

# Estructura de la Materia 2

Clase 14 - Teoría

## Docentes

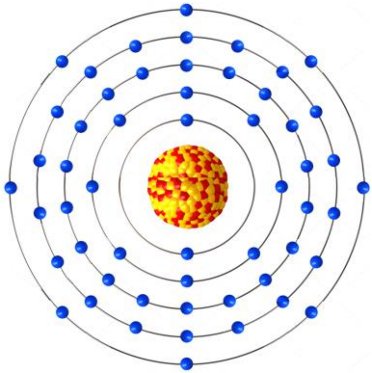
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Departamento de Física, FCEN, UBA – 2do Cuatrimestre, 2020

Web: <http://materias.df.uba.ar/edlm2a2020c2>

# Repaso

## Magnetismo en átomos aislados



$$\Delta \mathcal{H}_T = \mu_B \bar{H} \cdot (\bar{L} + g\bar{S}) + \frac{e^2}{8m_e c^2} \sum_i |\bar{H} \times \bar{r}_i|^2$$

Reglas de Hund

$$\Delta E_n = \underbrace{\mu_B \bar{H} \cdot \langle n | \bar{L} + g\bar{S} | n \rangle}_{\text{Paramagnetismo de Curie}} + \underbrace{\sum_{n' \neq n} \frac{|\langle n | \mu_B \bar{H} \cdot (\bar{L} + g\bar{S}) | n' \rangle|^2}{E_n - E_{n'}}}_{\text{Paramagnetismo de Van Vleck}} + \underbrace{\frac{e^2}{8m_e c^2} \langle n | \sum_i |\bar{H} \times \bar{r}_i|^2 | n \rangle}_{\text{Diamagnetismo de Larmor}}$$

Paramagnetismo de Curie

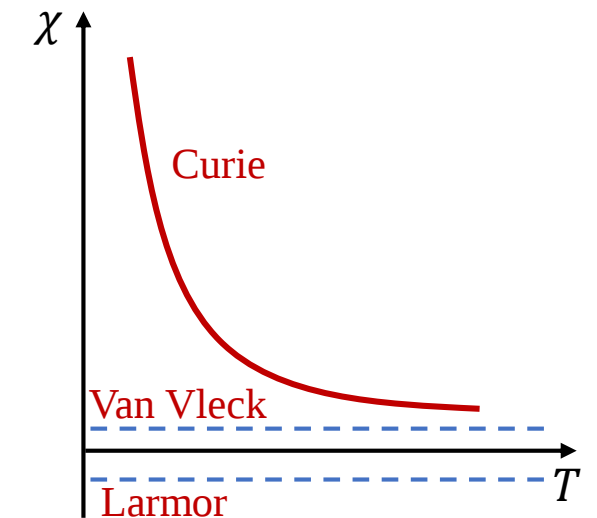
Paramagnetismo de Van Vleck

Diamagnetismo de Larmor

$J \neq 0$  (Paramagnetismo de Curie)  $\longrightarrow \Delta E_n = g_L \mu_B \bar{H} \cdot \langle n | \bar{J} | n \rangle$

$$\longrightarrow M = \frac{N}{V} \frac{g_L \mu_B}{2} \left[ (2J + 1) \coth \left( \frac{\beta g_L \mu_B H (2J + 1)}{2} \right) - \coth \left( \frac{\beta g_L \mu_B H}{2} \right) \right]$$

$$g_L \mu_B H \ll k_B T \longrightarrow \chi = \frac{\partial M}{\partial H} = \frac{N}{V} \frac{(g_L \mu_B)^2}{3k_B T} J(J + 1)$$



# Repaso

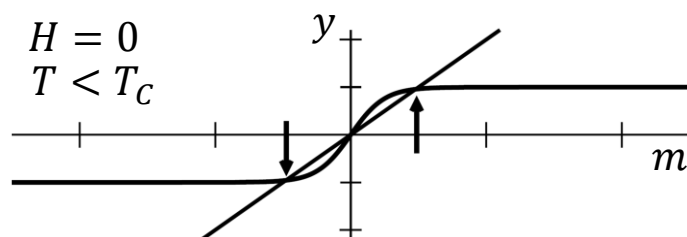
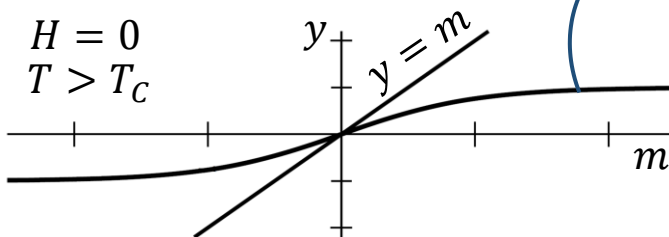
## Interacción entre espines: Orden ferromagnético

$$\mathcal{H} = -\frac{J_{int}}{2} \sum_{\langle i,j \rangle} \bar{S}_i \cdot \bar{S}_j + g_L \mu_B \bar{H} \cdot \sum_i \bar{S}_i, \quad J_{int} > 0$$

Campo medio → Para el sitio  $i$ :  $\mathcal{H}_i = \bar{S}_i \cdot \left[ -J_{int} \sum_j \langle \bar{S}_j \rangle + g_L \mu_B \bar{H} \right] = \bar{S}_i \cdot g_L \mu_B \bar{H}_{ef}$

$g_L \mu_B H_{ef} \ll k_B T$  →  $\chi = \frac{N}{V} \frac{(g_L \mu_B)^2}{3k_B(T - T_C)} S(S + 1)$ , con  $T_C = \frac{zJ_{int}S(S + 1)}{3k_B}$  (Ley de Curie-Weiss)

A campo nulo:  $m = \frac{g_L \mu_B}{2} \left[ (2S + 1) \coth \left( \frac{\beta(2S + 1)zJ_{int}}{2g_L \mu_B} m \right) - \coth \left( \frac{\beta zJ_{int}}{2g_L \mu_B} m \right) \right]$

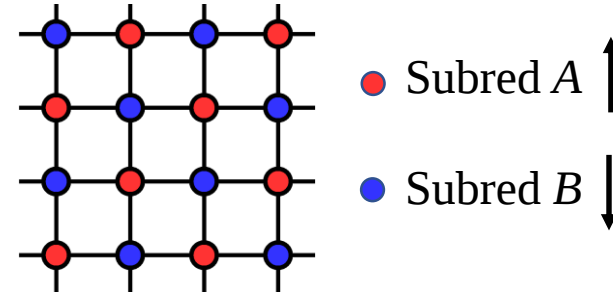


¡Magnetización espontánea cuando  $T < T_C$ !

# Magnetismo: Antiferromagnetismo

## Antiferromagneto: Interacción a primeros vecinos

$$\mathcal{H} = -\frac{J_{int}}{2} \sum_{\langle i,j \rangle} \bar{S}_i \cdot \bar{S}_j + g_L \mu_B \bar{H} \cdot \sum_i \bar{S}_i, \quad J_{int} < 0$$



## Campo medio

Para el sitio  $i,A$ :  $\mathcal{H}_{i,A} = \bar{S}_{i,A} \cdot \left[ -J_{int} \underset{\text{N}^\circ \text{ de coordinación}}{z} \langle \bar{S}_{j,B} \rangle + g_L \mu_B \bar{H} \right] = \bar{S}_{i,A} \cdot g_L \mu_B \bar{H}_{ef,B}$ ;  $\bar{H}_{ef,B} = \bar{H} - \frac{J_{int}}{g_L \mu_B} z \langle \bar{S}_{j,B} \rangle$

Para el sitio  $i,B$ :  $\mathcal{H}_{i,B} = \bar{S}_{i,B} \cdot \left[ -J_{int} z \langle \bar{S}_{j,A} \rangle + g_L \mu_B \bar{H} \right] = \bar{S}_{i,B} \cdot g_L \mu_B \bar{H}_{ef,A}$ ;  $\bar{H}_{ef,A} = \bar{H} - \frac{J_{int}}{g_L \mu_B} z \langle \bar{S}_{j,A} \rangle$

$$\bar{H} = H \hat{z} \rightarrow m_{A,B} = \frac{g_L \mu_B}{2} \left[ (2S + 1) \coth \left( \frac{\beta g_L \mu_B H_{ef,B,A} (2S + 1)}{2} \right) - \coth \left( \frac{\beta g_L \mu_B H_{ef,B,A}}{2} \right) \right]$$

$$\xrightarrow{g_L \mu_B H_{ef} \ll k_B T} m_{A,B} = \frac{(g_L \mu_B)^2}{3k_B T} S(S + 1) H_{ef,B,A} = \frac{(g_L \mu_B)^2}{3k_B T} S(S + 1) \left( H + \frac{z J_{int}}{(g_L \mu_B)^2} m_{B,A} \right)$$

# Magnetismo: Antiferromagnetismo

## Antiferromagneto: Interacción a primeros vecinos

$$g_L \mu_B H_{ef} \ll k_B T: m_{A,B} = \frac{(g_L \mu_B)^2}{3k_B T} S(S+1) \left( H + \frac{zJ_{int}}{(g_L \mu_B)^2} m_{B,A} \right)$$

$$\rightarrow m_A = m_B = m \rightarrow m \left( 1 - \frac{zJ_{int}}{3k_B T} S(S+1) \right) = \frac{(g_L \mu_B)^2}{3k_B T} S(S+1) H$$

$$\rightarrow m = \frac{(g_L \mu_B)^2}{3k_B T - zJ_{int} S(S+1)} S(S+1) H$$

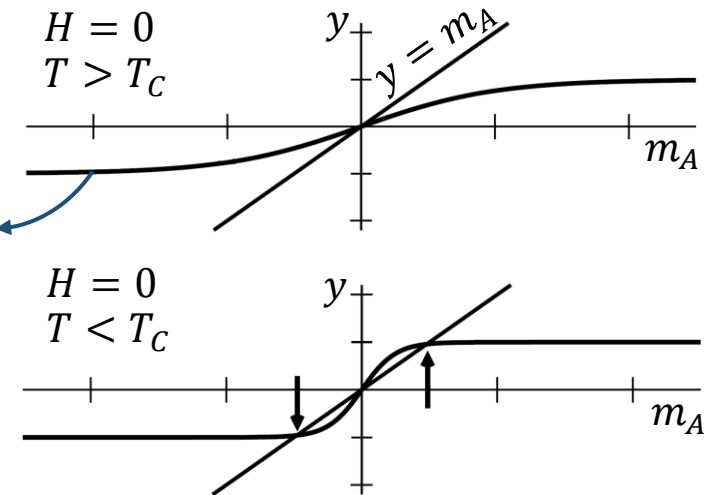
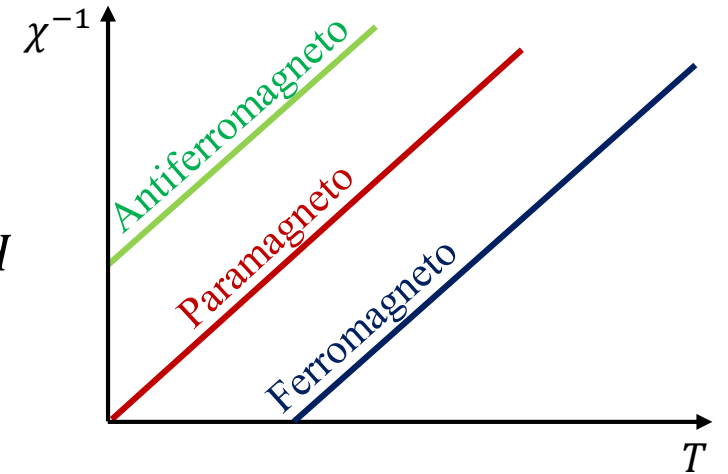
$$\rightarrow \chi = \frac{N}{V} \frac{(g_L \mu_B)^2}{3k_B (T + T_C)} S(S+1), \text{ con } T_C = -\frac{zJ_{int} S(S+1)}{3k_B}$$

Por otro lado, analizando a campo nulo:

$$m_{A,B} = \frac{g_L \mu_B}{2} \left[ (2S+1) \coth \left( \frac{\beta(2S+1)zJ_{int}}{2g_L \mu_B} m_{B,A} \right) - \coth \left( \frac{\beta zJ_{int}}{2g_L \mu_B} m_{B,A} \right) \right]$$

$$\rightarrow m_A = -m_B \text{ (coth es una función impar y } J_{int} < 0 \text{)}$$

$$\rightarrow \text{Magnetización espontánea (para cada subred) cuando } T < T_C$$



# Magnetismo: Dominios e histéresis

## Anisotropía magnetocristalina

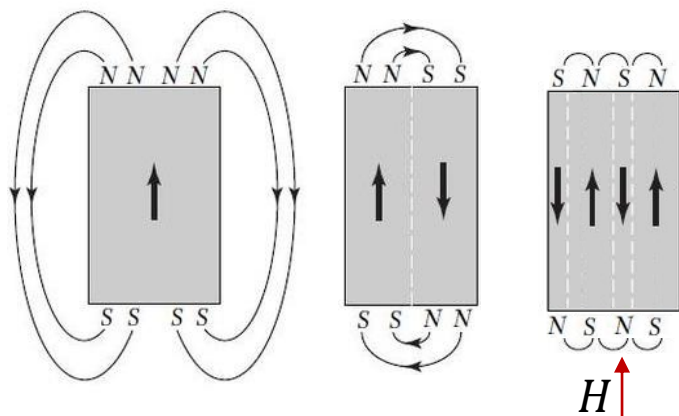
Debido al entorno anisotrópico de los átomos en una red cristalina, existen direcciones preferenciales para la orientación de los espines incluso en ausencia de campo magnético.

Una posibilidad sería:  $\mathcal{H} = -\frac{J_{int}}{2} \sum_{\langle i,j \rangle} \bar{S}_i \cdot \bar{S}_j - \kappa \sum_i (S_i^z)^2$  (Puede pensarse en un cristal tetragonal elongado en la dirección  $\hat{z}$ )

## Dominios magnéticos (ferromagneto)

Si bien la interacción dipolar magnética es despreciable frente a la interacción de intercambio, se torna apreciable cuando se tienen suficientes átomos, como ocurre en un material macroscópico ( $\sim 10^{23}$  átomos).

Esto sucede porque la interacción dipolar magnética es de largo alcance, mientras que la de intercambio es de corto alcance.



Energía magnetostática:  $\frac{1}{8\pi} \int H^2 dV$  Formar dominios magnéticos disminuye la energía total del sistema.

La región entre dominios recibe el nombre de “pared de dominio”.

Aplicar un campo magnético externo desplaza paredes de dominio.

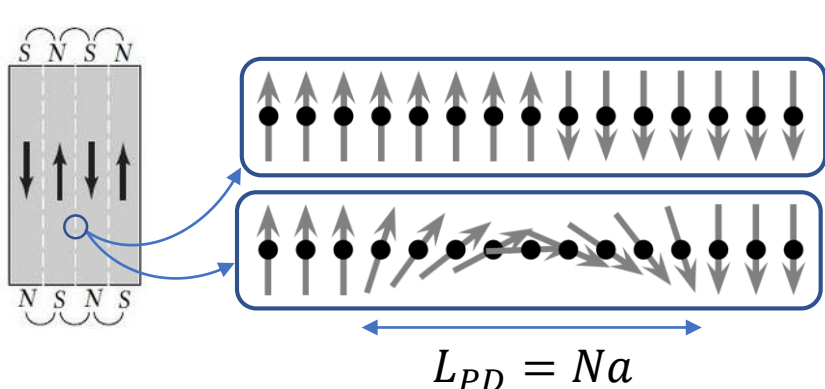


[https://en.wikipedia.org/wiki/Magnetic\\_domain](https://en.wikipedia.org/wiki/Magnetic_domain)

0.1 mm

# Magnetismo: Dominios e histéresis

## Pared de dominio



$$E_{int} = -J_{int} \bar{S}_i \cdot \bar{S}_j = -J_{int} S^2 \cos(\theta_i - \theta_j) \approx -J_{int} S^2 \left( 1 - \frac{(\delta\theta)^2}{2} \right)$$

$$\rightarrow \delta E_{int} = J_{int} S^2 (\delta\theta)^2 / 2 = J_{int} S^2 (\pi/N)^2 / 2$$

$$\rightarrow E_{int}^{PD} = N J_{int} S^2 (\pi/N)^2 / 2$$

$$E_{ani} = -\kappa (S_i^z)^2 = -\kappa [S \cos \theta_i]^2 \rightarrow \delta E_{ani} = \kappa S^2 (1 - \cos^2 \theta_i) \rightarrow E_{ani}^{PD} = \sum_i \kappa S^2 \sin^2 \theta_i$$

$$\rightarrow E_{ani}^{PD} = \kappa S^2 \int_0^\pi \sin^2 \theta d\theta \left( \frac{N}{\pi} \right) = \frac{N}{\pi} \kappa S^2 \int_0^\pi \frac{1 - \cos(2\theta)}{2} d\theta = \frac{N}{\pi} \kappa S^2 \left( \frac{\theta}{2} - \frac{\sin(2\theta)}{4} \right) \Big|_0^\pi = \frac{N \kappa S^2}{2}$$

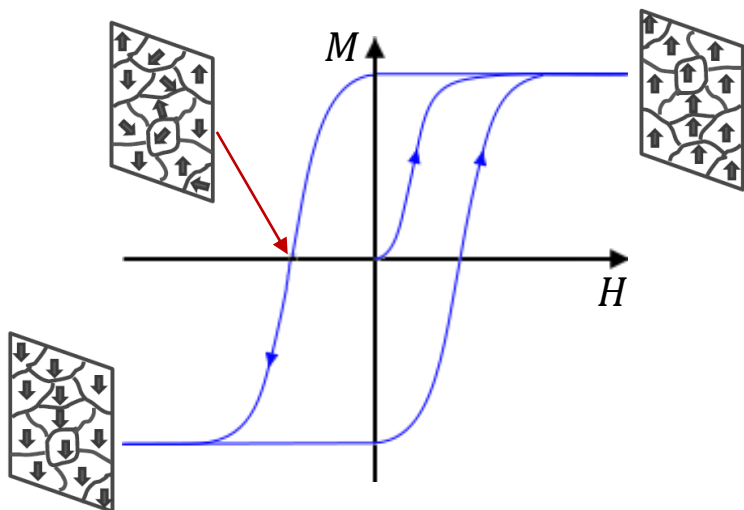
$$\rightarrow E_{Total}^{PD} = \frac{J_{int} S^2 \pi^2}{2N} + \frac{N \kappa S^2}{2} \rightarrow \frac{\partial E_{Total}^{PD}}{\partial N} = 0 = -\frac{J_{int} S^2 \pi^2}{2N^2} + \frac{\kappa S^2}{2} \rightarrow \frac{J_{int} \pi^2}{N^2} = \kappa$$

$$\rightarrow N = \pi \sqrt{J_{int} / \kappa} \rightarrow E_{Total, min}^{PD} = \pi S^2 \sqrt{J_{int} \kappa}$$

(Notar que si un cristal es extremadamente pequeño, puede resultar conveniente formar un monodominio)

# Magnetismo: Dominios e histéresis

## Histéresis en ferromagnetos



Para un grano cristalino:  $\frac{\Delta E}{V} = \underbrace{g_L \mu_B}_{\text{Densidad de espines}} \rho \bar{S} \cdot \bar{H} - \kappa \rho S_{\text{eje-grano}}^2 + \underbrace{int}_{\text{cte}}$

$$\rightarrow \frac{\Delta E}{V} = -\bar{M} \cdot \bar{H} - \kappa \frac{M_{\text{eje-grano}}^2}{(g_L \mu_B)^2 \rho} = -\bar{M} \cdot \bar{H} - \kappa' M_{\text{eje-grano}}^2$$

$$\bar{H} = H \hat{z} \rightarrow \frac{\Delta E}{V} = -|M||H|\cos\theta - \kappa'|M|^2\cos^2(\theta - \underbrace{\phi}_{=0})$$

$\hat{z}$   
Eje grano

→  $\Delta E$  es mínimo cuando  $\bar{M}$  y  $\bar{H}$  son paralelos, y puede existir un mínimo relativo cuando son antiparalelos.

$$\frac{\partial(\Delta E)}{\partial \theta} = 0 \rightarrow -|M||H|\sin\theta - 2\kappa'|M|^2\cos\theta\sin\theta = 0 \rightarrow \theta = 0, \pi, \arcsin\left(-\frac{|H|}{2\kappa'|M|}\right)$$

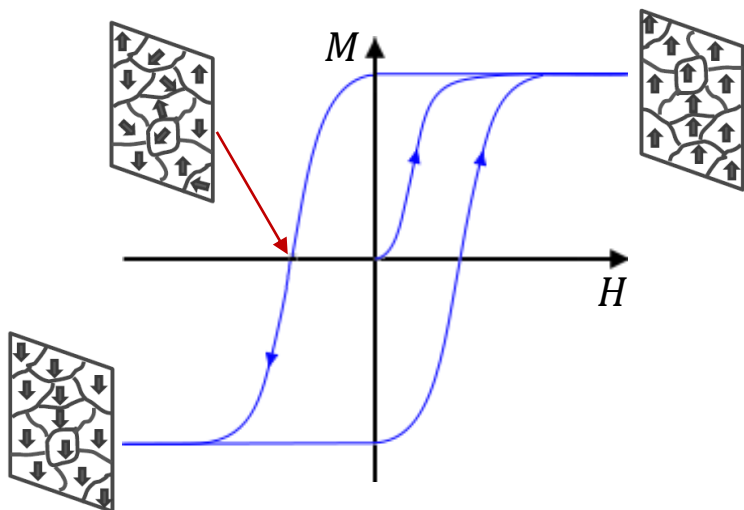
→  $H_{\text{crítico}} = 2\kappa'|M|$  → Si  $|H| < H_{\text{crítico}}$  existe un mínimo relativo, además del mínimo absoluto

Si  $\bar{M}$  apunta en la dirección  $-\hat{z}$  y se aplica un campo en la dirección  $\hat{z}$

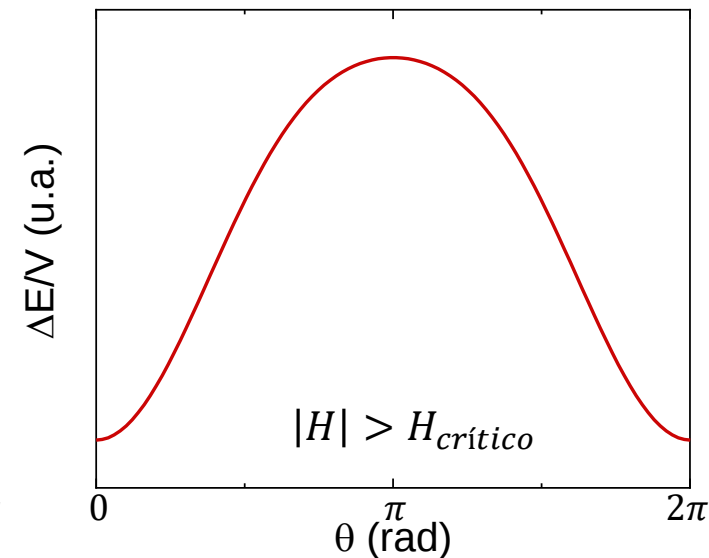
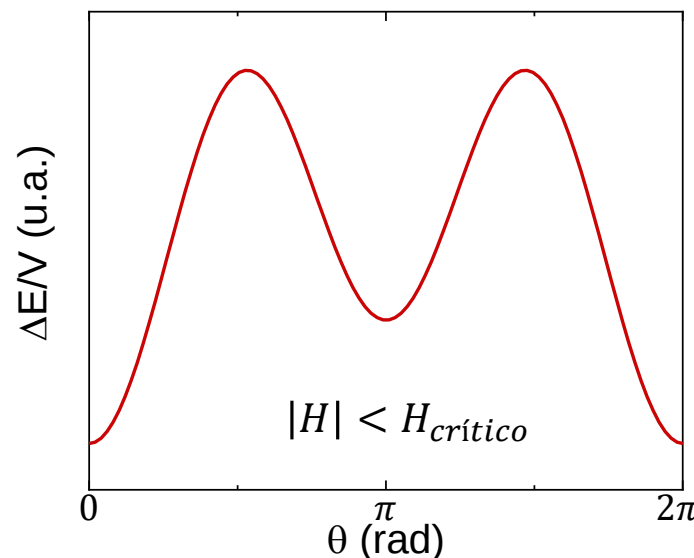
→ Debe ser suficientemente grande ( $> H_{\text{crítico}}$ ) para rotar a los espines.

# Magnetismo: Dominios e histéresis

## Histéresis en ferromagnetos



$$\Delta E/V = -|M||H|\cos\theta - \kappa'|M|^2\cos^2\theta$$



→  $\Delta E$  es mínimo cuando  $\vec{M}$  y  $\vec{H}$  son paralelos, y puede existir un mínimo relativo cuando son antiparalelos.

$$\frac{\partial(\Delta E)}{\partial\theta} = 0 \rightarrow -|M||H|\sin\theta - 2\kappa'|M|^2\cos\theta\sin\theta = 0 \rightarrow \theta = 0, \pi, \arccos\left(-\frac{|H|}{2\kappa'|M|}\right)$$

→  $H_{crítico} = 2\kappa'|M|$  → Si  $|H| < H_{crítico}$  existe un mínimo relativo, además del mínimo absoluto

Si  $\vec{M}$  apunta en la dirección  $-\hat{z}$  y se aplica un campo en la dirección  $\hat{z}$



Debe ser suficientemente grande ( $> H_{crítico}$ ) para rotar a los espines.

# Magnetismo: Ferromagnetismo itinerante

## Magnetismo itinerante: Orden magnético a campo nulo

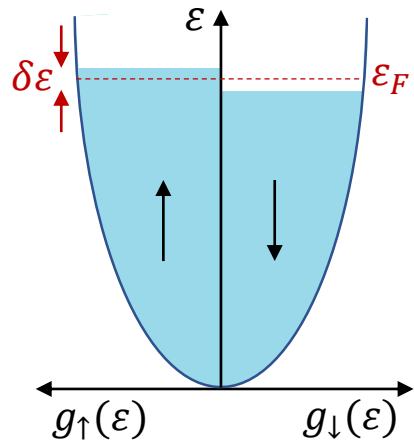
$$\mathcal{H} = \mathcal{H}_{\text{Tight-Binding}} + \mathcal{H}_{\text{Hubbard}} \quad \mathcal{H}_{\text{Hubbard}} = U \sum_i n_{i\uparrow} n_{i\downarrow}$$

$i$ : Corre sobre sitios de la red

$U$ : Costo energético por tener  $2e^-$  en el mismo sitio

$n_{i\uparrow}(n_{i\downarrow})$ : N° de  $e^-$  con espín  $\uparrow$  ( $\downarrow$ ) en el sitio  $i$

¿Conviene tener  $\rho_{\uparrow} \neq \rho_{\downarrow}$ ?



$$\begin{cases} \varepsilon_{F,\uparrow} = \varepsilon_F + \delta\varepsilon/2 \\ \varepsilon_{F,\downarrow} = \varepsilon_F - \delta\varepsilon/2 \end{cases}$$

$$\rho_{\uparrow} - \rho_{\downarrow} = \int_0^{\varepsilon_F + \frac{\delta\varepsilon}{2}} \frac{g(\varepsilon)}{2} d\varepsilon - \int_0^{\varepsilon_F - \frac{\delta\varepsilon}{2}} \frac{g(\varepsilon)}{2} d\varepsilon \approx \delta\varepsilon \frac{g(\varepsilon_F)}{2}$$

N° medio de  $e^-$  por sitio:  $x$

$$= (\rho_{\uparrow} - \rho_{\downarrow})v$$

$$\text{Aproximo: } U n_{i\uparrow} n_{i\downarrow} = \frac{U}{4} (n_{i\uparrow} + n_{i\downarrow})^2 - \frac{U}{4} (n_{i\uparrow} - n_{i\downarrow})^2 \approx \frac{U}{4} \langle n_{i\uparrow} + n_{i\downarrow} \rangle^2 - \frac{U}{4} \langle n_{i\uparrow} - n_{i\downarrow} \rangle^2$$

$$\text{Magnetización: } M = -\frac{g}{2} \mu_B (\rho_{\uparrow} - \rho_{\downarrow}) = -\frac{g \mu_B \delta\varepsilon}{4} g(\varepsilon_F) \rightarrow \frac{E_{\text{Hubbard}}}{V} = \boxed{\frac{U}{4} \frac{x^2}{v} - \frac{U}{v} \left( \frac{Mv}{g \mu_B} \right)^2}$$

$$\text{E cinética: } \frac{K}{V} = \int_0^{\varepsilon_F + \frac{\delta\varepsilon}{2}} \varepsilon \frac{g(\varepsilon)}{2} d\varepsilon + \int_0^{\varepsilon_F - \frac{\delta\varepsilon}{2}} \varepsilon \frac{g(\varepsilon)}{2} d\varepsilon = 2 \int_0^{\varepsilon_F} \varepsilon \frac{g(\varepsilon)}{2} d\varepsilon + \int_{\varepsilon_F}^{\varepsilon_F + \frac{\delta\varepsilon}{2}} \varepsilon \frac{g(\varepsilon)}{2} d\varepsilon - \int_{\varepsilon_F - \frac{\delta\varepsilon}{2}}^{\varepsilon_F} \varepsilon \frac{g(\varepsilon)}{2} d\varepsilon$$

$= K(M=0)$

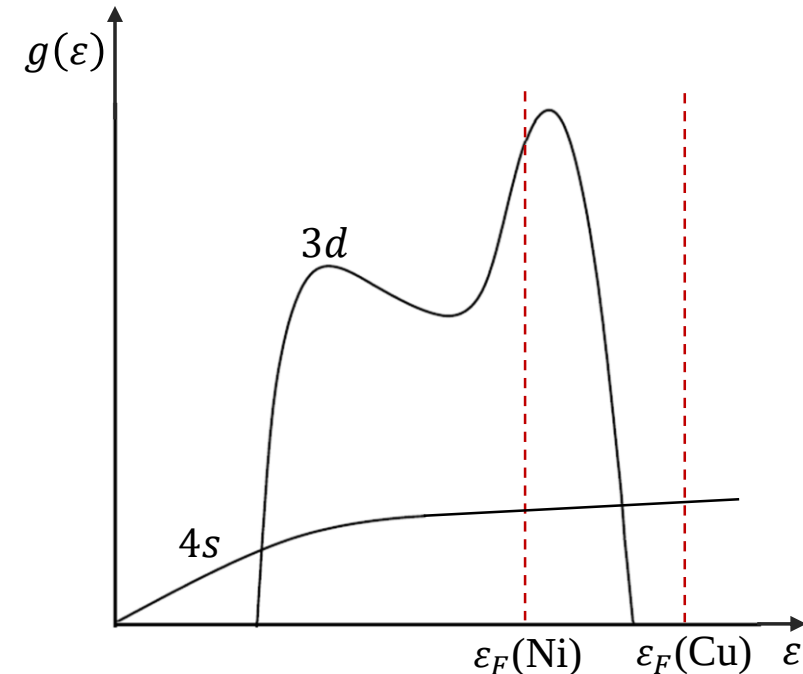
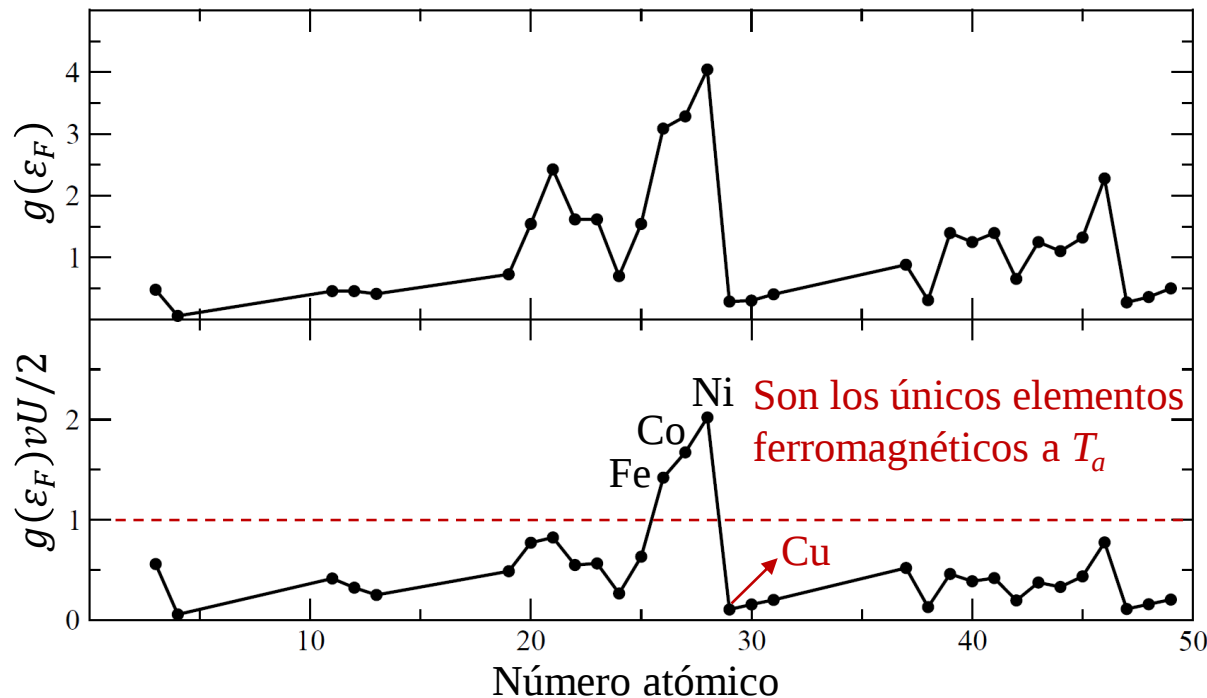
$$\approx \frac{K_0}{V} + \frac{g(\varepsilon_F)}{2} \left\{ \left[ \frac{(\varepsilon_F + \delta\varepsilon/2)^2}{2} - \frac{\varepsilon_F^2}{2} \right] - \left[ \frac{\varepsilon_F^2}{2} - \frac{(\varepsilon_F - \delta\varepsilon/2)^2}{2} \right] \right\} = \frac{K_0}{V} + \frac{g(\varepsilon_F)}{2} \left( \frac{\delta\varepsilon}{2} \right)^2 = \boxed{\frac{K_0}{V} + \frac{g(\varepsilon_F)}{2} \left( \frac{2M}{g \mu_B g(\varepsilon_F)} \right)^2}$$

# Magnetismo: Ferromagnetismo itinerante

## Magnetismo itinerante: Orden magnético a campo nulo

$$\frac{E}{V} = \frac{K + E_{Hubbard}}{V} = \frac{K_0 + \overset{= E_{Hubbard}(M=0)}{\underset{= E(M=0)}{U_0}}}{V} + \frac{1}{2g(\varepsilon_F)} \left( \frac{2M}{g\mu_B} \right)^2 - \frac{U}{v} \left( \frac{Mv}{g\mu_B} \right)^2 = \frac{\overset{= E(M=0)}{E_0}}{V} + \left( \frac{M}{g\mu_B} \right)^2 \left[ \frac{2}{g(\varepsilon_F)} - vU \right]$$

¿Cuándo conviene tener  $M \neq 0$ ?  $\rightarrow \frac{2}{g(\varepsilon_F)} - vU < 0 \rightarrow g(\varepsilon_F) > \frac{2}{vU} \rightarrow \frac{g(\varepsilon_F)vU}{2} > 1$  (Criterio de Stoner)

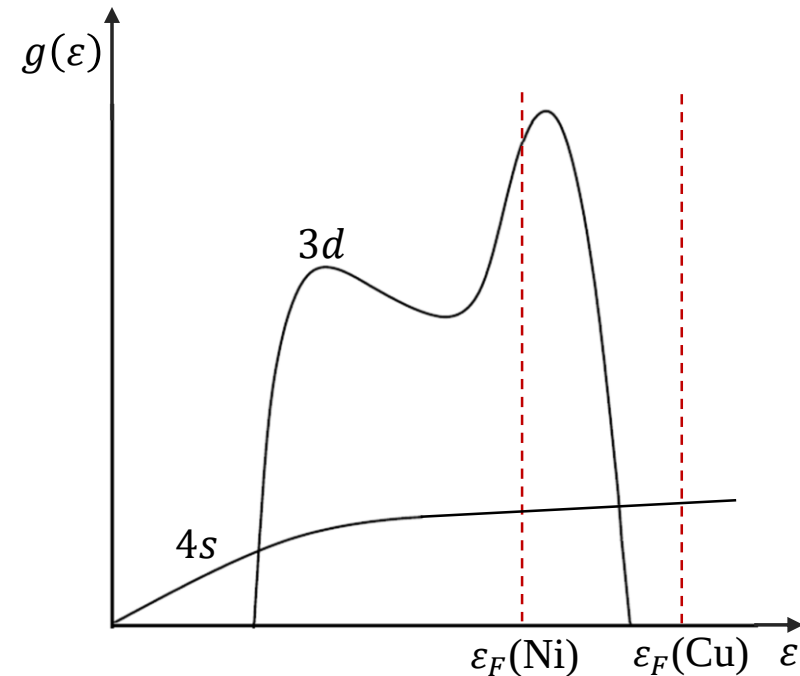
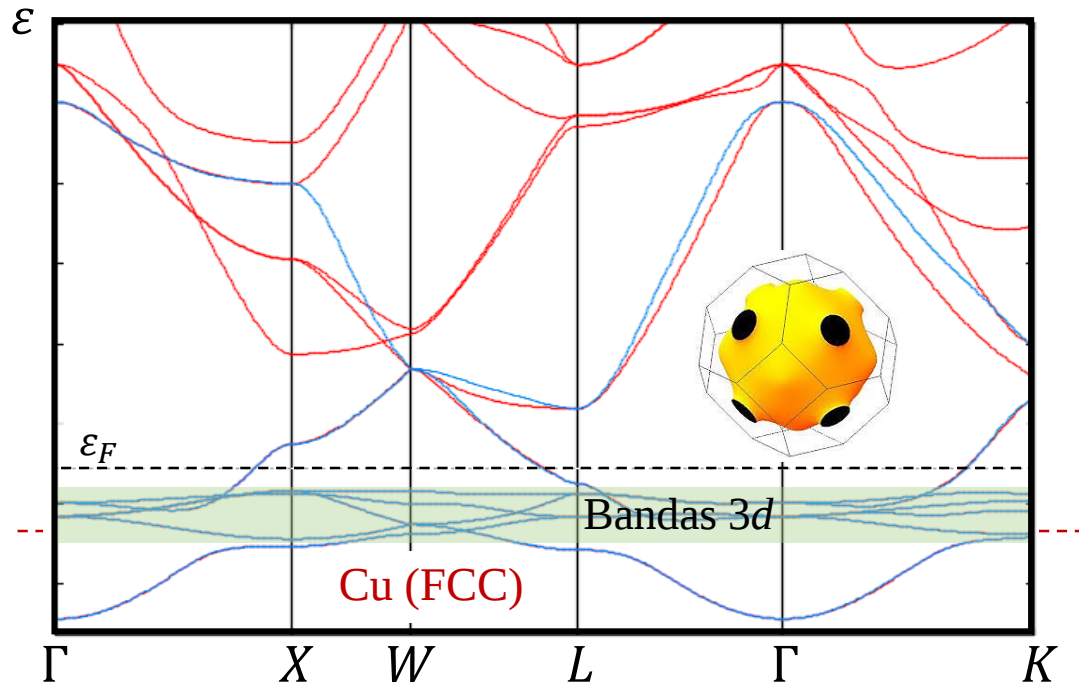


# Magnetismo: Ferromagnetismo itinerante

## Magnetismo itinerante: Orden magnético a campo nulo

$$\frac{E}{V} = \frac{K + E_{Hubbard}}{V} = \frac{K_0 + \overset{= E_{Hubbard}(M=0)}{\underbrace{U_0}}}{V} + \frac{1}{2g(\varepsilon_F)} \left( \frac{2M}{g\mu_B} \right)^2 - \frac{U}{v} \left( \frac{Mv}{g\mu_B} \right)^2 = \overset{= E(M=0)}{\underbrace{\frac{E_0}{V}}} + \left( \frac{M}{g\mu_B} \right)^2 \left[ \frac{2}{g(\varepsilon_F)} - vU \right]$$

¿Cuándo conviene tener  $M \neq 0$ ?  $\rightarrow \frac{2}{g(\varepsilon_F)} - vU < 0 \rightarrow g(\varepsilon_F) > \frac{2}{vU} \rightarrow \frac{g(\varepsilon_F)vU}{2} > 1$  (Criterio de Stoner)



# Magnetismo: La tabla periódica

## Magnetismo en la tabla periódica

Considerando todas las contribuciones, se obtiene un comportamiento dominante.

(e<sup>-</sup> de conducción: paramagnetismo de Pauli:  $\chi_{Pauli} = \mu_B^2 g(\epsilon_F)$ ; diamagnetismo de Landau:  $\chi_{Landau} = -\frac{1}{3} \chi_{Pauli}$ )

e<sup>-</sup> libres

|

$-\frac{1}{3}$

|                                                                         |                                                                                  |                                                                         |                                                                            |                                                                     |                                                                          |                                                                       |                                                                    |                                                                      |                                                                       |                                                                        |                                                                        |                                                                       |                                             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| 1<br>1.0080<br>20.28<br>17.81<br>0.08988<br>1s <sup>1</sup><br><b>H</b> | 2<br>4.002602<br>4.216<br>0.8 (26 bar)<br>0.1767<br>1s <sup>2</sup><br><b>He</b> | 3<br>6.97<br>1615<br>453.69<br>0.53<br>[He]2s <sup>1</sup><br><b>Li</b> | 4<br>9.012182<br>2745<br>1560<br>1.848<br>[He]2s <sup>2</sup><br><b>Be</b> | 5<br>51.9961<br>39.948<br>1.673<br>[Ne]3s <sup>1</sup><br><b>Na</b> | 6<br>24.3050<br>1363<br>922<br>1.738<br>[Ne]3s <sup>2</sup><br><b>Mg</b> | 7<br>54.938045<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Al</b> | 8<br>55.845<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Si</b> | 9<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>P</b> | 10<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>S</b> | 11<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Cl</b> | 12<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ar</b> | 13<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>K</b> | 14<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ca</b> | 15<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Sc</b> | 16<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ti</b> | 17<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>V</b> | 18<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Cr</b> | 19<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Mn</b> | 20<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Fe</b> | 21<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Co</b> | 22<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ni</b> | 23<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Cu</b> | 24<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Zn</b> | 25<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ga</b> | 26<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ge</b> | 27<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>As</b> | 28<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Se</b> | 29<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Br</b> | 30<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Kr</b> | 31<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Rb</b> | 32<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Sr</b> | 33<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Y</b> | 34<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Zr</b> | 35<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Nb</b> | 36<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Mo</b> | 37<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Tc</b> | 38<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ru</b> | 39<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Rh</b> | 40<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Pd</b> | 41<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ag</b> | 42<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Cd</b> | 43<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>In</b> | 44<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Sn</b> | 45<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Sb</b> | 46<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Te</b> | 47<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>I</b> | 48<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Xe</b> | 49<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Cs</b> | 50<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ba</b> | 51<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>La</b> | 52<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ce</b> | 53<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Pr</b> | 54<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Nd</b> | 55<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Pm</b> | 56<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Sm</b> | 57<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Eu</b> | 58<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Gd</b> | 59<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Tb</b> | 60<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Dy</b> | 61<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ho</b> | 62<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Er</b> | 63<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Tm</b> | 64<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Yb</b> | 65<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Lu</b> | 66<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Hf</b> | 67<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ta</b> | 68<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>W</b> | 69<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Re</b> | 70<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Os</b> | 71<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ir</b> | 72<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Pt</b> | 73<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Au</b> | 74<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Hg</b> | 75<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Tl</b> | 76<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Pb</b> | 77<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Bi</b> | 78<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Po</b> | 79<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>At</b> | 80<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Rn</b> | 81<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Fr</b> | 82<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ra</b> | 83<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ac</b> | 84<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Th</b> | 85<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Pa</b> | 86<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>U</b> | 87<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Np</b> | 88<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Pu</b> | 89<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Am</b> | 90<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Cm</b> | 91<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Bk</b> | 92<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Cf</b> | 93<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Es</b> | 94<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Fm</b> | 95<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Md</b> | 96<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>No</b> | 97<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Lr</b> | 98<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>La</b> | 99<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ce</b> | 100<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Pr</b> | 101<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Nd</b> | 102<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Pm</b> | 103<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Sm</b> | 104<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Eu</b> | 105<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Gd</b> | 106<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Tb</b> | 107<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Dy</b> | 108<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ho</b> | 109<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Er</b> | 110<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Tm</b> | 111<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Yb</b> | 112<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Lu</b> | 113<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Hf</b> | 114<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ta</b> | 115<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>W</b> | 116<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Re</b> | 117<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Os</b> | 118<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ir</b> | 119<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Pt</b> | 120<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Au</b> | 121<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Hg</b> | 122<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Tl</b> | 123<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Pb</b> | 124<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Bi</b> | 125<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Po</b> | 126<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>At</b> | 127<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Rn</b> | 128<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Fr</b> | 129<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ra</b> | 130<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ac</b> | 131<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Th</b> | 132<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Pa</b> | 133<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>U</b> | 134<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Np</b> | 135<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Pu</b> | 136<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Am</b> | 137<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Cm</b> | 138<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Bk</b> | 139<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Cf</b> | 140<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Es</b> | 141<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Fm</b> | 142<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Md</b> | 143<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>No</b> | 144<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Lr</b> | 145<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>La</b> | 146<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ce</b> | 147<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Pr</b> | 148<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Nd</b> | 149<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Pm</b> | 150<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Sm</b> | 151<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Eu</b> | 152<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Gd</b> | 153<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Tb</b> | 154<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Dy</b> | 155<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ho</b> | 156<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Er</b> | 157<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Tm</b> | 158<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Yb</b> | 159<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Lu</b> | 160<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Hf</b> | 161<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ta</b> | 162<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>W</b> | 163<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Re</b> | 164<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Os</b> | 165<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ir</b> | 166<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Pt</b> | 167<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Au</b> | 168<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Hg</b> | 169<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Tl</b> | 170<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Pb</b> | 171<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Bi</b> | 172<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Po</b> | 173<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>At</b> | 174<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Rn</b> | 175<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Fr</b> | 176<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ra</b> | 177<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ac</b> | 178<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Th</b> | 179<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Pa</b> | 180<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>U</b> | 181<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Np</b> | 182<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Pu</b> | 183<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Am</b> | 184<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Cm</b> | 185<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Bk</b> | 186<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Cf</b> | 187<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Es</b> | 188<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Fm</b> | 189<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Md</b> | 190<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>No</b> | 191<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Lr</b> | 192<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>La</b> | 193<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ce</b> | 194<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Pr</b> | 195<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Nd</b> | 196<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Pm</b> | 197<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Sm</b> | 198<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Eu</b> | 199<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Gd</b> | 200<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Tb</b> | 201<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Dy</b> | 202<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ho</b> | 203<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Er</b> | 204<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Tm</b> | 205<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Yb</b> | 206<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Lu</b> | 207<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Hf</b> | 208<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ta</b> | 209<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>W</b> | 210<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Re</b> | 211<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Os</b> | 212<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Ir</b> | 213<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Pt</b> | 214<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Au</b> | 215<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Hg</b> | 216<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Tl</b> | 217<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Pb</b> | 218<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Bi</b> | 219<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>Po</b> | 220<br>58.933195<br>39.948<br>1.673<br>[Ne]3s <sup>2</sup><br><b>At</b> | 221<br>58.933 |
|-------------------------------------------------------------------------|----------------------------------------------------------------------------------|-------------------------------------------------------------------------|----------------------------------------------------------------------------|---------------------------------------------------------------------|--------------------------------------------------------------------------|-----------------------------------------------------------------------|--------------------------------------------------------------------|----------------------------------------------------------------------|-----------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|-----------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|-----------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|-----------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|-----------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|------------------------------------------------------------------------|-----------------------------------------------------------------------|---------------------------------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# Resumen

- Modelo de campo medio en un antiferromagneto
- Anisotropía magnetocristalina y formación de dominios
- Ciclo de histéresis de un ferromagneto
- Magnetismo itinerante
- Hamiltoniano de Hubbard y Criterio de Stoner

