

Estrutura dos sólidos cristalinos: Rede cristalina

Ciência dos Materiais

2. Estrutura dos sólidos cristalinos

ligações químicas

rede cristalina

célula unitária

raio atômico

modelo de empacotamento compacto em sólidos metálicos

sítios cristalinos octaédricos e tetraédricos

superfícies de baixo índice de Miller

estruturas polifásicas e polimorfismo em metais

Ciências dos materiais

2. Estrutura dos sólidos cristalinos

rede cristalina

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graph TD; A[Ciências dos materiais] --- B[2. Estrutura dos sólidos cristalinos]; B --- C[rede cristalina];
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Materiais Metálicos



Materiais Cerâmicos



Vênus de Willendorf



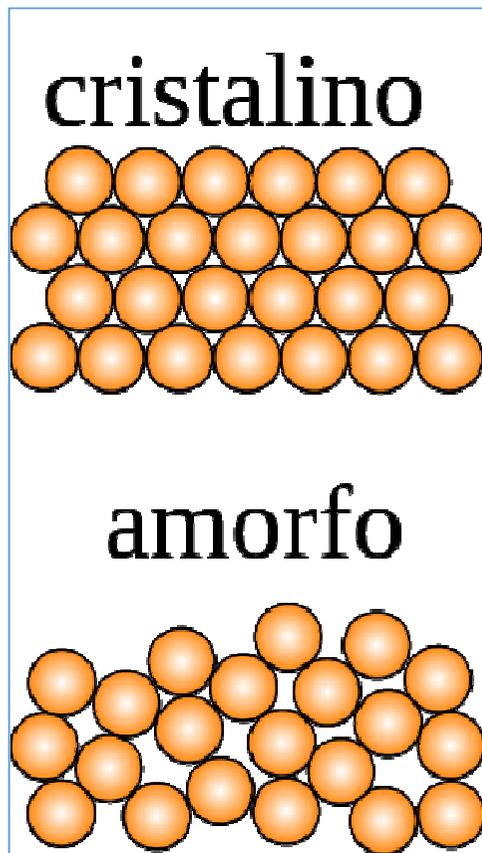
Cerâmica da China

Materiais Poliméricos - Plásticos

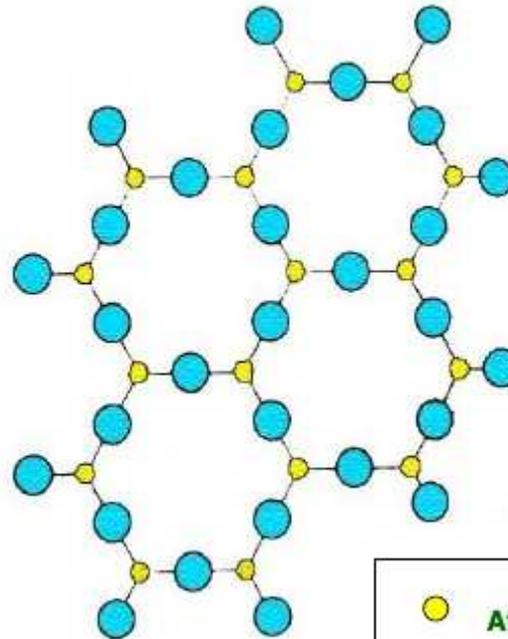


As substâncias com estrutura interna ordenada e composição química definida, são denominadas de **cristais** e as substâncias sem estrutura interna são denominadas **amorfas, não-cristalinas** ou **estrutura de vidro**. Podem ser identificadas através de difração de raios X. Toda substância que não apresenta um ordenamento atômico em uma escala que não pode produzir uma ordem regular de manchas de difração, quando a substância é atravessada por onda de comprimento específico (como raios X, elétrons, nêutrons, etc.) é considerada uma substância amorfa ou não-cristalina.

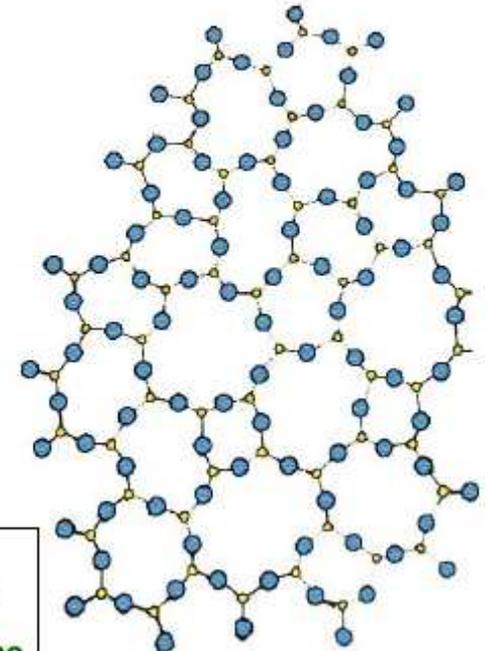
Sílica, SiO₂



Estructura de un Cristal



Estructura de un Vidrio



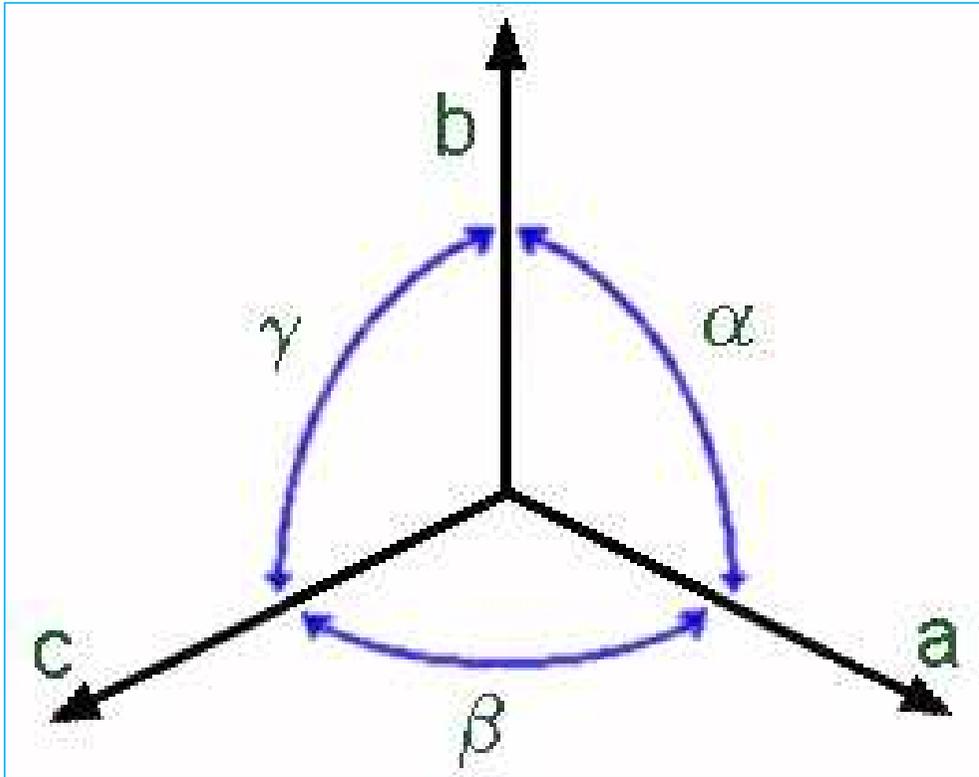
- Atomo de Silicio
- Atomo de Oxigeno

O termo **crystal** é usado para “qualquer sólido com estrutura interna ordenada tridimensional, ou seja, com forma geométrica regular e que apresenta unidades mínimas de repetição.

Cada cela unitária fica determinada através de:

- i) 3 arestas diferentes ou iguais denominadas de: a_o , b_o , c_o e
- ii) 3 ângulos diferentes ou iguais: α , β , γ

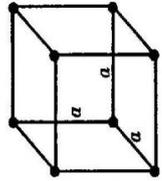
Sistema de coordenadas



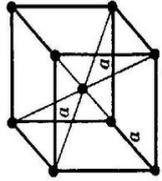
Como critério para descrição adotou-se a seguinte orientação para os eixos:

- o **eixo a**, que ocupa a posição horizontal e está em posição antero-posterior;
- o **eixo c**, que também é horizontal e ocupa a posição orientada da direita para esquerda;
- e o **eixo b**, que é vertical.

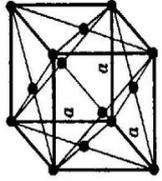
REDES ESPACIAIS DE BRAVAIS: A. Bravais foi um físico francês (1811-1863) que em 1848 demonstrou, geometricamente, que somente é possível a existência de 14 tipos de retículos espaciais, os quais são chamados de **REDES ESPACIAIS DE BRAVAIS** ou **RETÍCULOS DE BRAVAIS**. A unidade mais simples de um retículo é conhecida como "**cela unitária**".



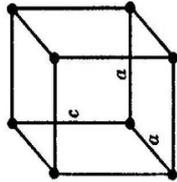
Cúbico Simples (P)



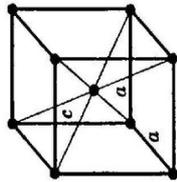
Cúbico de Corpo Centrado (I)



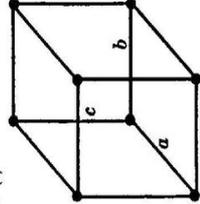
Cúbico de Faces Centradas (F)



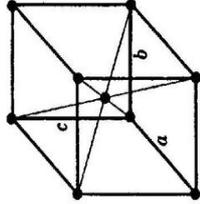
Tetragonal Simples (P)



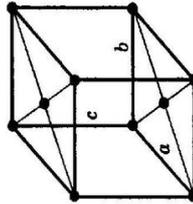
Tetragonal de Corpo Centrado (I)



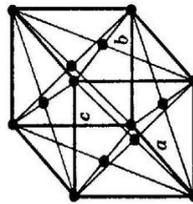
Ortorrômico Simples (P)



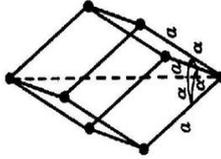
Ortorrômico de Corpo Centrado (I)



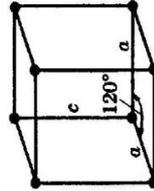
Ortorrômico de Base Centrada (C)



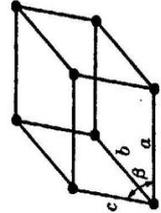
Ortorrômico de Faces Centradas (F)



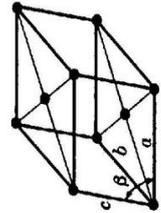
Romboédrico (R)



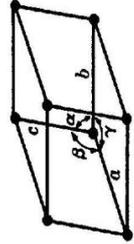
Hexagonal (P)



Monoclínico Simples (P)



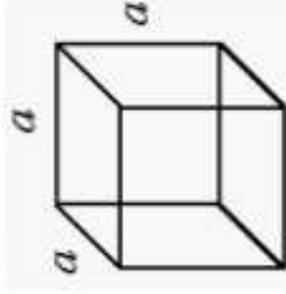
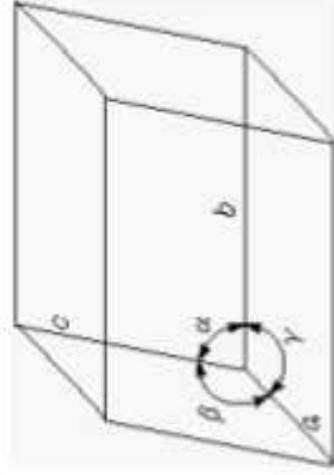
Monoclínico de Base Centrada (C)



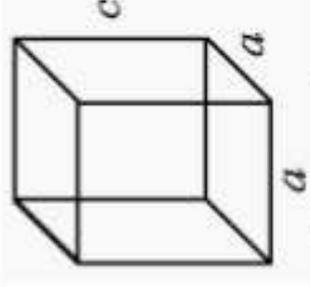
Triclínico (P)

Os 7 Sistemas Cristalinos

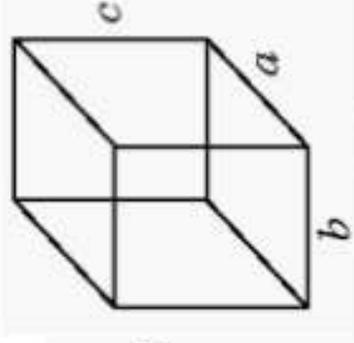
- Só existem 7 tipos de células unitárias que preenchem totalmente o espaço



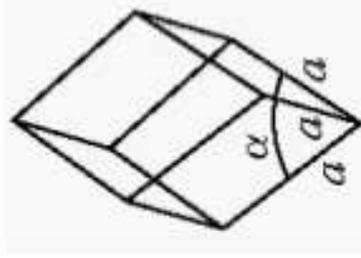
Cúbica
 $a=b=c$, $\alpha=\beta=\gamma=90^\circ$



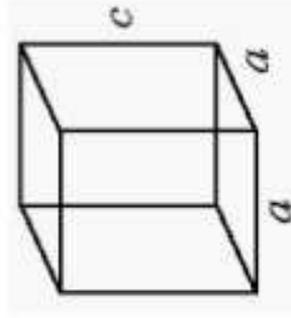
Tetragonal
 $a=b \neq c$, $\alpha=\beta=\gamma=90^\circ$



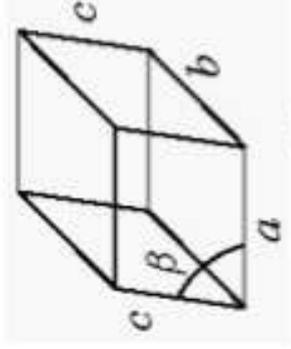
Ortorrômbica
 $a \neq b \neq c$, $\alpha=\beta=\gamma=90^\circ$



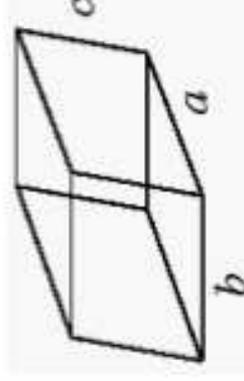
Romboédrica
 $a=b=c$, $\alpha=\beta=\gamma \neq 90^\circ$



Hexagonal*
 $a=b \neq c$, $\alpha=\beta=90^\circ$, $\gamma=120^\circ$



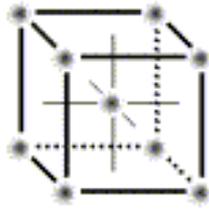
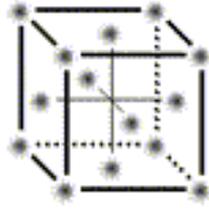
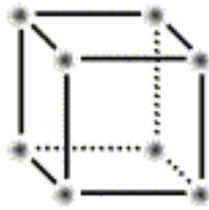
Monoclínica
 $a \neq b \neq c$, $\alpha=\gamma=90^\circ \neq \beta$



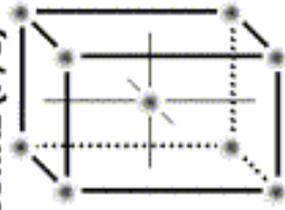
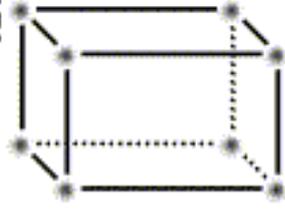
Triclínica
 $a \neq b \neq c$, $\alpha \neq \beta \neq \gamma \neq 90^\circ$

AS 14 REDES DE BRAVAIS

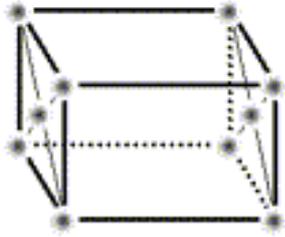
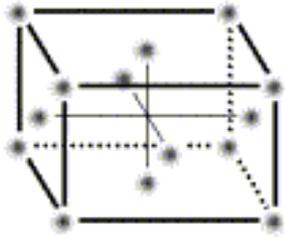
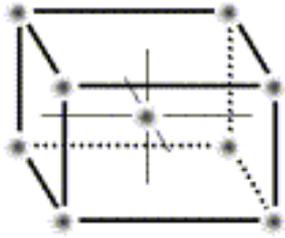
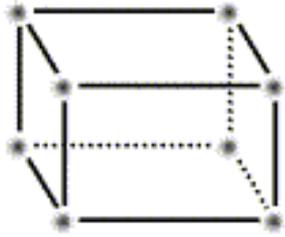
CUBICA (P, F, I)



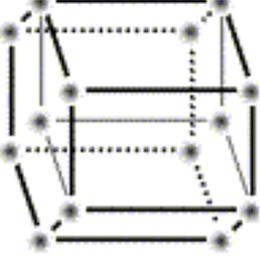
TETRAGONAL (P, I)



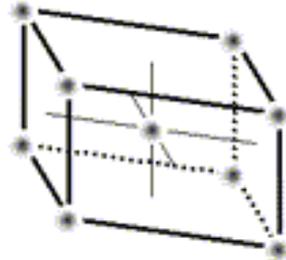
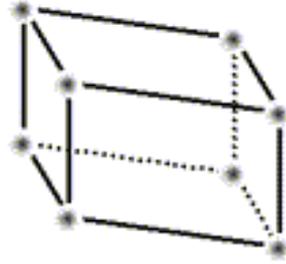
ORTORRÓMBICA (P, I, F, C)



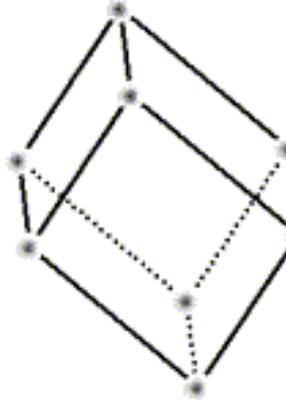
**TRIGONAL /
HEXAGONAL P**



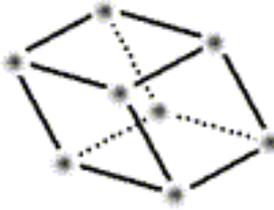
MONOCLÍNICA (P, C)



TRICLÍNICA



TRIGONAL





CALCANTITA – $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$ - triclínico



ANGLESITA - PbSO_4 - ortorrômbico

A **aparência externa** dos cristais é interpretada, há muito tempo, como derivada de uma estrutura interna periódica. Entretanto, na maioria das vezes os minerais se apresentam sem aparência externa poliédrica, sem que isto signifique que carecem de estrutura interna cristalina.

Quartzo - sílica (dióxido de silício, SiO_2), **Sistema cristalino:** Hexagonal
(estrutura cristalina trigonal composta por tetraedros de sílica)



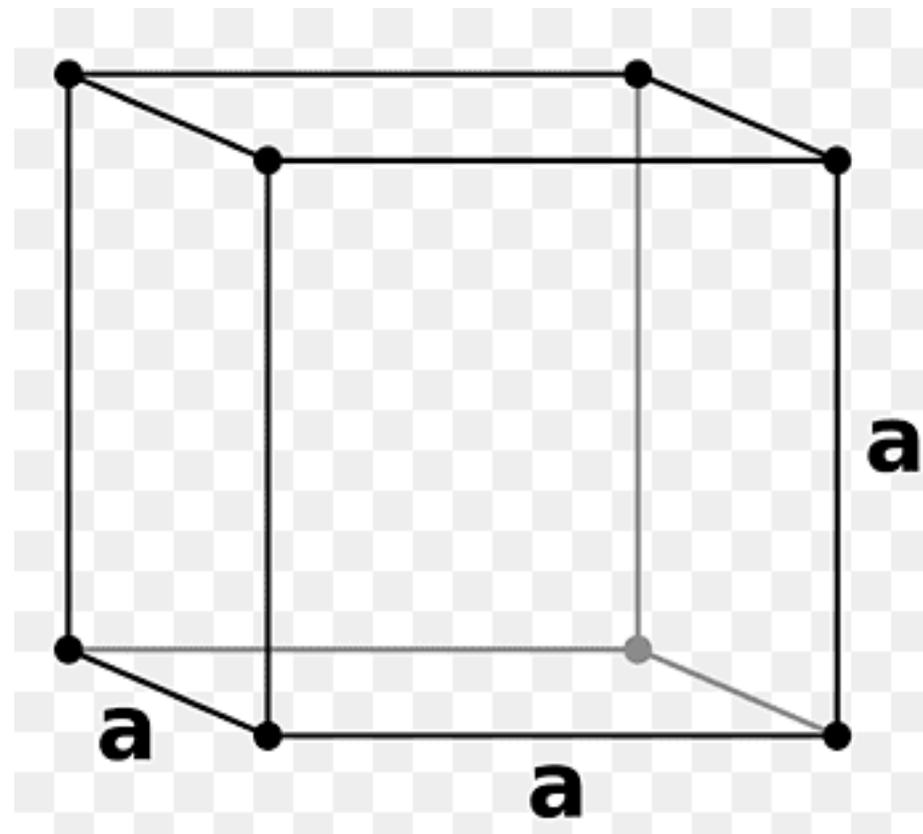
Sal gema (NaCl) halite
Sistema cúbico



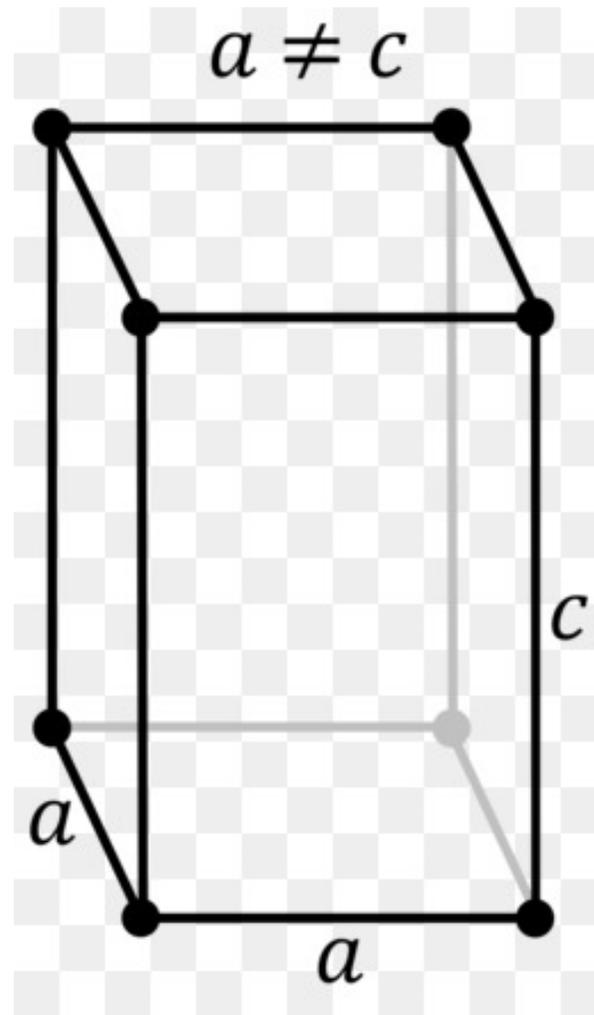
Gesso $\text{Ca}[\text{SO}_4] \cdot 2\text{H}_2\text{O}$
Sistema monoclinico



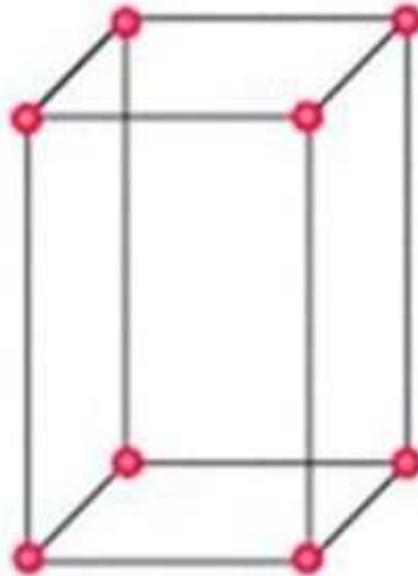
Sistema cristalino cúbico (isométrico)



Sistema cristalino tetragonal



Sistema cristalino ortorrômbico

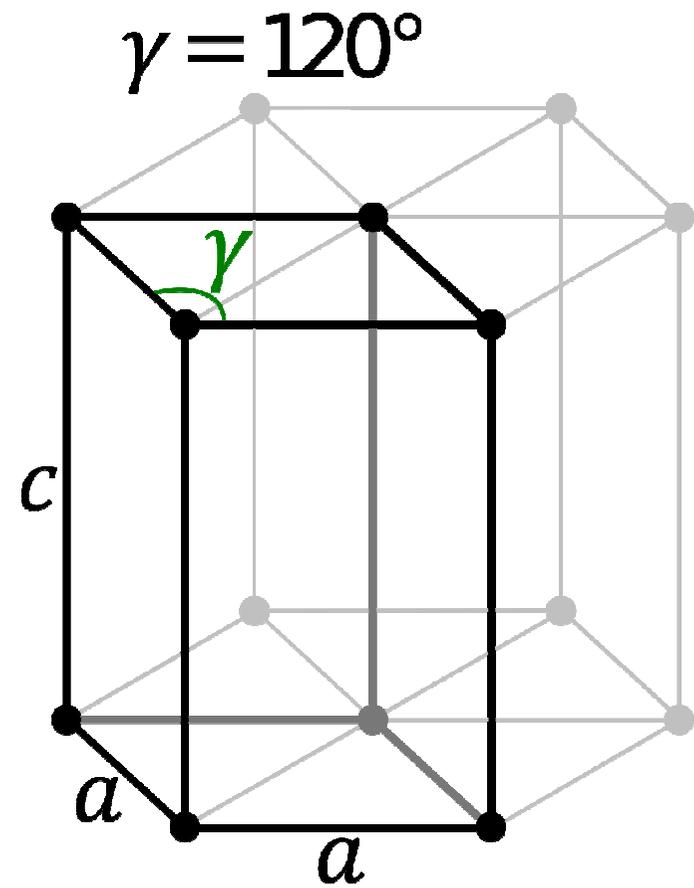
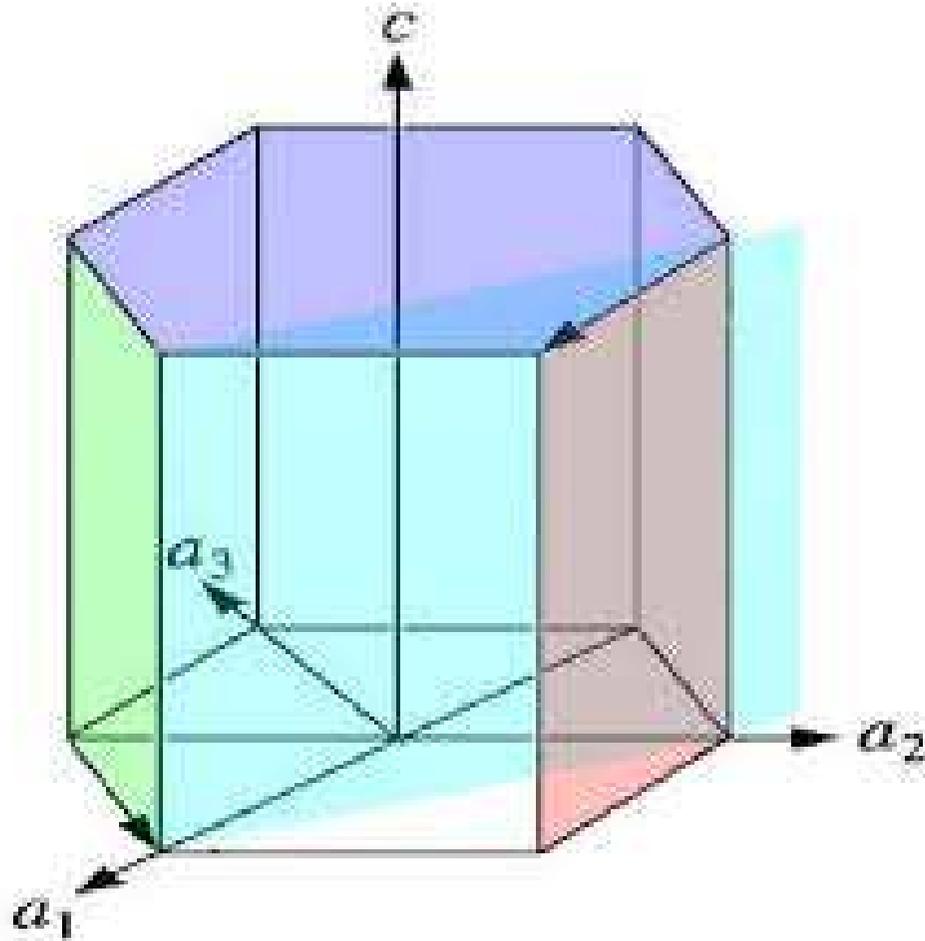


Ortorrômbico

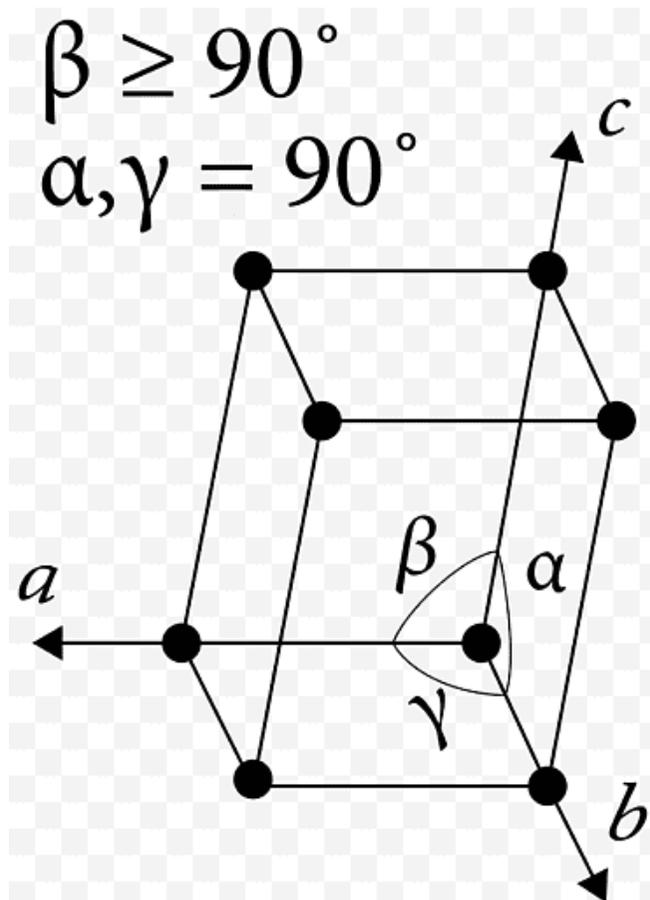
$$a \neq b \neq c$$

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

Sistema cristalino hexagonal



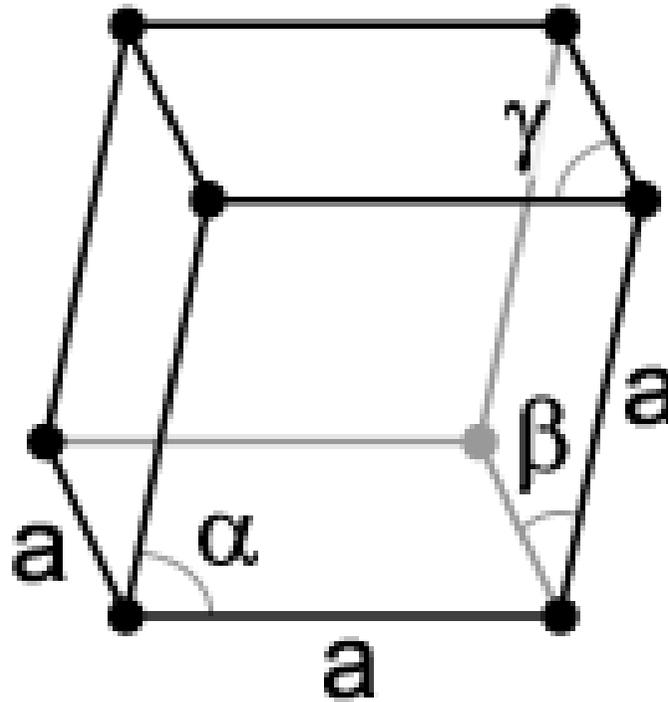
Sistema cristalino monoclinico



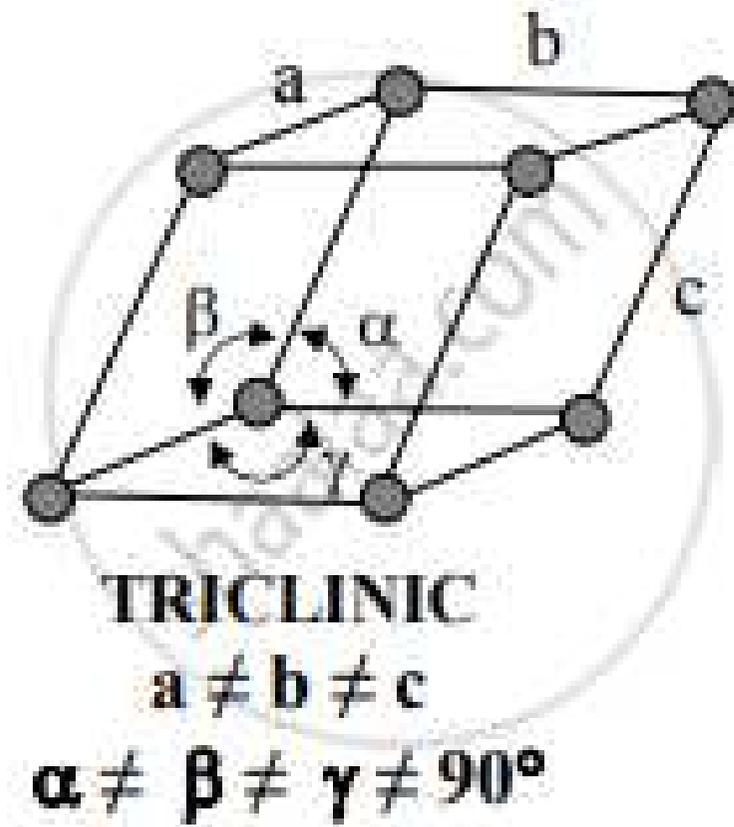
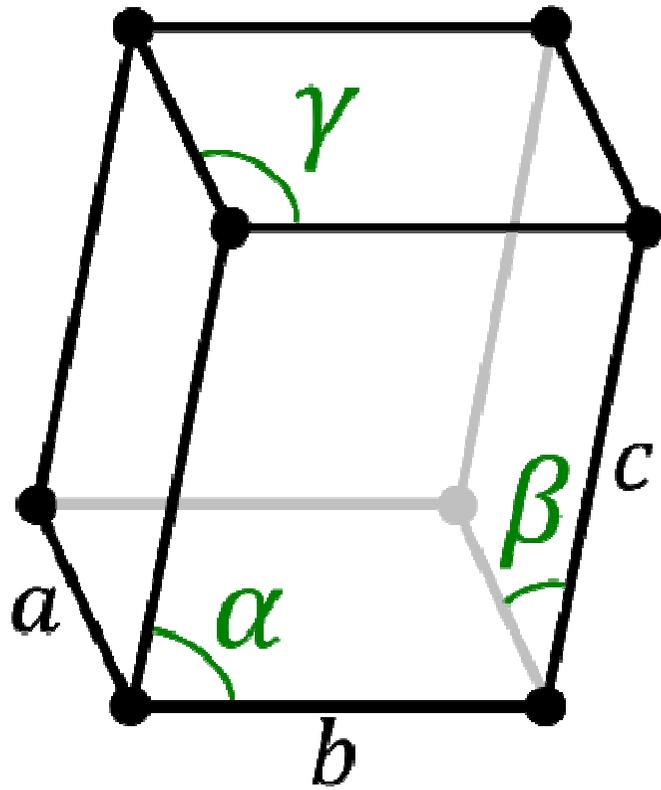
$$a \neq b \neq c$$

Sistema cristalino romboédrico (trigonal)

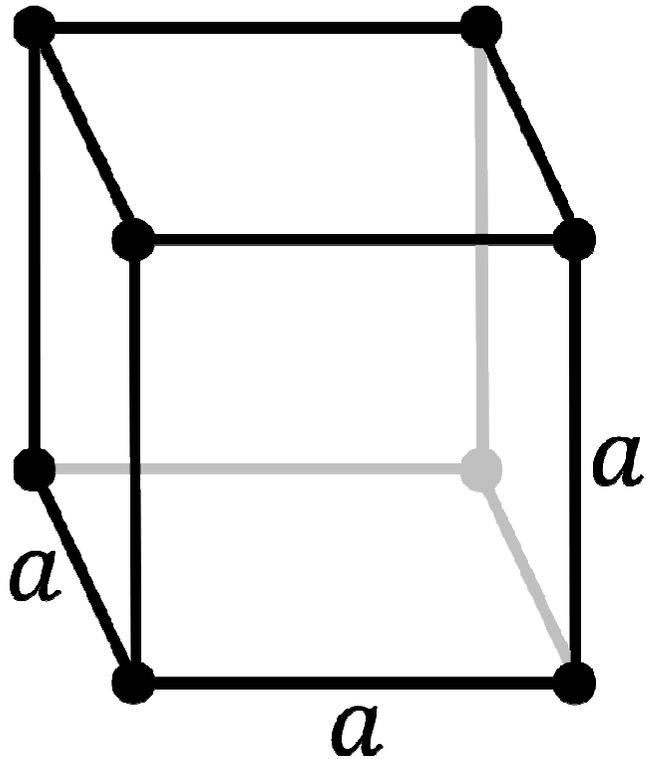
$$\alpha, \beta, \gamma \neq 90^\circ$$



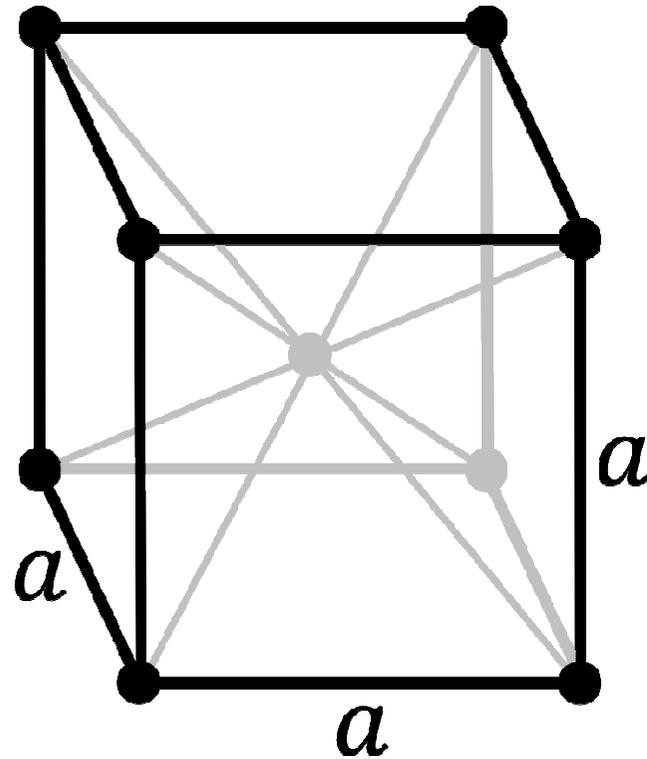
Sistema cristalino triclínico



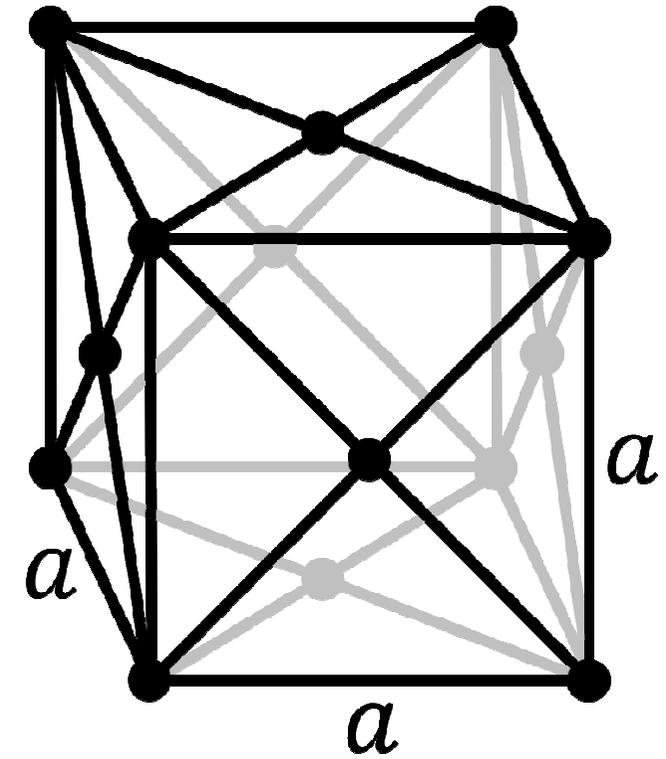
Sistema cristalino cúbico (isométrico)



Cúbico primitivo ou
simples - CS



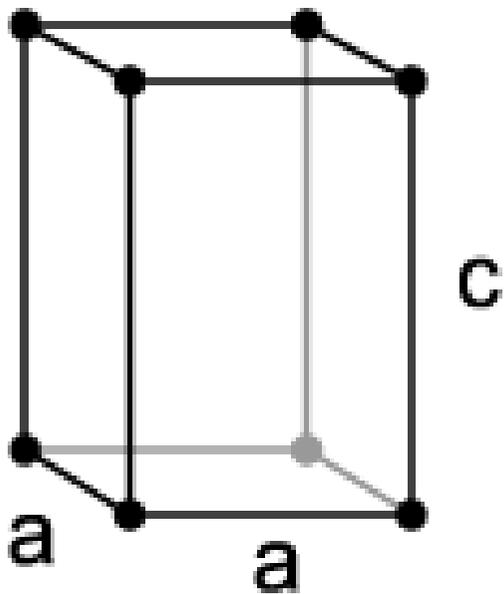
Cúbico de corpo
centrado - CCC



Cúbico de face
centrada - CFC

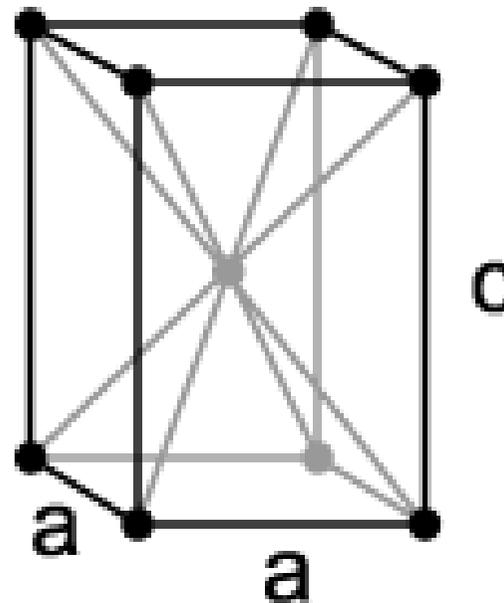
Sistema cristalino tetragonal

$a \neq c$



Tetragonal simples

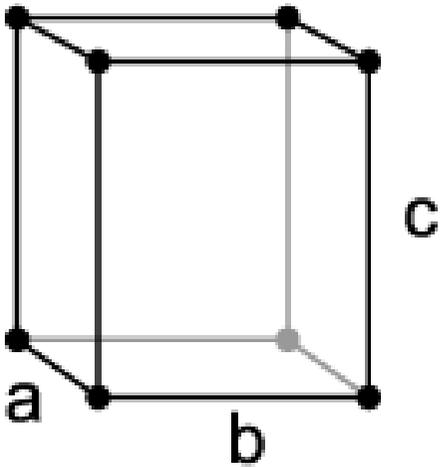
$a \neq c$



Tetragonal centrado
no volume

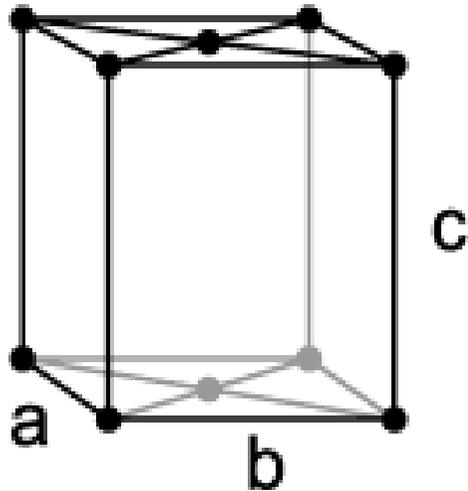
Sistema cristalino ortorrômbico

$$a \neq b \neq c$$



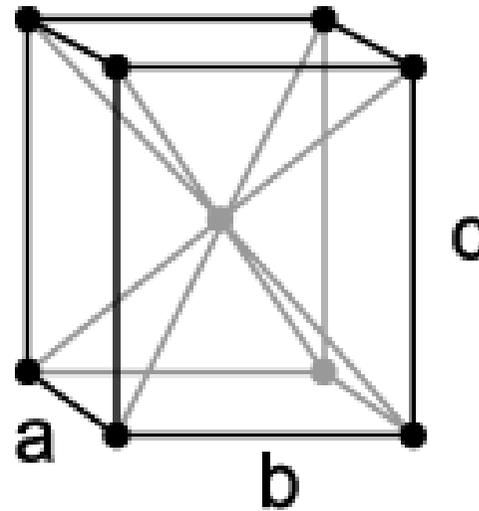
Simplex

$$a \neq b \neq c$$



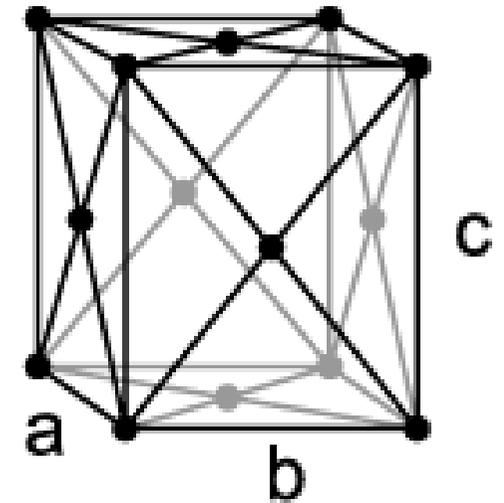
Centrado
na base

$$a \neq b \neq c$$



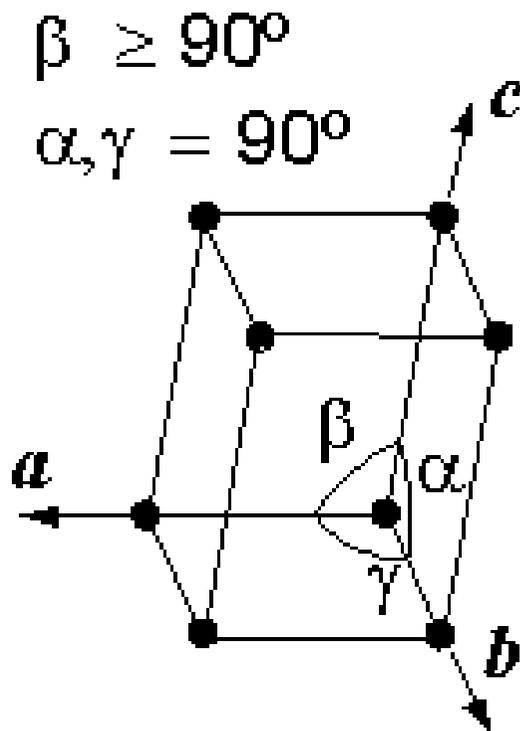
Centrado
no volume

$$a \neq b \neq c$$

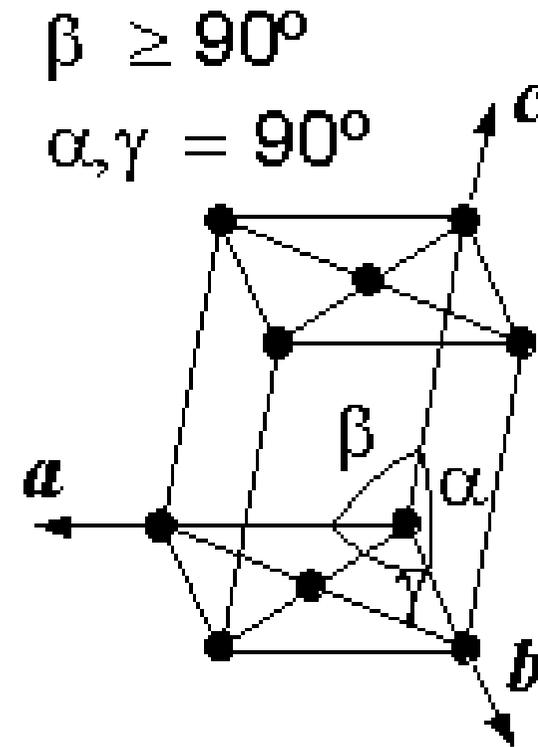


Centrado
na face

Sistema cristalino monoclínico



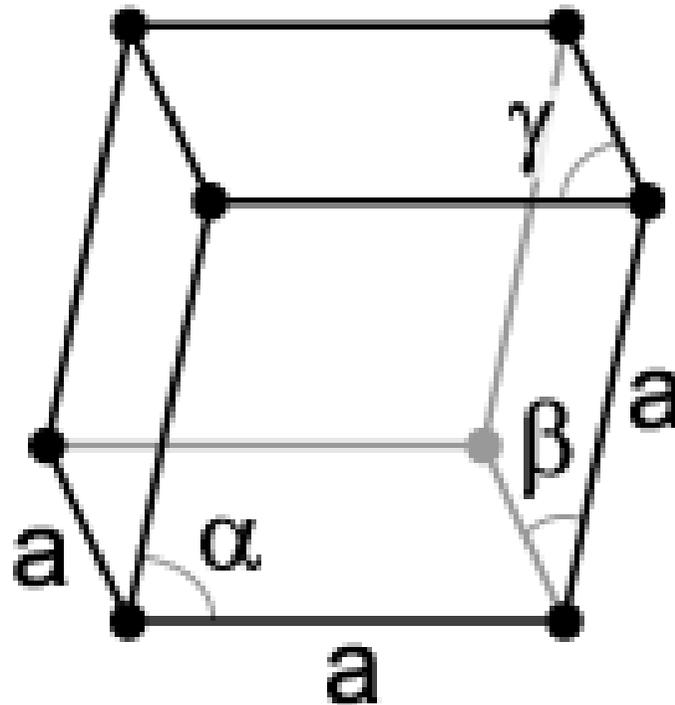
Simple



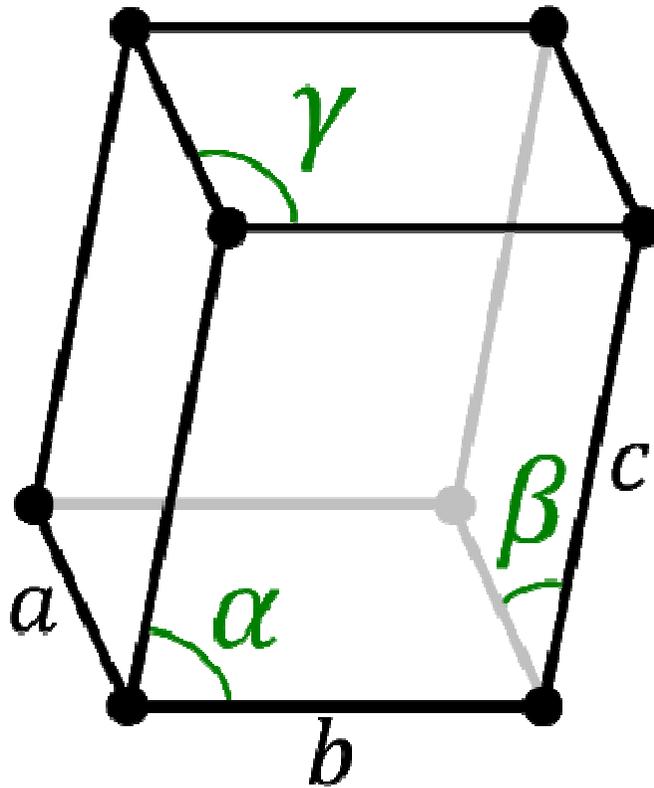
Centrado na base

Sistema cristalino romboédrico ou trigonal

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



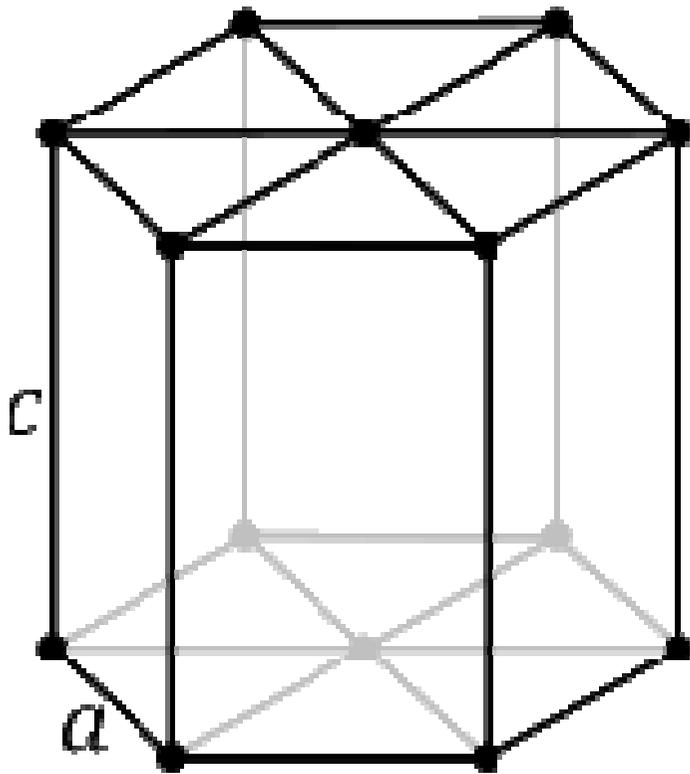
Sistema cristalino triclinico



$$\alpha \neq \beta \neq \gamma$$

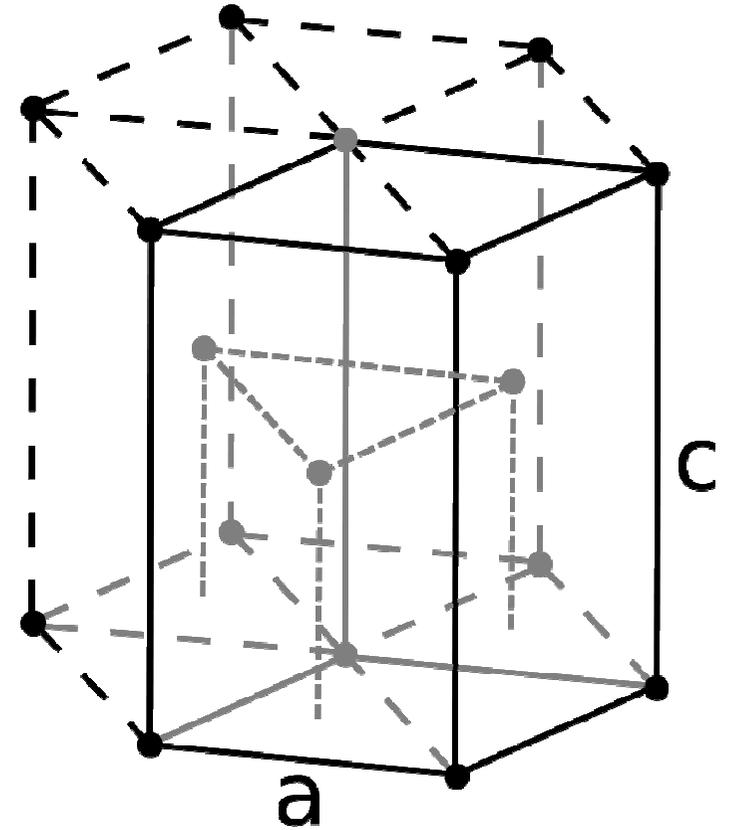
$$a \neq b \neq c$$

Sistema cristalino hexagonal

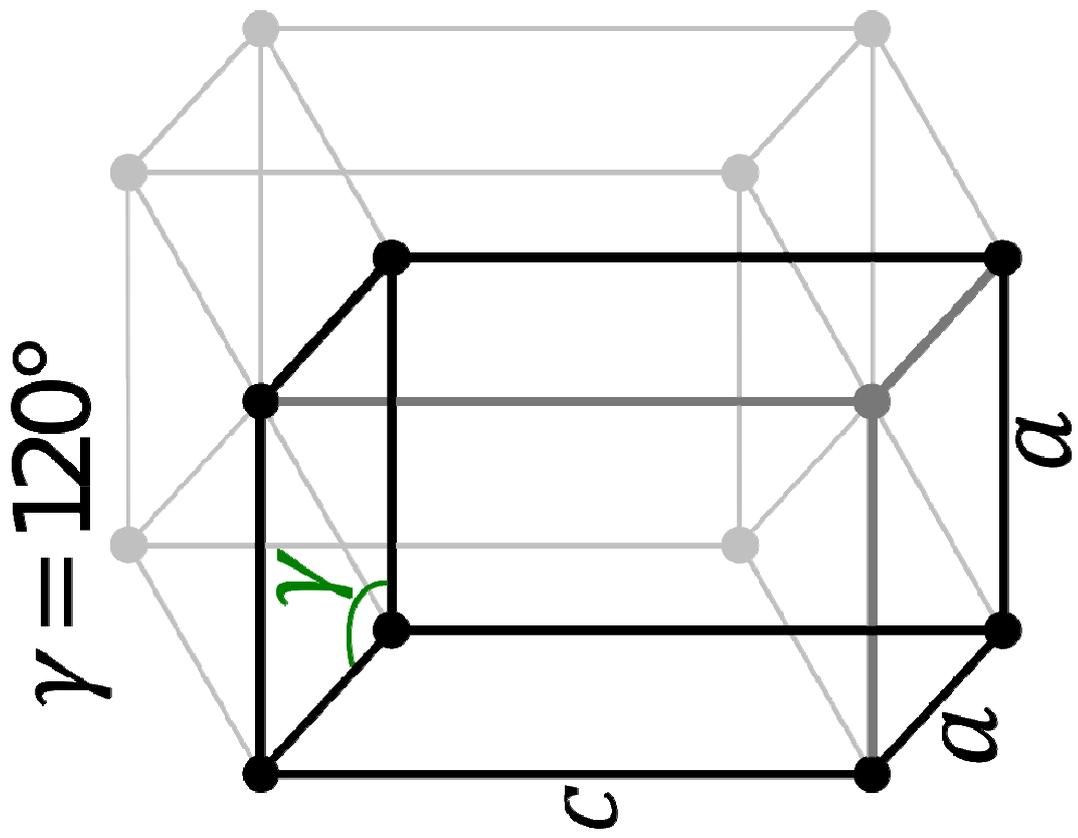


Hexagonal simples

$$a \neq c$$



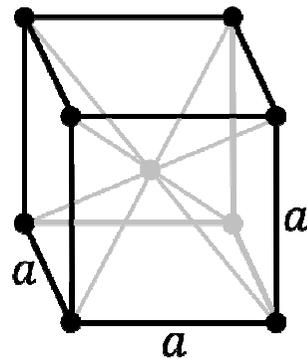
Hexagonal compacto



Sistema de cristalização	Eixos	Ângulos entre os eixos
<u>Cúbico</u>	$a = b = c$	$\alpha = \beta = \gamma = 90^\circ$
<u>Tetragonal</u>	$a = b \neq c$	$\alpha = \beta = \gamma = 90^\circ$
<u>Ortorrômbico</u>	$a \neq b \neq c \neq a$	$\alpha = \beta = \gamma = 90^\circ$
<u>Hexagonal</u>	$a = b \neq c$	$\alpha = \beta = 90^\circ; \gamma = 120^\circ$
<u>Romboédrico</u> ou <u>Trigonal</u>	$a = b = c$	$\alpha = \beta = \gamma \neq 90^\circ$
<u>Monoclínico</u>	$a \neq b \neq c \neq a$	$\alpha = \gamma = 90^\circ; \beta \neq 90^\circ$
<u>Triclínico</u>	$a \neq b \neq c \neq a$	$\alpha \neq \beta \neq \gamma$ (todos $\neq 90^\circ$)

A aresta da célula unitária cúbica de corpo centrado do cristal de ferro, na temperatura ambiente, é igual a $0.287 \times 10^{-9} \text{ m}$ ou $0,287 \text{ nm}$. Quantas células unitárias de ferro puro poderão ser alinhadas lado a lado, em uma extensão de 1 mm :

Ferro se empacota no sistema cúbico de corpo centrado



$$a = 0,287 \text{ nm}$$

Resposta:

$$1\text{mm} \times \frac{1 \text{ célula unitária}}{0,287 \text{ nm} \times 10^{-6} \text{ mm/nm}} = 3,48 \times 10^6 \text{ células unitárias}$$

Ou seja, em 1 mm podem ser alinhadas 3.480.000 de células cúbicas de corpo centrado.

