Estructura de la Materia 2

Clase 1 - Teoría

Docentes

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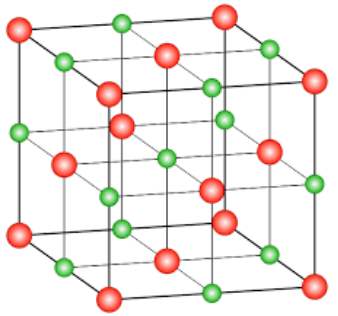
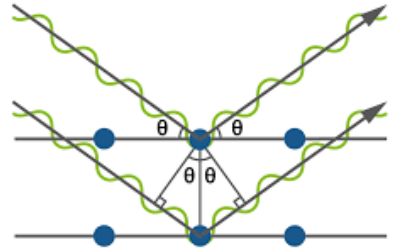
Departamento de Física, FCEN, UBA – Segundo Cuatrimestre, 2022

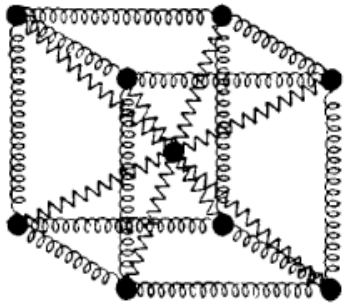
Web: http://materias.df.uba.ar/edlm2a2022c2

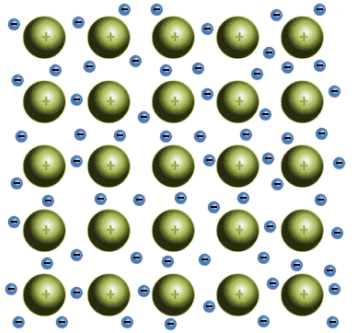
Programa de la materia

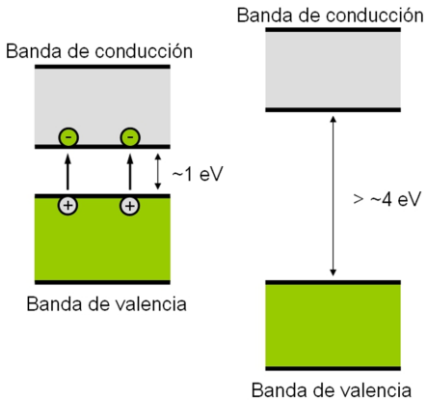
- Red cristalina, red recíproca y difracción de rayos X
- Clasificación de los sólidos y energía de cohesión
- Vibraciones, fonones y propiedades térmicas
- Electrones en sólidos (potencial periódico)
- Semiconductores y juntura semiconductora
- Magnetismo en sólidos
- Introducción a los aisladores topológicos

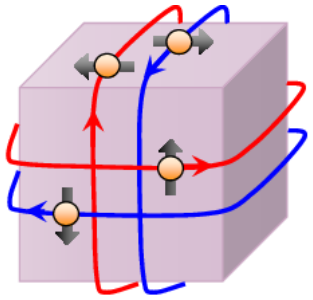












Cronograma de la materia

Semana	Teórica (M)	Práctica (V)
1 (15/08)	Red cristalina y red recíproca*	Guía 1
2 (22/08)	Planos de la red y difracción de rayos X	Guía 1
3 (29/08)	Cohesión en sólidos	Guía 2
4 (05/09)	Dinámica de redes (virtual)	Guía 2
5 (12/09)	Fonones y propiedades térmicas (virtual)	Guía 3
6 (19/09)	Electrones libres y electrones de Bloch	Guía 3
7 (26/09)	-	-
8 (03/10)	Primer Parcial	-
9 (10/10)	Electrones en un potencial débil	Guía 4
10 (17/10)	Modelo de enlaces fuertes	Guía 5
11 (24/10)	Dinámica de electrones y Efecto Hall*	Guía 6
12 (31/10)	Semiconductor intrínseco y extrínseco	Guía 7
13 (07/11)	Juntura semiconductora	Guía 7
14 (14/11)	Magnetismo localizado	Guía 8
15 (21/11)	Dominios y magnetismo itinerante	Guía 8
16 (28/11)	Aisladores topológicos	Segundo Parcial
- (05/12)	Primer recuperatorio	-
- (12/12)	Segundo recuperatorio	-

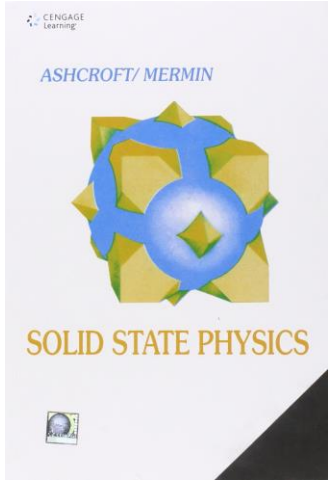
*La clase se completa durante la primera mitad de la clase del viernes.

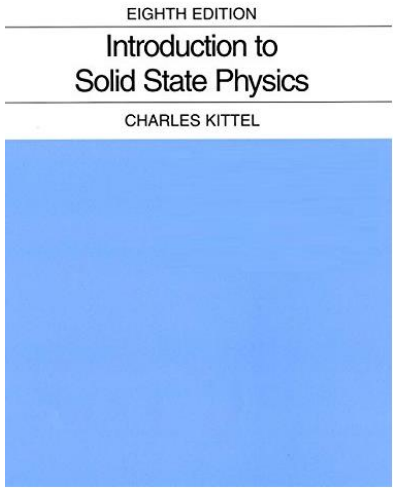
Régimen de promoción:

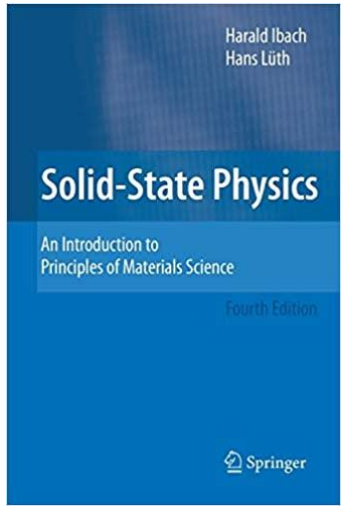
Dos parciales con un recuperatorio c/u al final del cuatrimestre. Examen final.

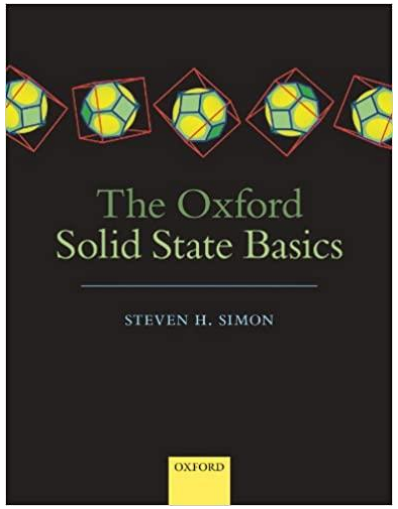
Literatura

- *Solid State Physics*, N. Ashcroft & N. Mermin
- *Introduction to solid state physics*, C. Kittel
- *The Oxford Solid State Basics*, S. Simon
- *Solid State Physics*, Ibach & Luth
- *Topological Insulators*, M. Franz & L. Molenkamp
- …









Material digital

- Clases Prof. A. Camjayi, DF-UBA (1C 2021)

  https://www.youtube.com/playlist?list=PLNbPNPgqTfs7CoMRDlxi2nLwuHbfaJ2PF

- Edición previa del curso, DF-UBA (2C 2020)

  https://www.youtube.com/playlist?list=PLNbPNPgqTfs5buwHWp8FtAsT7pyu2y_Lf

- Clases Prof. P. Tamborenea, DF-UBA (2C 2012)

  https://www.df.uba.ar/en/cursos-online/6629-estructura-de-la-materia-2-2do-cuatrimestre-2012

- Clases Prof. S. Scandolo, ICTP (Italia)

  https://www.youtube.com/playlist?list=PLZi2V5wYkgCIoOoFjHv8WooNGLokyto7p

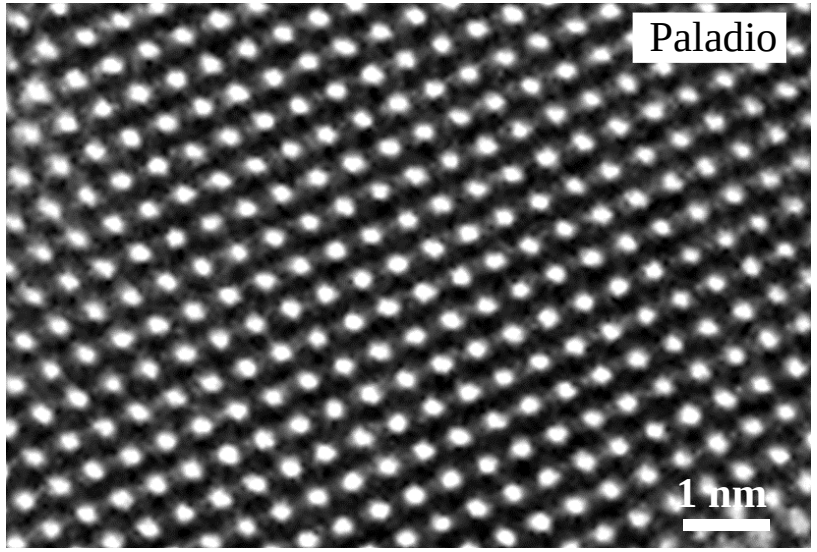
- Clases Prof. S. H. Simon, Oxford (Inglaterra)

  http://podcasts.ox.ac.uk/series/oxford-solid-state-basics

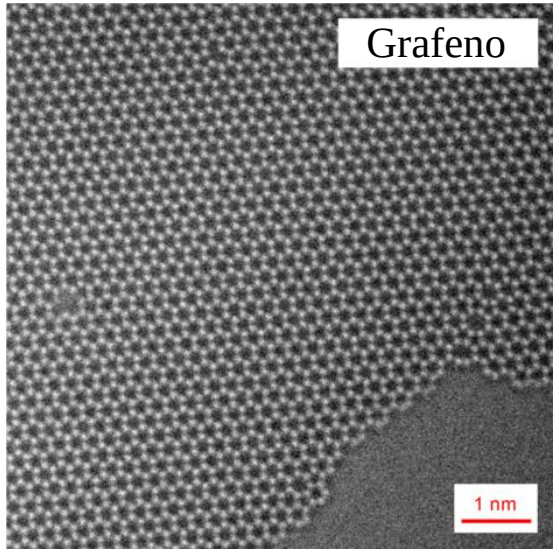
- …

Redes cristalinas

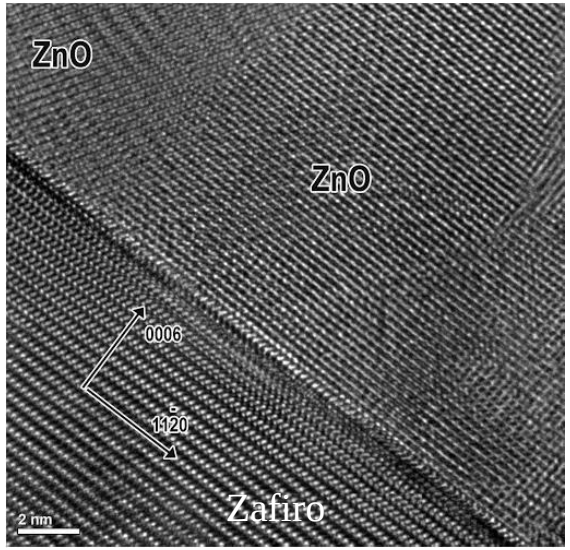
Imágenes de microscopia electrónica de alta resolución



https://www.knmf.kit.edu/TEM.php



https://www.salve-project.de/

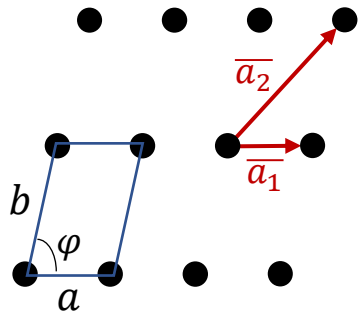


http://www.microscopy.cz/

Redes cristalinas: Redes en 2D

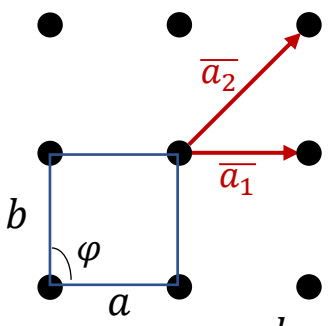
Redes de Bravais en 2D

Oblicua



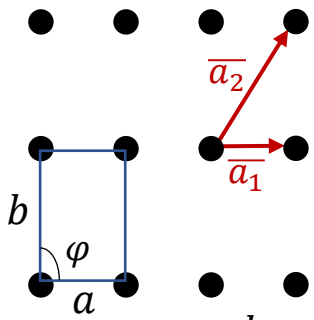
$a \neq b$
$\varphi \neq 90°$

Cuadrada



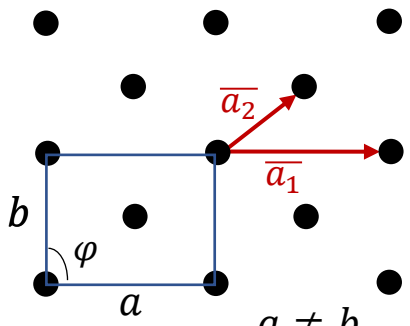
$a = b$
$\varphi = 90°$

Rectangular



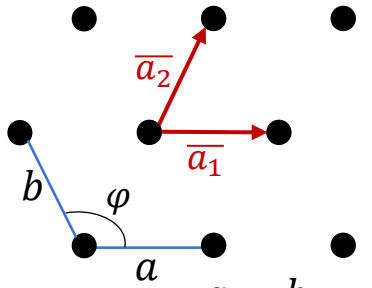
$a \neq b$
$\varphi = 90°$

Rectangular centrada



$a \neq b$
$\varphi = 90°$

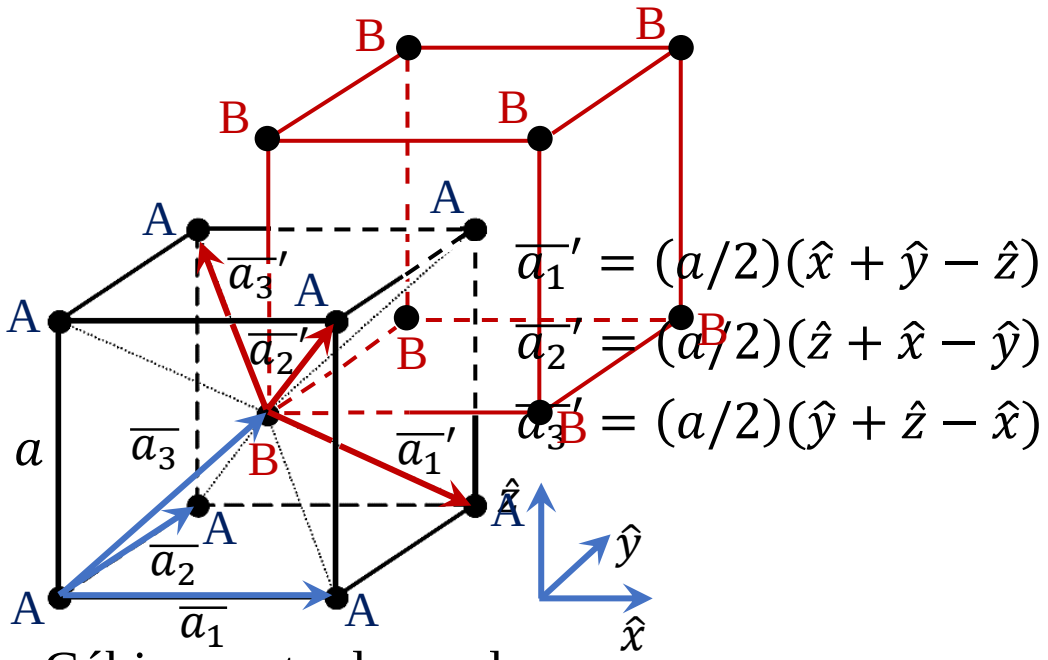
Hexagonal



$a = b$
$\varphi = 120°$

Redes cristalinas: Redes en 3D

Otras redes de simetría cúbica



$\overline{a_1}' = (a/2)(\hat{x} + \hat{y} - \hat{z})$

$\overline{a_2}' = (a/2)(\hat{z} + \hat{x} - \hat{y})$

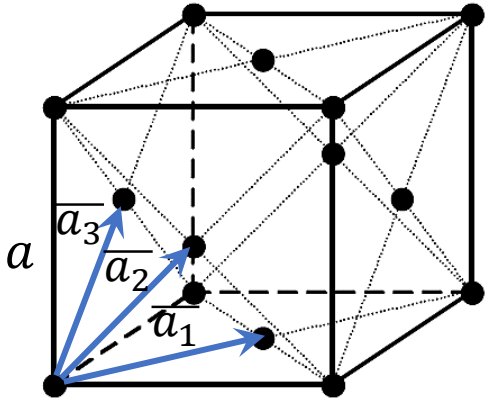
$\overline{a_3}' = (a/2)(\hat{y} + \hat{z} - \hat{x})$

Cúbica centrada en el cuerpo
(BCC, *body-centered cubic*)

$\overline{a_1} = a\hat{x}$

$\overline{a_2} = a\hat{y}$

$\overline{a_3} = (a/2)(\hat{x} + \hat{y} + \hat{z})$



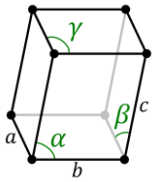
Cúbica centrada en las caras
(FCC, *face-centered cubic*)

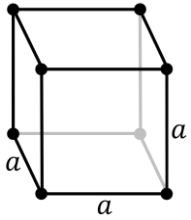
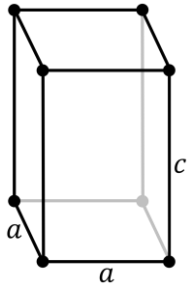
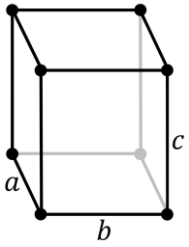
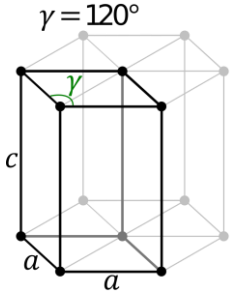
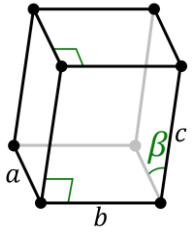
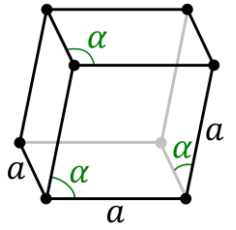
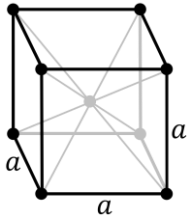
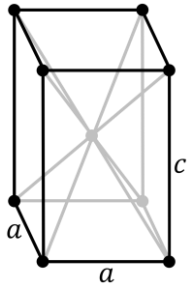
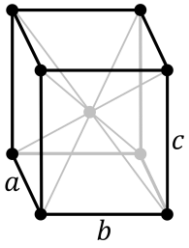
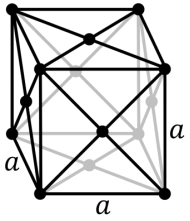
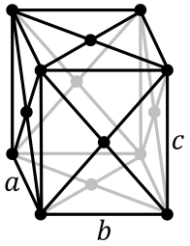
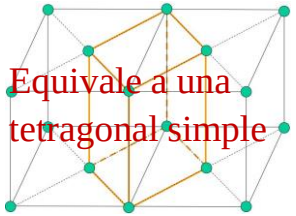
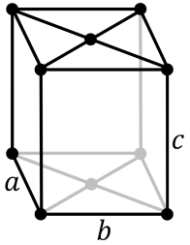
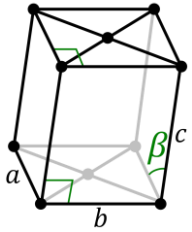
$\overline{a_1} = (a/2)(\hat{x} + \hat{y})$

$\overline{a_2} = (a/2)(\hat{x} + \hat{z})$

$\overline{a_3} = (a/2)(\hat{y} + \hat{z})$

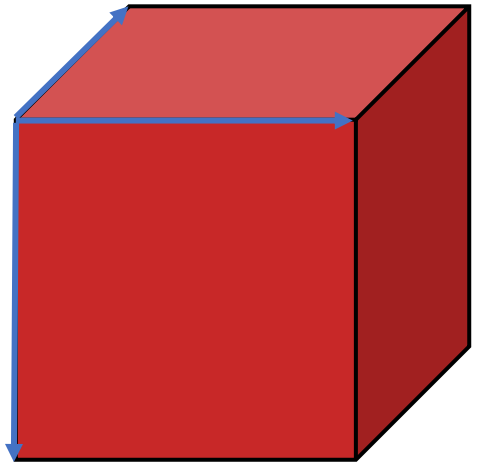
Redes cristalinas: Redes de Bravais en 3D



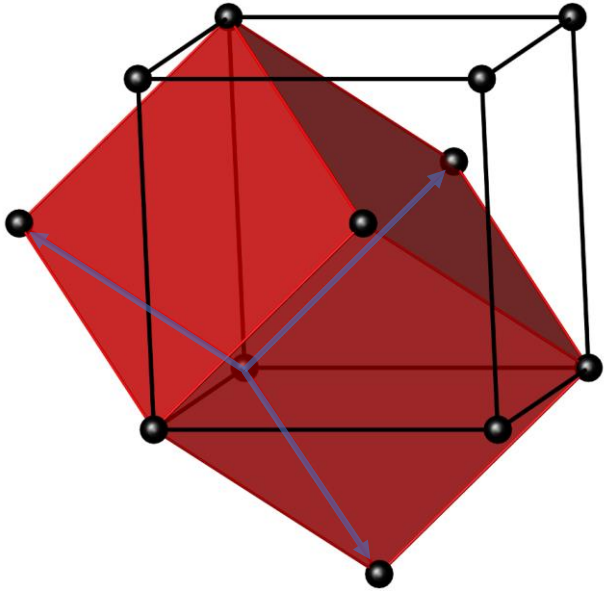
	Cúbica	Tetragonal	Ortorrómbica	Hexagonal	Monoclínica	Trigonal
	$a = b = c$ $\alpha = \beta = \gamma = 90°$	$a = b \neq c$ $\alpha = \beta = \gamma = 90°$	$a \neq b \neq c$ $\alpha = \beta = \gamma = 90°$	$a = b \neq c$ $\alpha = \beta = 90°, \gamma = 120°$	$a \neq b \neq c$ $\alpha = \gamma = 90° \neq \beta$	$a = b = c$ $\alpha = \beta = \gamma \neq 90° < 120°$
Simple						
Centrada en el cuerpo						
Centrada en las caras		Equivale a una tetragonal centrada en el cuerpo				
Centrada en las bases	 Equivale a una tetragonal simple	Equivale a una tetragonal simple				

Redes cristalinas: Celda primitiva

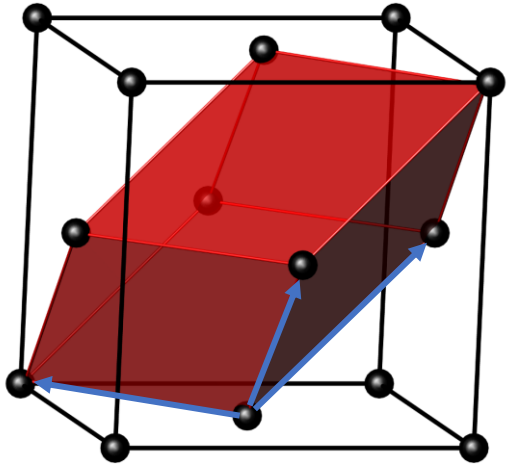
Celda primitiva (CP)



CP de una SC



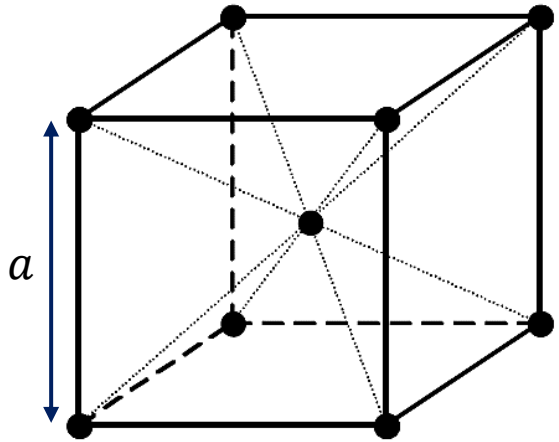
CP de una BCC



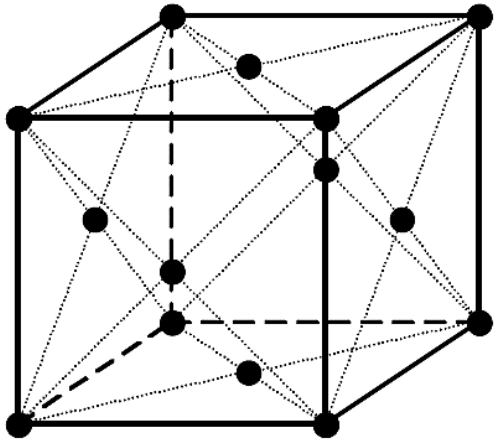
CP de una FCC

Redes cristalinas: Celda unidad

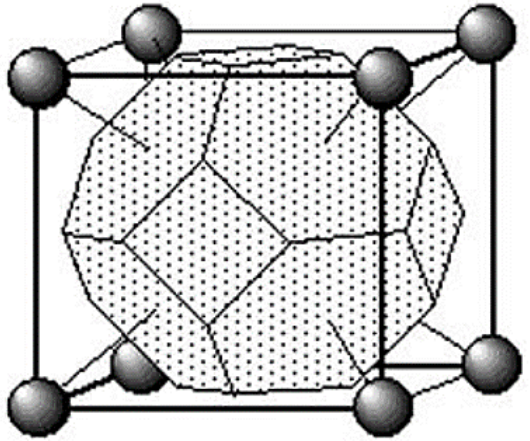
Celda unidad no-primitiva



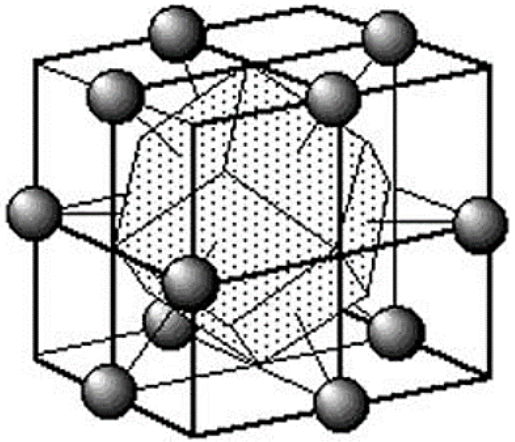
CU cúbica de una BCC



CU cúbica de una FCC



Celda de WZ de una BCC

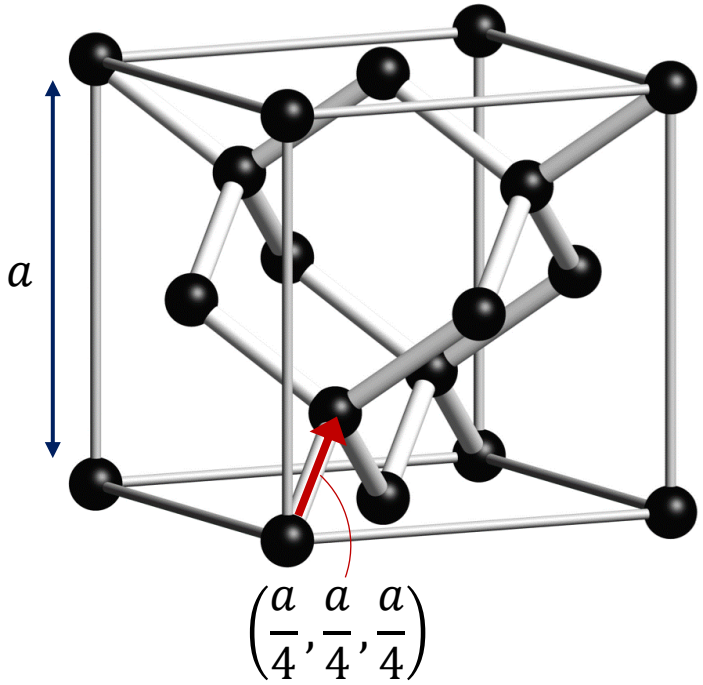


Celda de WZ de una FCC

Redes cristalinas: Red con una base

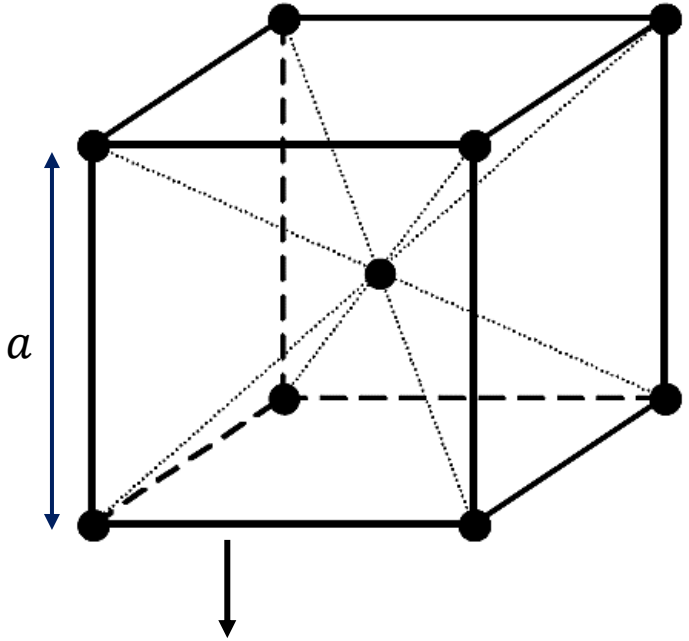
Estructura cristalina; Red con una base

Ejemplos en 3D. El concepto se puede utilizar también para enfatizar la simetría de una RB.

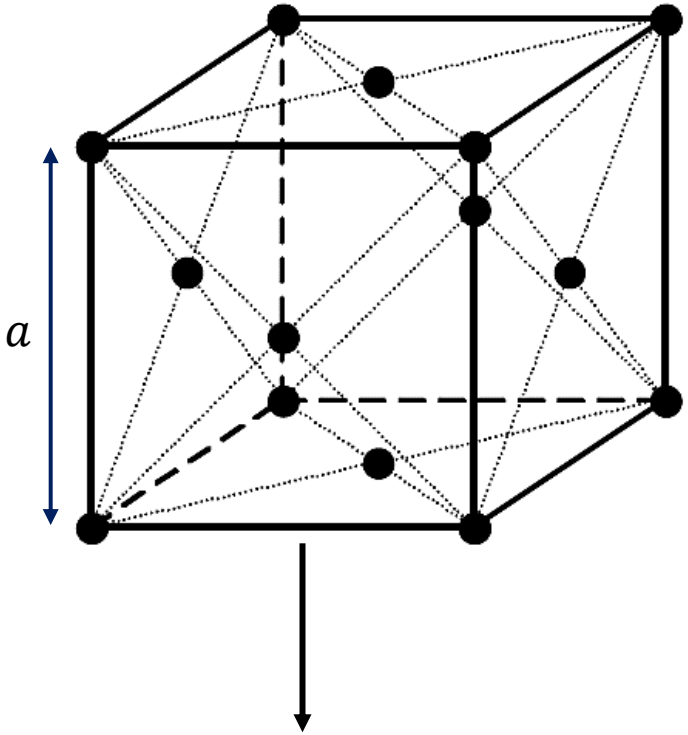


Diamante: 2 FCC interpenetradas.

FCC + $\{\mathbf{0};\frac{a}{4}(\hat{x}+\hat{y}+\hat{z})\}$



BCC: SC + $\{\mathbf{0};\frac{a}{2}(\hat{x}+\hat{y}+\hat{z})\}$

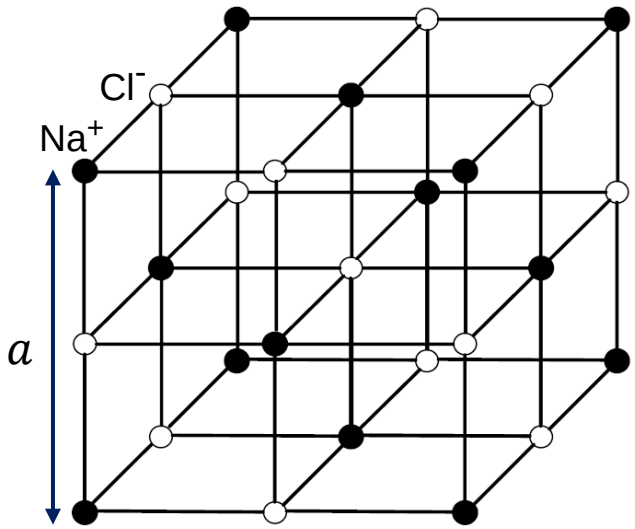


FCC: SC + $\{\mathbf{0};\frac{a}{2}(\hat{x}+\hat{y});\frac{a}{2}(\hat{y}+\hat{z});\frac{a}{2}(\hat{z}+\hat{x})\}$

Redes cristalinas: Red con una base

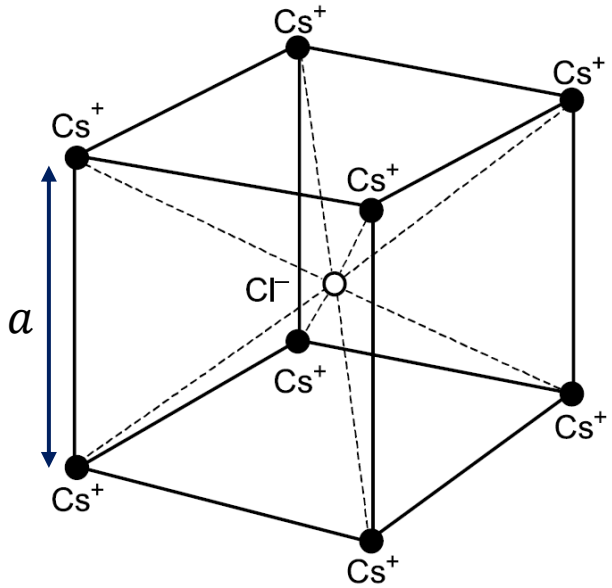
Estructura cristalina; Red con una base

Ejemplos de estructuras diatómicas.



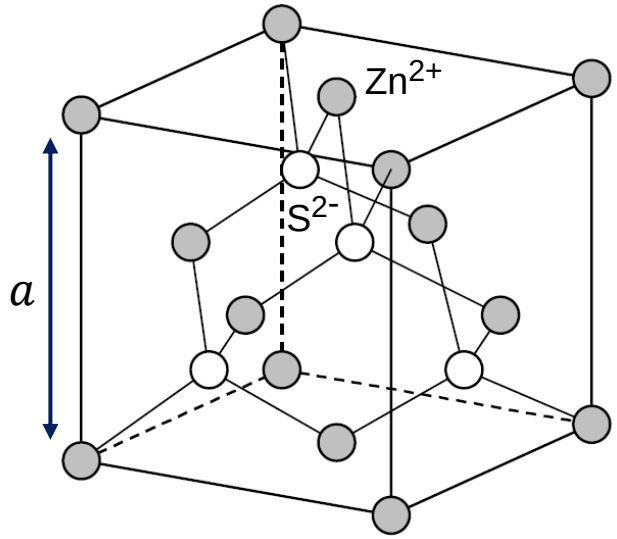
Cloruro de Sodio

FCC + $\{Na^+: \mathbf{0}, Cl^-: \frac{a}{2}(\hat{x}+\hat{y}+\hat{z})\}$



Cloruro de Cesio

SC + $\{Cs^+: \mathbf{0}, Cl^-: \frac{a}{2}(\hat{x}+\hat{y}+\hat{z})\}$



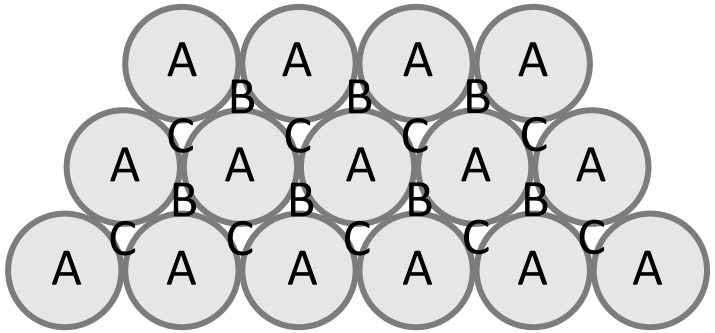
Sulfuro de Zinc (Zinc blenda)

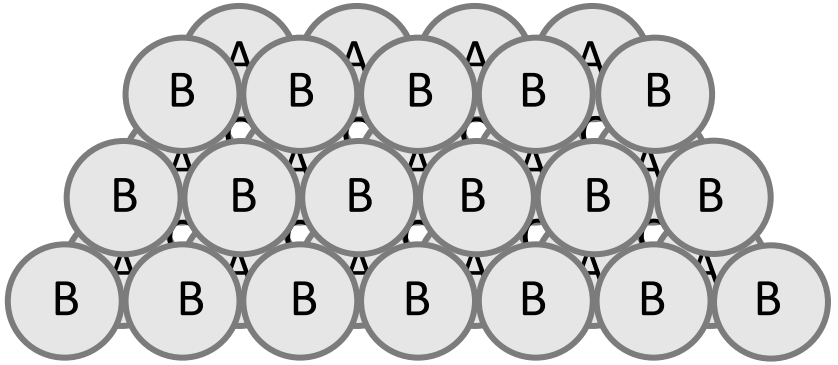
FCC + $\{Zn^{2+}: \mathbf{0}, S^{2-}: \frac{a}{4}(\hat{x}+\hat{y}+\hat{z})\}$

Redes cristalinas: Empaquetamiento

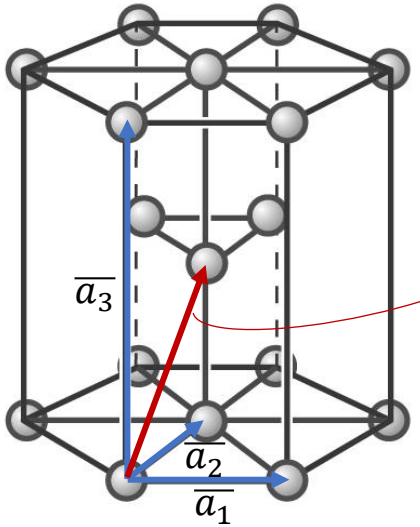
Empaquetamiento compacto

Apilamos pequeñas esferas rígidas (“átomos”) que se atraen e intentan acercarse lo máximo posible.





Continuamos apilando a las esferas → …ABCABC… (FCC) ó …ABABAB… (HCP).



Hexagonal compacta (HCP, *hexagonal close-packed*)
Hexagonal simple + base de 2 átomos.

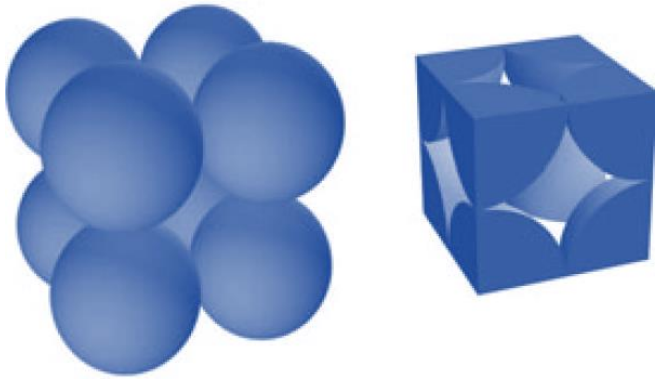
$\frac{1}{3}\overline{a_1} + \frac{1}{3}\overline{a_2} + \frac{1}{2}\overline{a_3}$

Unos 30 elementos cristalizan en esta estructura: Cd, Co, Mg, Nd, Ti, Zn, etc.

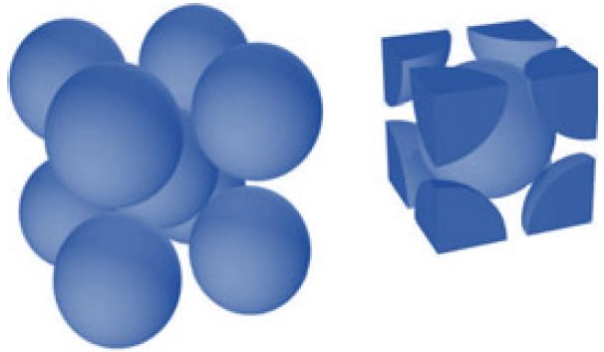
Redes cristalinas: Empaquetamiento

Empaquetamiento compacto

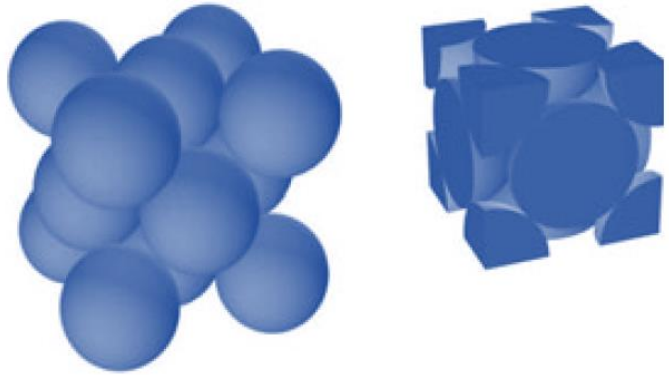
Comparemos el apilamiento de una SC, BCC, y FCC.



SC



BCC



FCC

¡La SC es la menos compacta de las estructuras!

Resumen

- Redes de Bravais
- Celda primitiva, celda de Wigner-Seitz
- Celda unidad o celda convencional
- Red con una base, estructura cristalina
- Empaquetamiento compacto