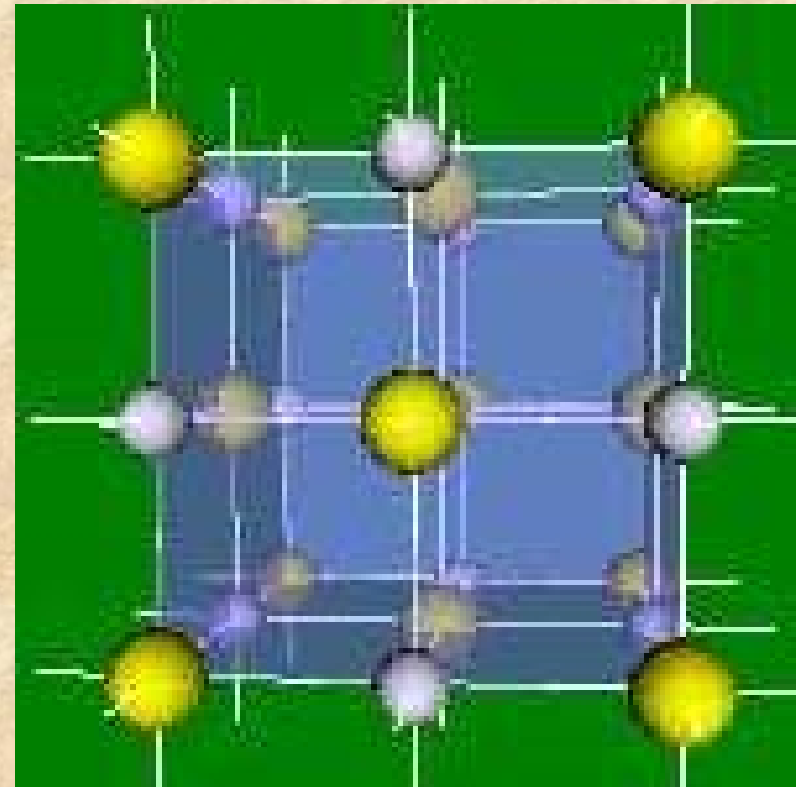
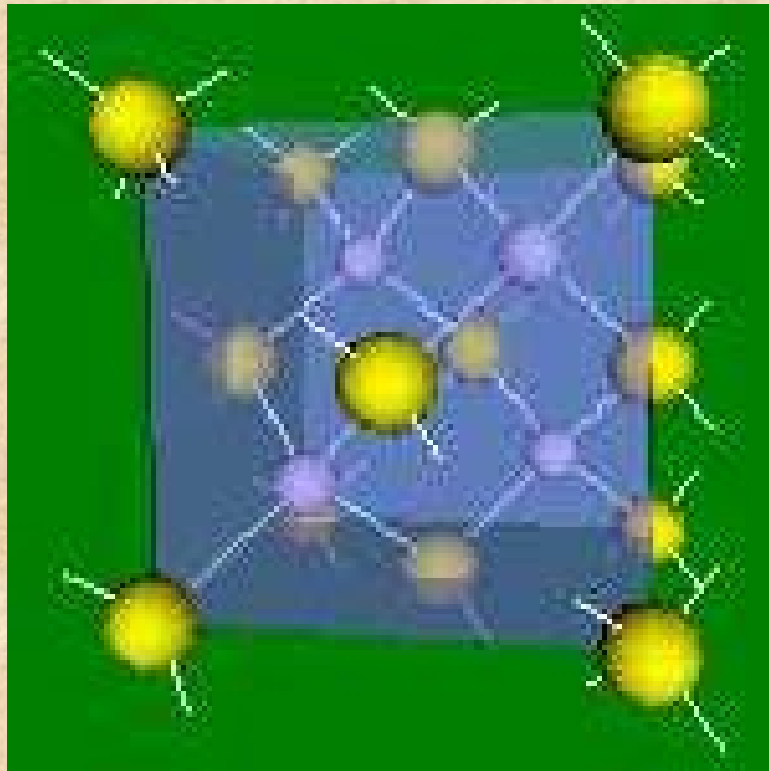
Eje X

Eje Z

Eje Y

REDES CRISTALINAS REALES

ClNa (KClMgO, BaO, etc)



AsGa (ZnS, InAs, InP, AlAs, Diamante,
Ge, Si, etc)