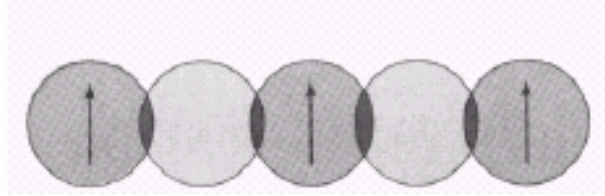


Superintercambio

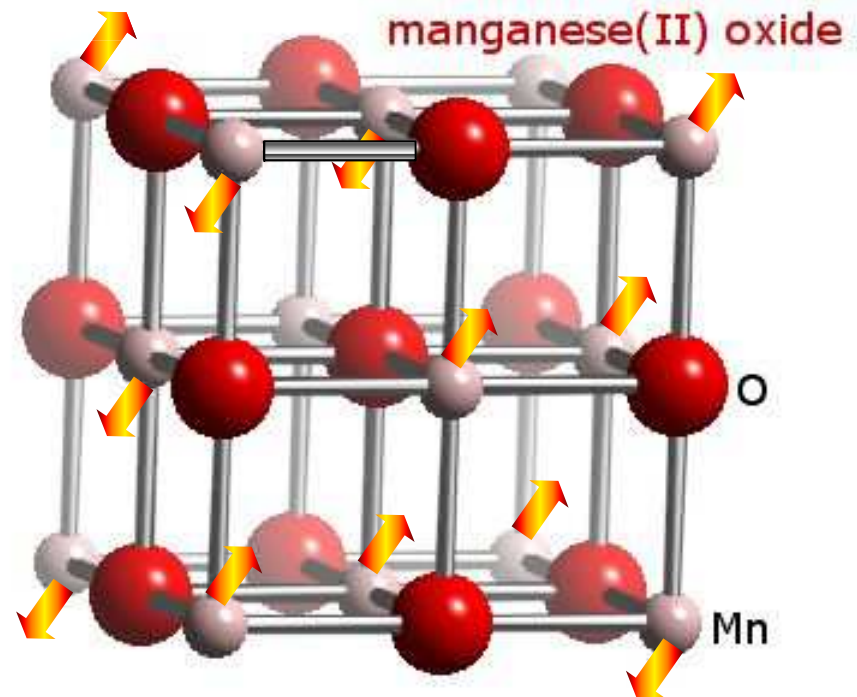
Superexchange.

A magnetic ion⁺ induces a spin polarisation in other magnetic ion which is coupled by their common non-magnetic neighbour.

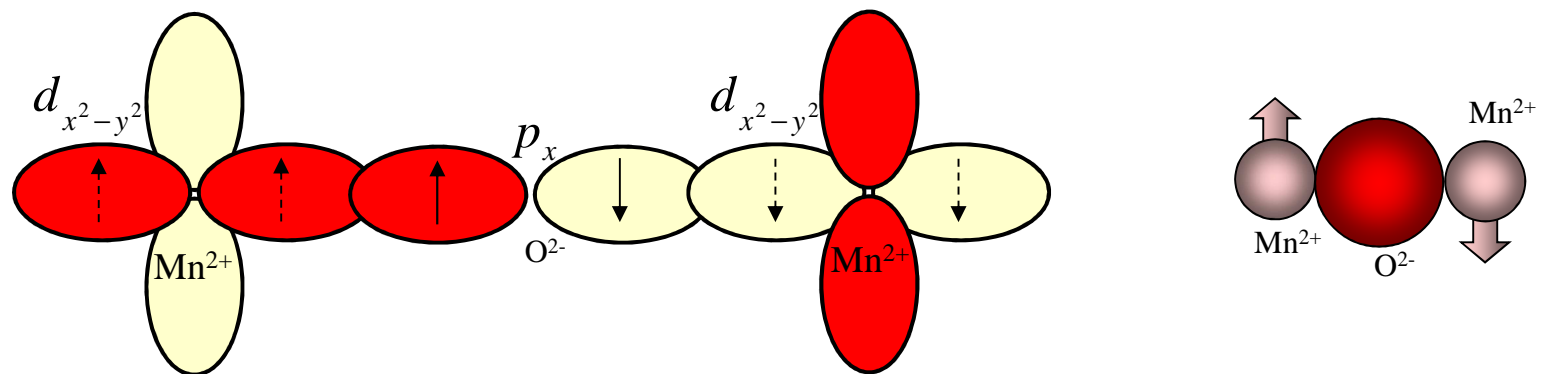
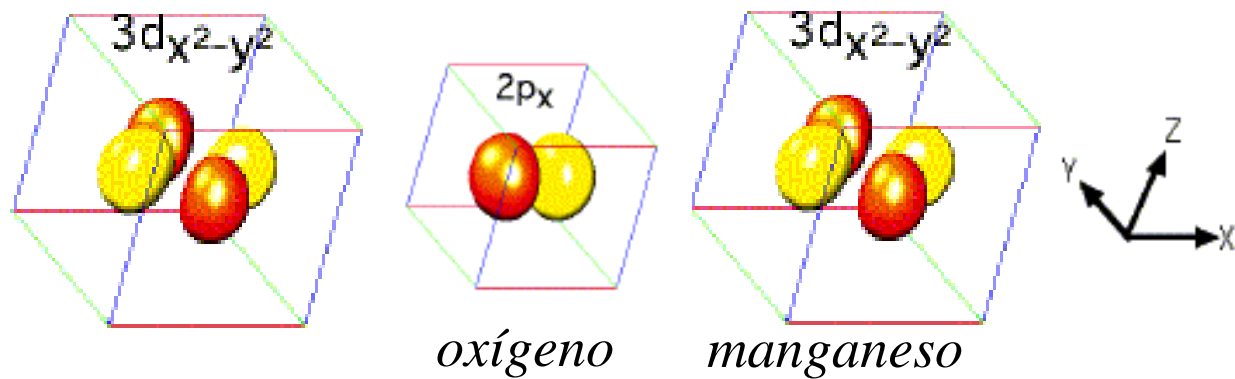


Ejemplo: MnO

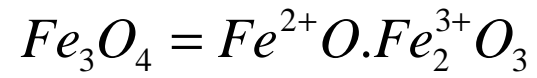
Antiferromagneto $T_N = 118$ K
momentos magnéticos paralelos a planos (111)
planos (111) vecinos están ordenados AFM



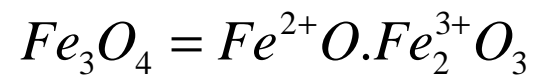
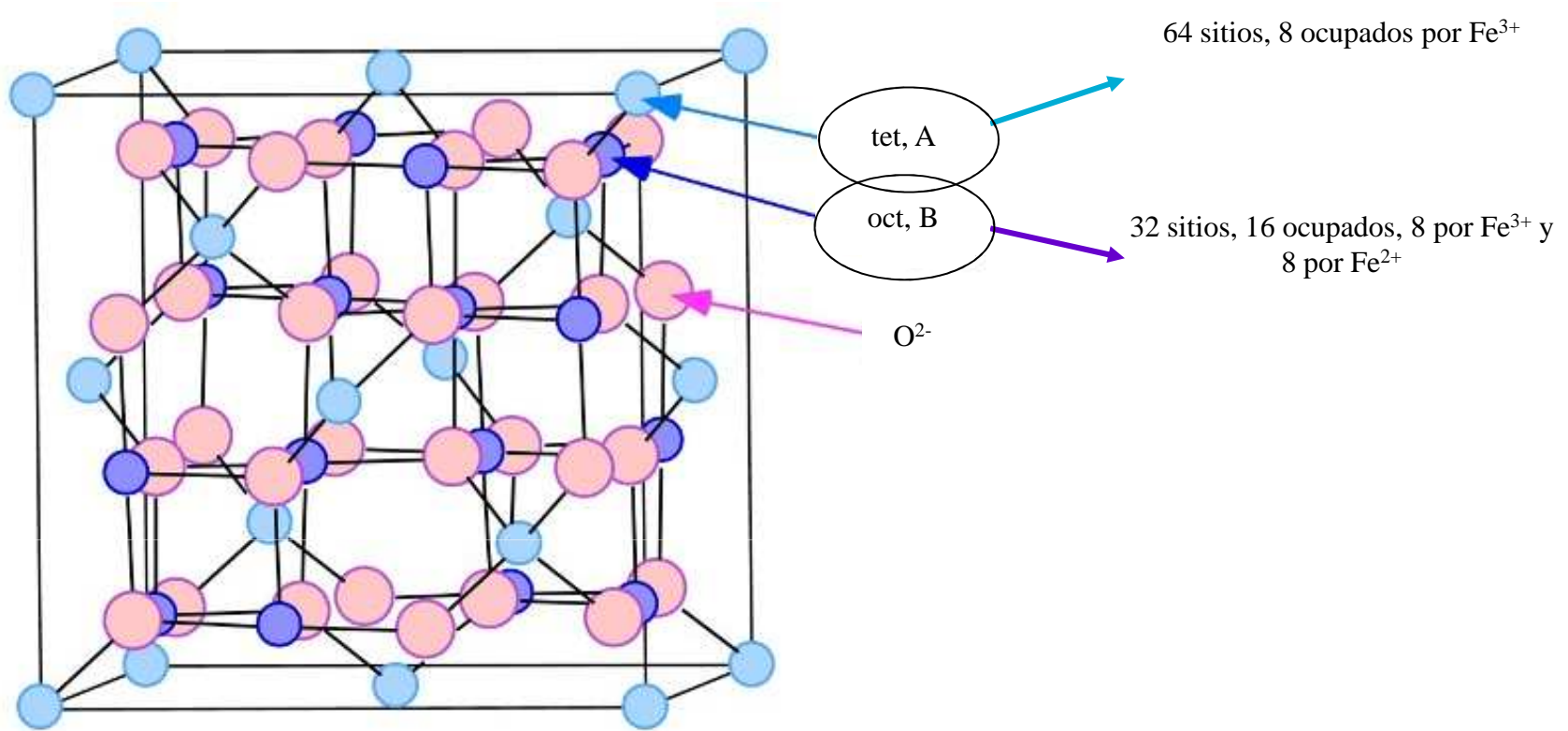
MnO



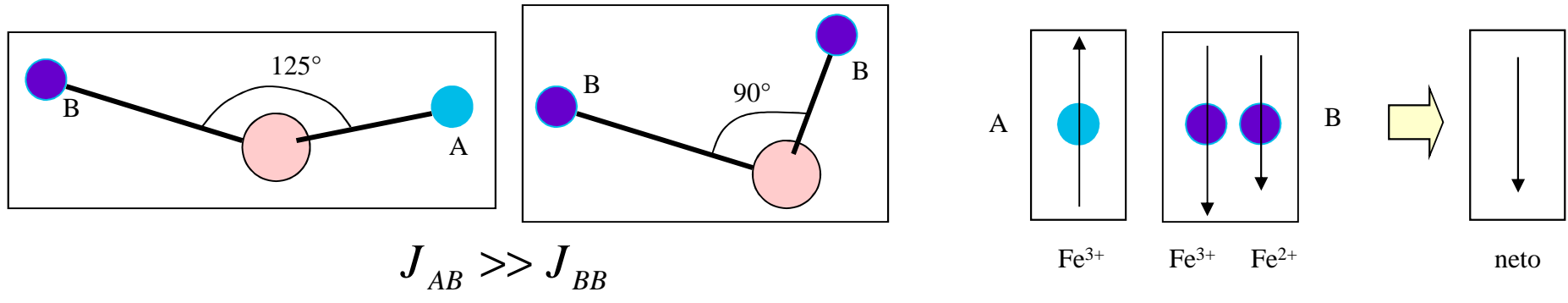
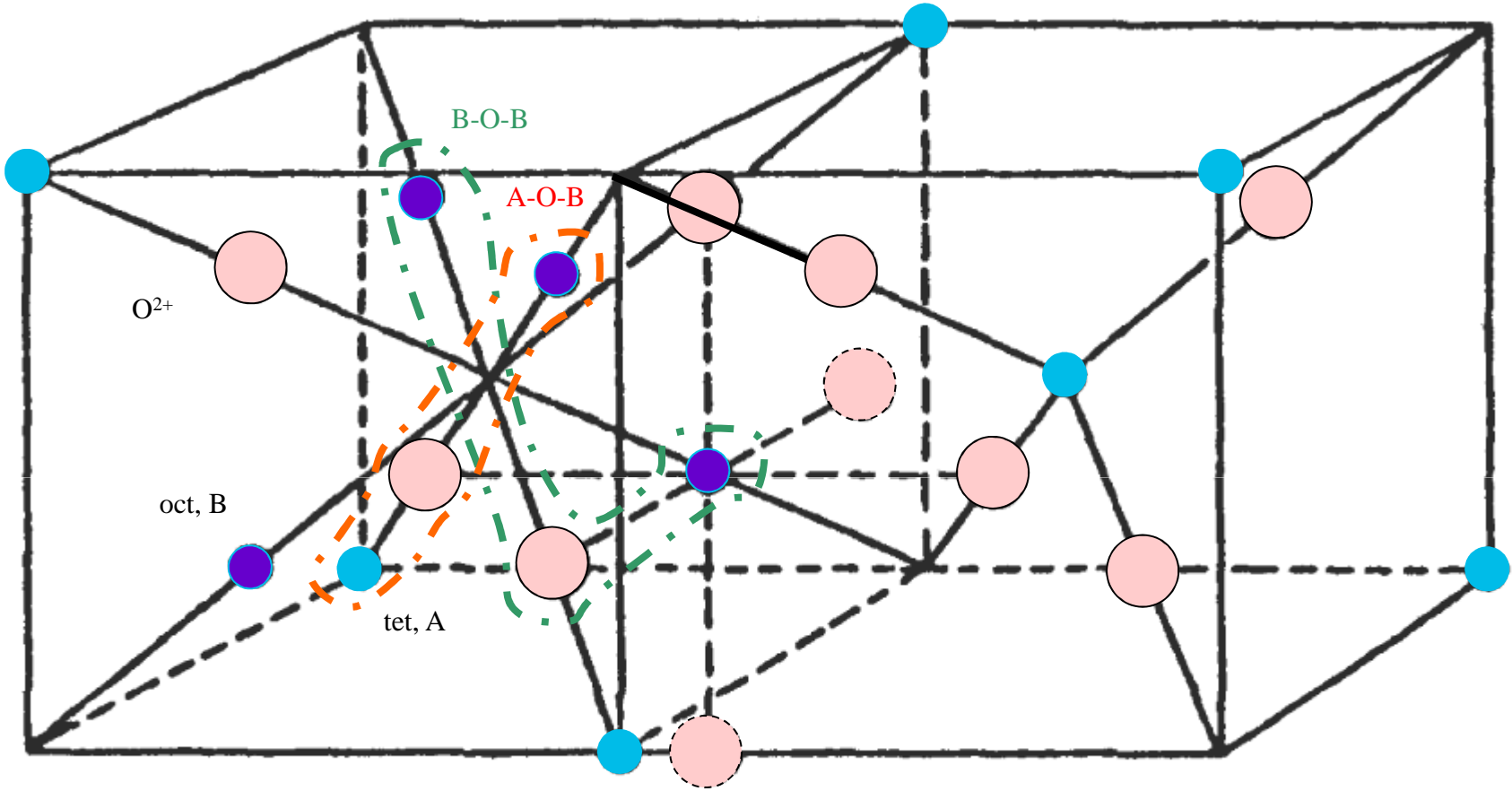
Magnetita: espinela de Fe



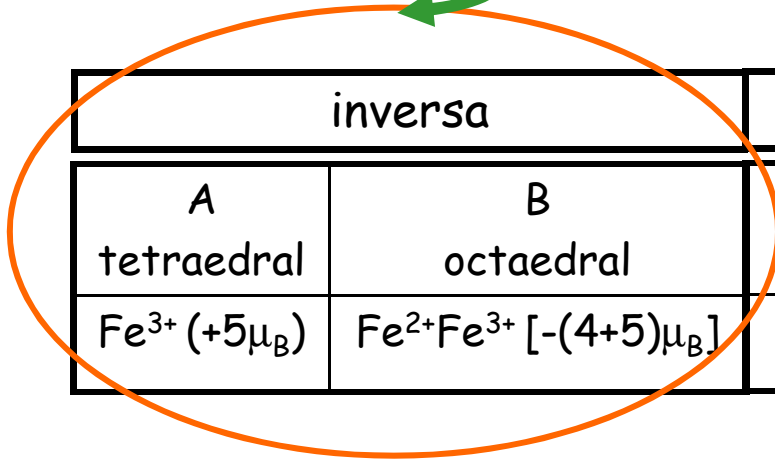
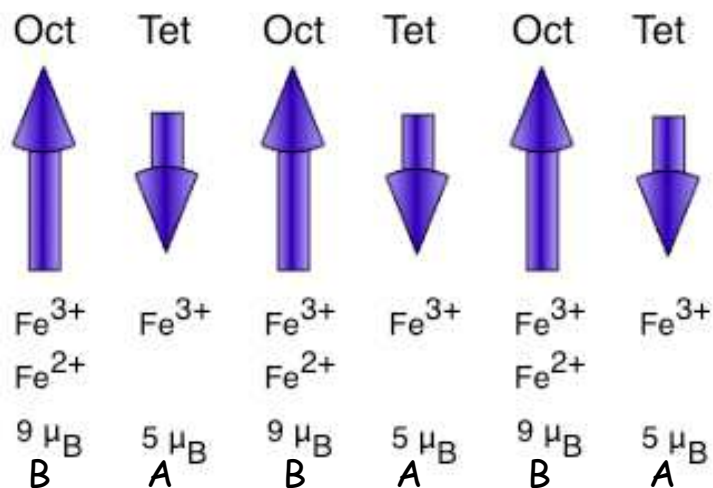
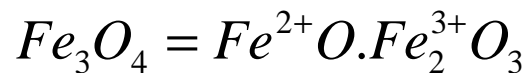
óxido	estructura	Estructura magnética	$\mu(\mu_B)$	$\sigma(\text{emu/g})$	$T_N(\text{K})$
Fe_3O_4 magnetita	espinela	ferri	4.1 por form	96	858



$$\langle \vec{\mu} \rangle_{\text{Fe}_3\text{O}_4} \approx \mu_{\text{Fe}^{3+}} (\uparrow) + \mu_{\text{Fe}^{3+}} (\downarrow) + \mu_{\text{Fe}^{2+}} (\uparrow) \approx \mu_{\text{Fe}^{2+}} (\uparrow) = 4\mu_B \hat{u}_z$$



Magnetita o espinela de Fe

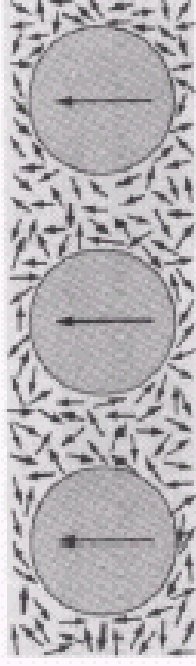


inversa		normal	
A	B	A	B
tetraedral	octaedral	tetraedral	octaedral
$Fe^{3+} (+5\mu_B)$	$Fe^{2+}Fe^{3+} [-(4+5)\mu_B]$	$Fe^{2+} (+4\mu_B)$	$2Fe^{3+} [2(-5)\mu_B]$

Intercambio indirecto

Indirect exchange interaction.

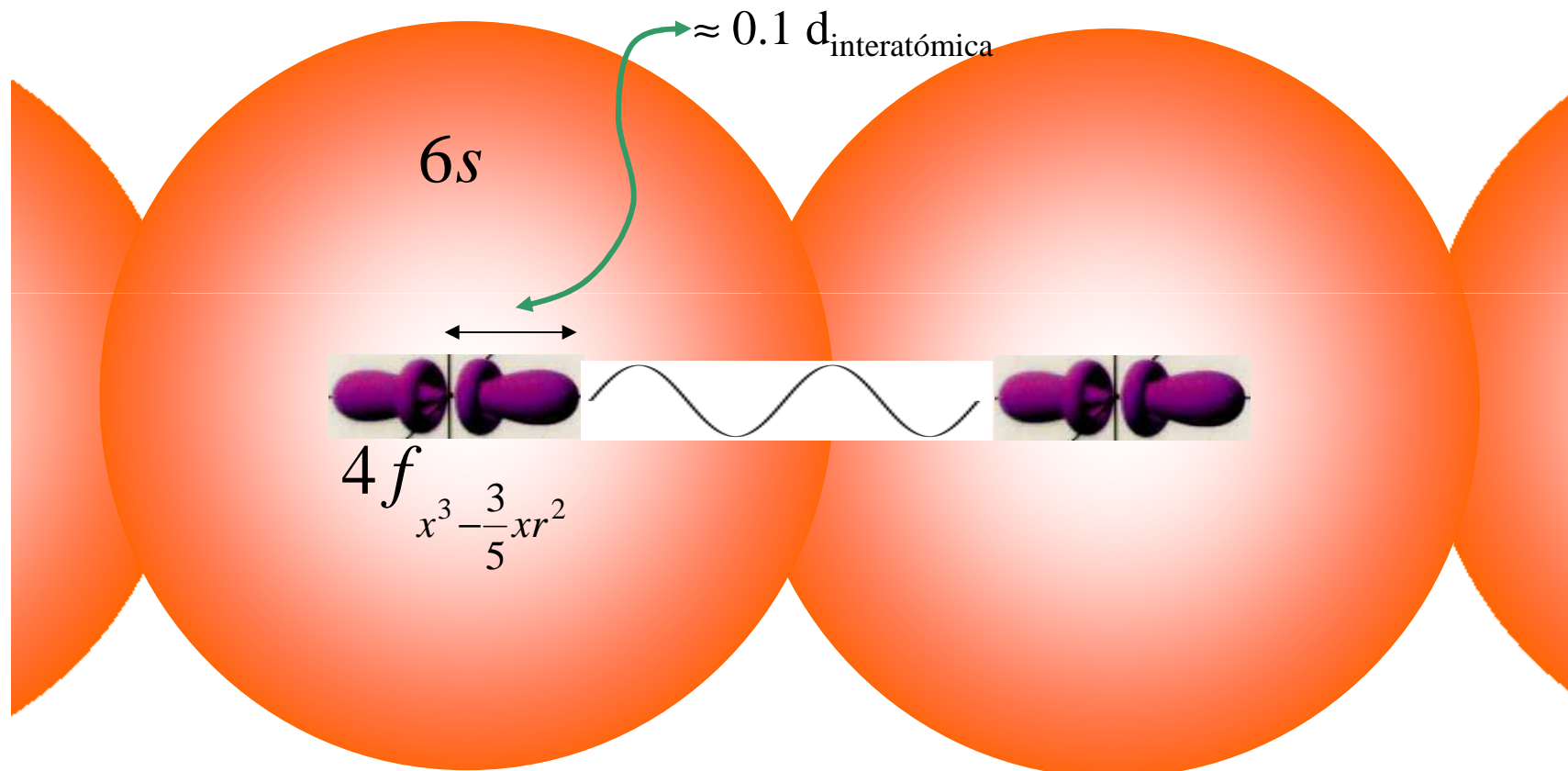
A magnetic ion induces a spin polarisation in the conduction electrons in its neighbourhood. This spin polarisation in the itinerant electrons is felt by the moments of other magnetic ions within range leading to an indirect coupling.



Tierras raras o lantánidos

57	58	59	60	61	62	63	64	65	66	67	68	69	70
La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb
138.9	140.1	140.9	144.2	146.9	150.4	152.0	157.3	158.9	162.5	164.9	167.3	168.9	173.0

$$4f^n 5d^1 6s^2$$



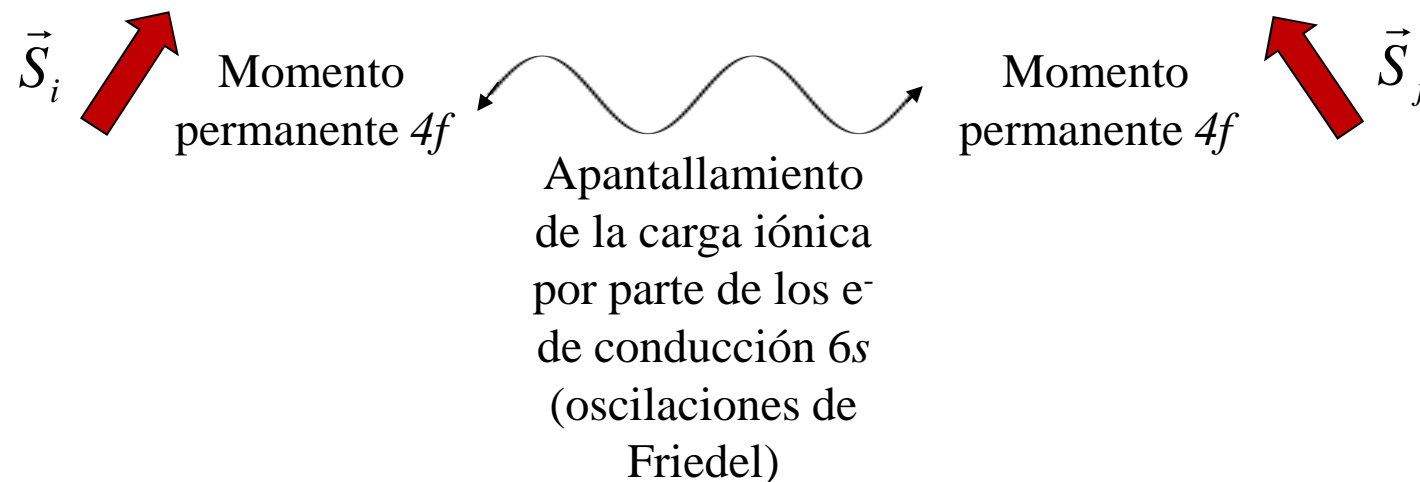
$$4f \quad x^3 - \frac{3}{5}xr^2$$

$$U_{J_{ij}} = -2J_{ij} \vec{S}_i \cdot \vec{S}_j$$

Tierras raras pesadas

$$U_{J_{ij}} = -2J_{ij} \vec{S}_i \cdot \vec{S}_j$$

Polarización
débil de los
electrones $6s$
(intercambio
débil f - s)



Compuestos de tierras raras con
estequiometría variable: **vidrios de spin**

Modelo RKKY: Ruderman y Kittel, Kasuya y Yosida

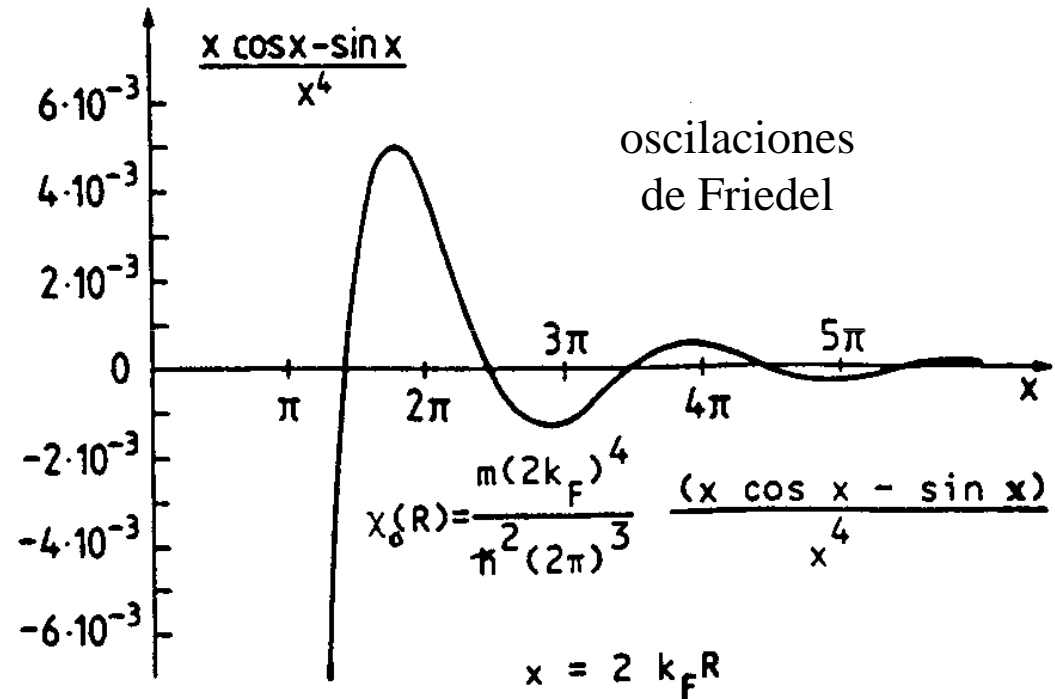
$$H = -2J_{ij}\vec{S}_i \cdot \vec{S}_j \approx -2J_{ij}S_{iz}S_{jz} \quad J_{ij} \text{ interacción de intercambio entre tierras raras}$$



$$J_{ij}(R_{ij}) = 3\pi n J D(E_F) \left[\frac{\overset{F(x)}{\sin(2k_F R_{ij}) - (2k_F R_{ij}) \cos(2k_F R_{ij})}}{(2k_F R_{ij})^4} \right]$$

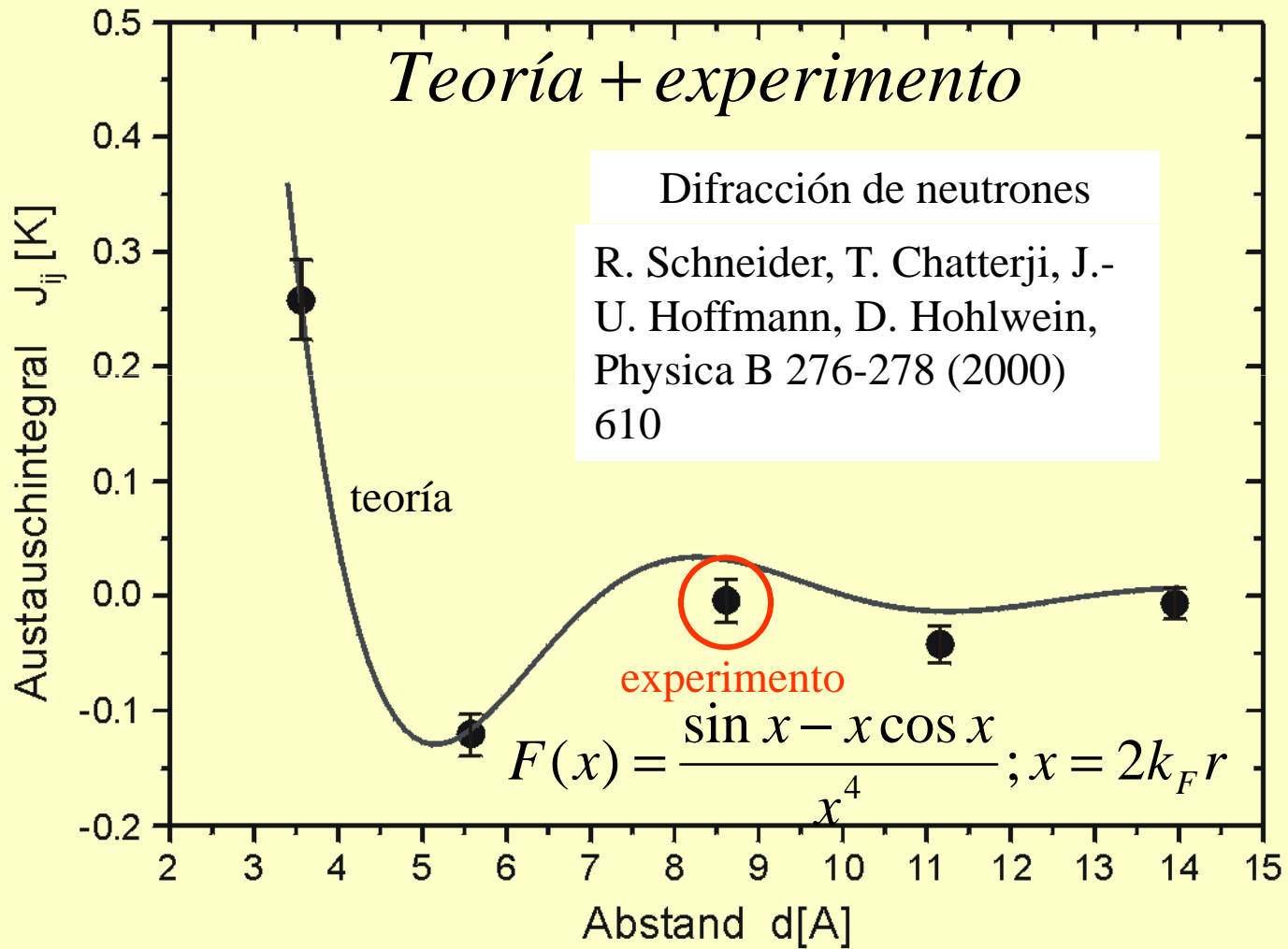
n	número de electrones s /átomo
J	interacción de intercambio s-d
k_F	“momento” lineal de Fermi
R_{ij}	distancia entre tierras raras
$D(E_F)$	densidad de estados al nivel de Fermi

$$F(x) = \frac{\sin x - x \cos x}{x^4}; x = 2k_F r$$



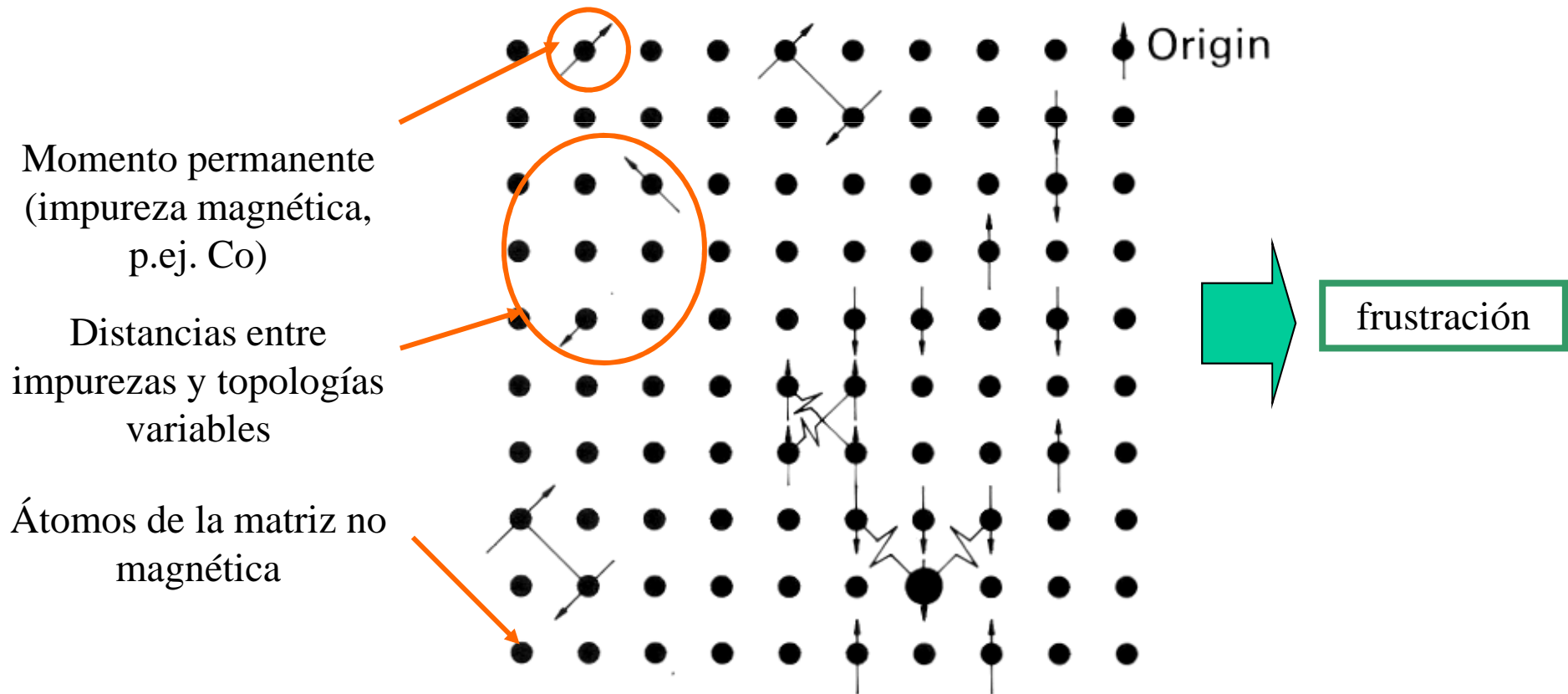
Distribución de carga de electrones
de conducción $6s$ alrededor de un
sitio $4f$

Resultados experimentales en
compuesto de Holmio

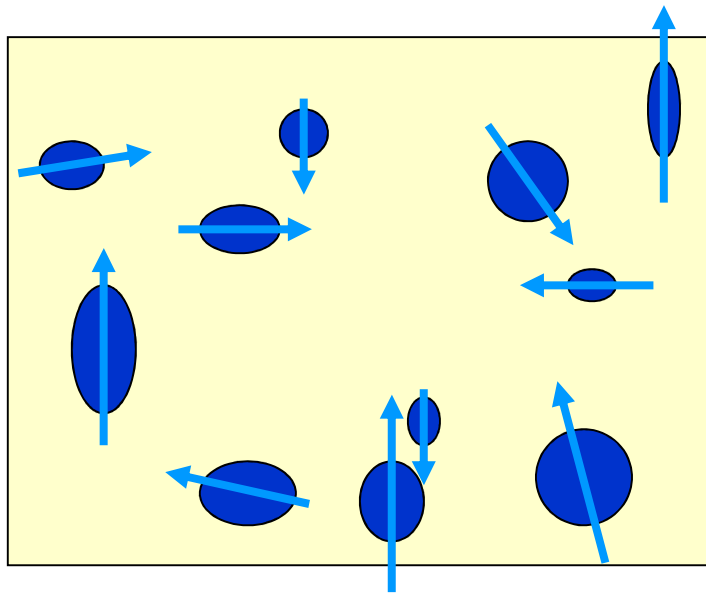


vidrios de spin

- compuesto no magnético con iones magnéticos de tierra rara substitucionales
 $\text{Eu}_x\text{Sr}_{1-x}\text{S}$ (semiconductor)
 $\text{La}_{1-x}\text{Gd}_x\text{Al}_2$ (metal)
- Elementos con momentos permanentes (Mn, Fe, Gd, Eu, ...) diluidos en metales nobles no magnéticos ($\text{Cu}_{1-x}\text{Mn}_x$, $\text{Au}_{1-x}\text{Fe}_x$, vidrios de spin canónicos)

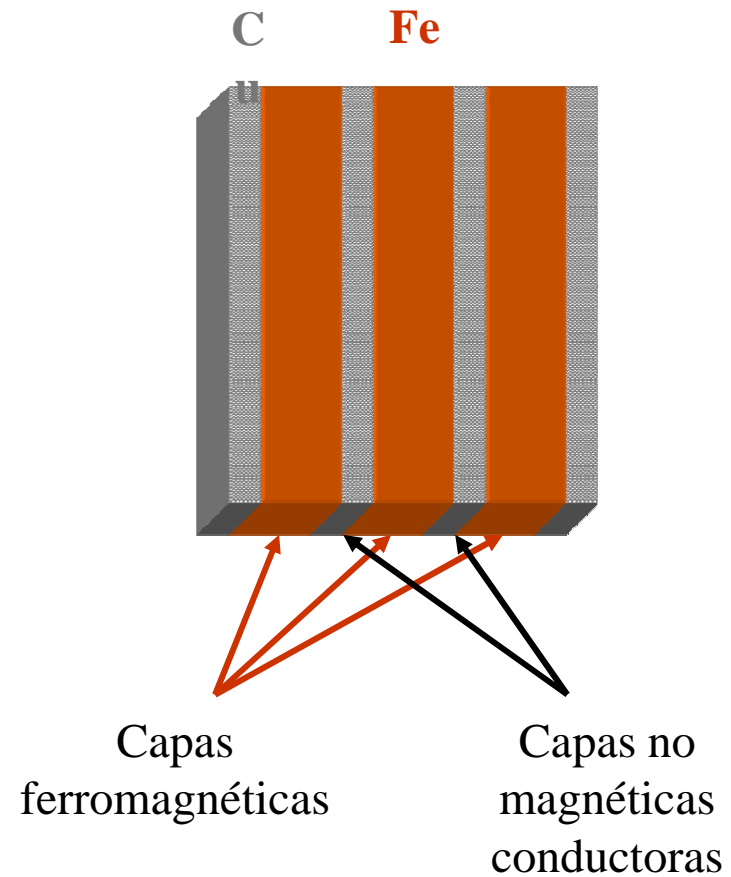


Vidrio de clusters de spin (cluster glass)



Partículas o clusters magnéticos en
matriz no magnética conductora
($\text{Cu}_{1-x}\text{Fe}_x$, $\text{Au}_{1-x}\text{Fe}_x$, $\text{Cu}_{1-x}\text{Co}_x$)

Acoplamiento en multicapas



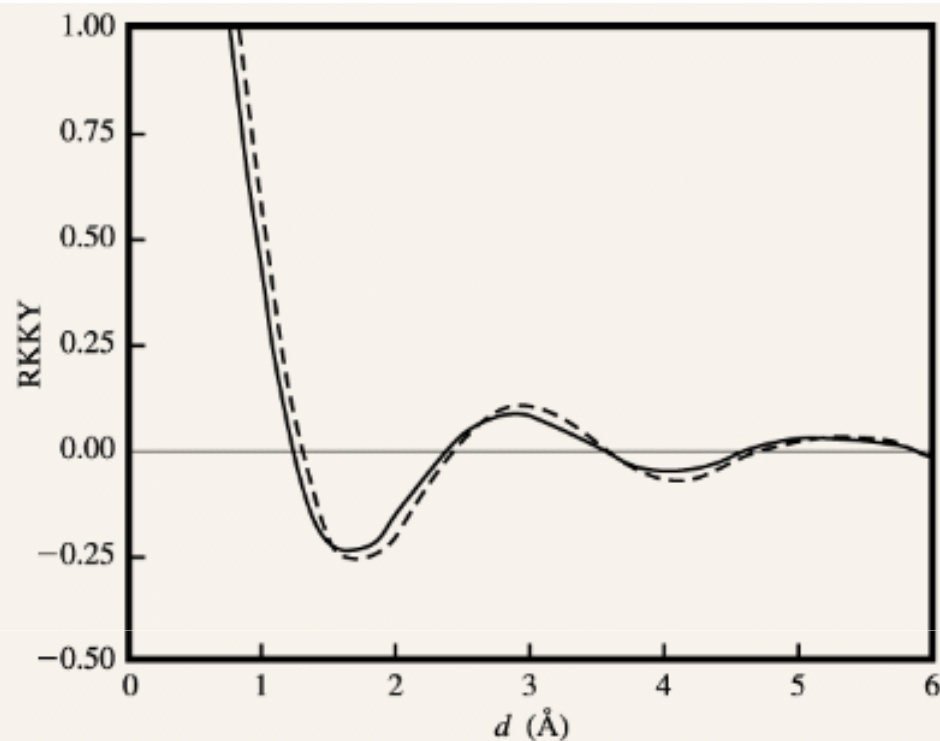


Figure 2

RKKY coupling between two magnetic layers separated by a distance d , for free electron bands. The units for RKKY coupling are unspecified. The Fermi energy is taken to be that for Cu. Solid line: Free electrons, no potential well. Dashed line: Effect of a small potential well relative to the Fermi energy. A phase shift is induced, and the RKKY coupling is enhanced for separations d greater than about 0.5 \AA .

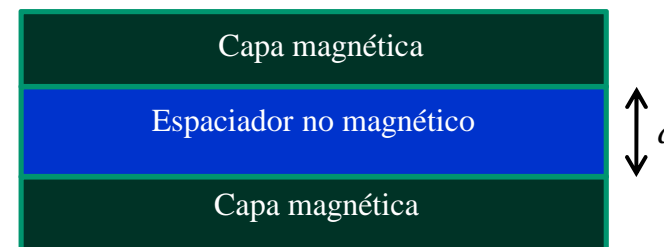
Modelo para acoplamiento
oscilatorio $J(r)$ entre dos capas
magnéticas separadas una
distancia r por otra no
magnética

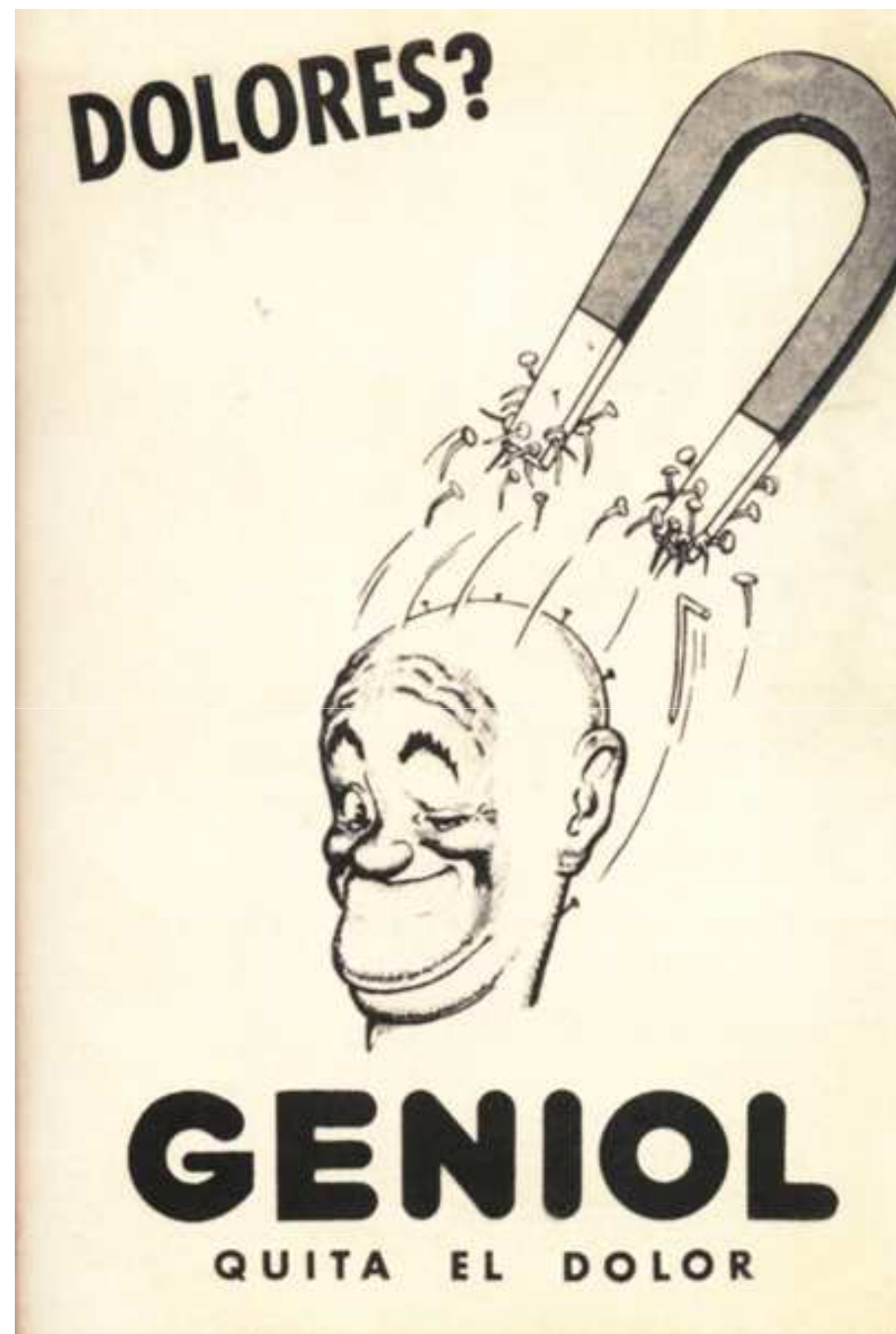
Theory of exchange coupling in
magnetic multilayers

by B. A. Jones



Volume 42, Number 1, 1998





Fin módulo