

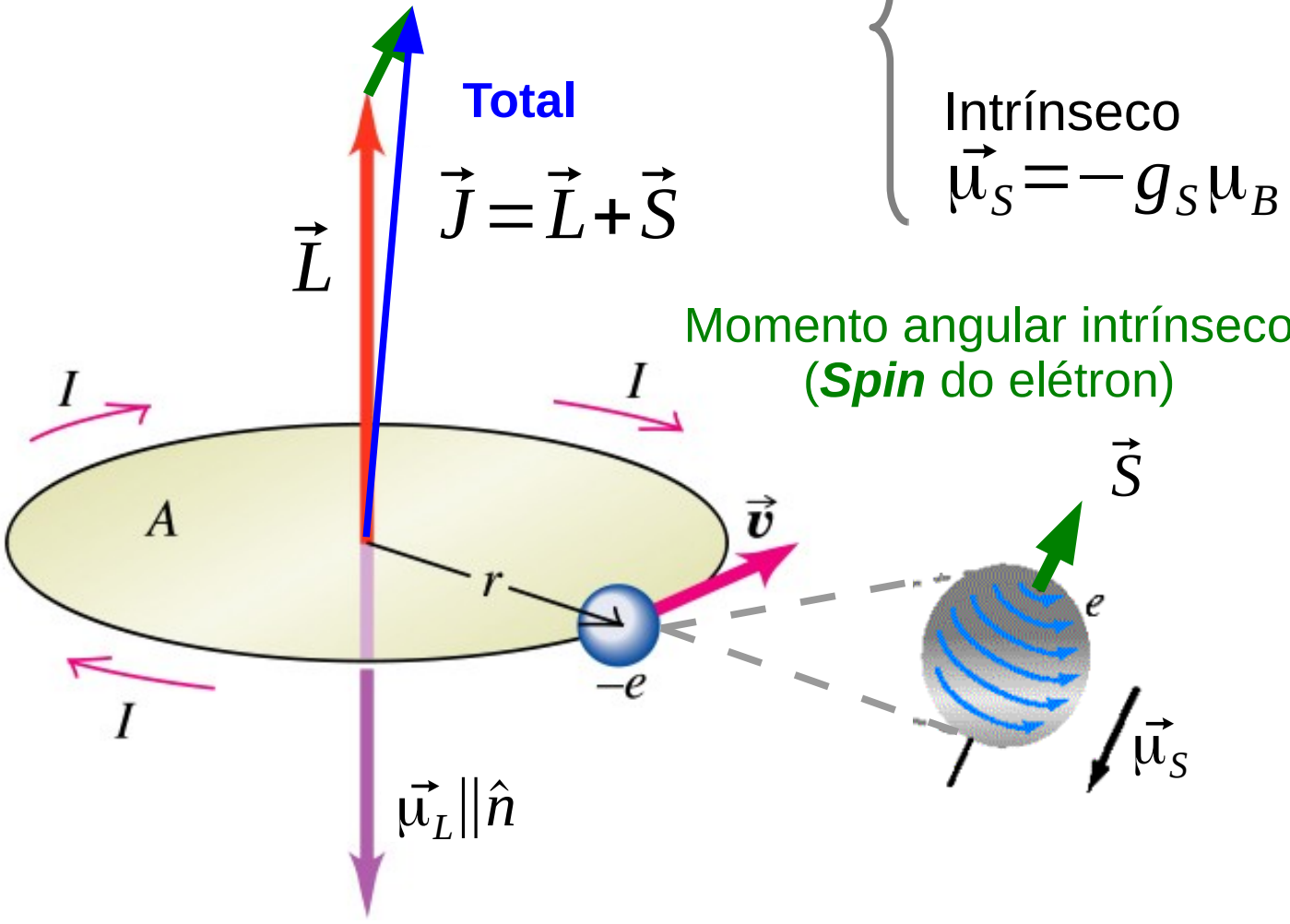
Momento de dipolo magnético total de um elétron em uma órbita atômica

Momento angular orbital

$$\vec{L} = \vec{r} \times m_e \vec{v} = -m_e r v \hat{n}$$

$$\vec{\mu}_J = \vec{\mu}_L + \vec{\mu}_S$$

{	Orbital	$\vec{\mu}_L = I A \hat{n} = \frac{e r v}{2} \hat{n} = -g_L \mu_B \frac{\vec{L}}{\hbar}$
	Intrínseco	$\vec{\mu}_S = -g_S \mu_B \frac{\vec{S}}{\hbar}$



Total
 $\vec{J} = \vec{L} + \vec{S}$

Momento angular intrínseco (*Spin* do elétron)

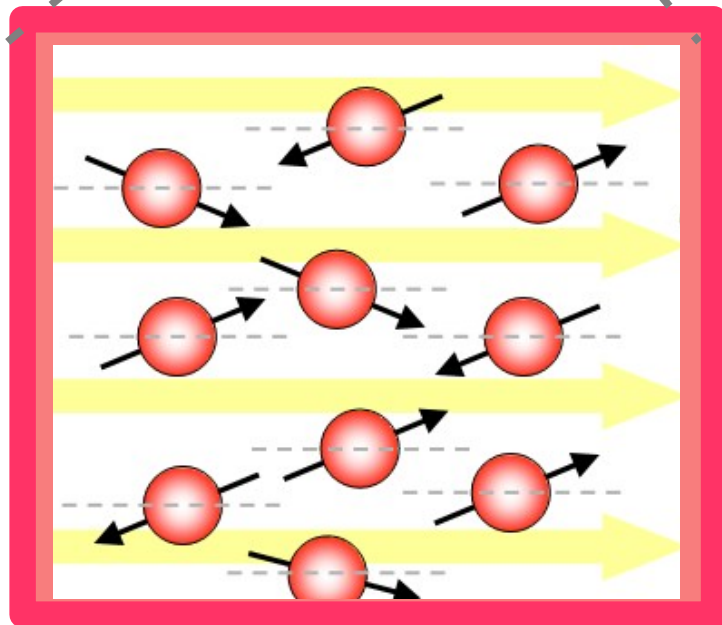
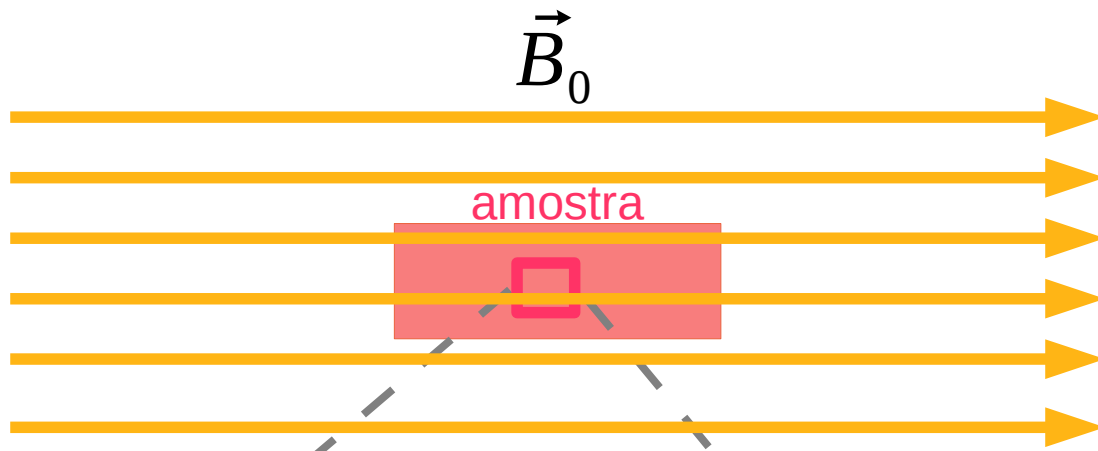
Fatores giromagnéticos

$$\begin{cases} g_L = 1 \\ g_S \approx 2 \end{cases}$$

Magneton de Bohr

$$\mu_B = \frac{e \hbar}{2 m_e}$$

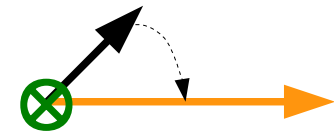
Amostra de material magnético em campo externo



OBS.: Campo versus Temperatura
(alinhamento x desalinhamento)

Torque sobre dipolo magnético

$$\vec{\tau} = \vec{\mu}_m \times \vec{B}$$



Magnetização

$$\vec{M} = \rho_N \langle \vec{\mu}_m \rangle$$

Número de dipolos magnéticos por unidade de volume

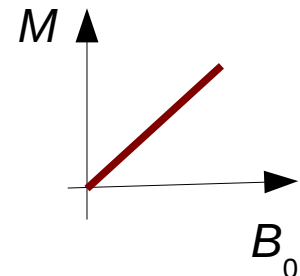
(Momento de dipolo magnético por unidade de volume)

$$[\text{Am}^2/\text{m}^3 = \text{A/m}]$$

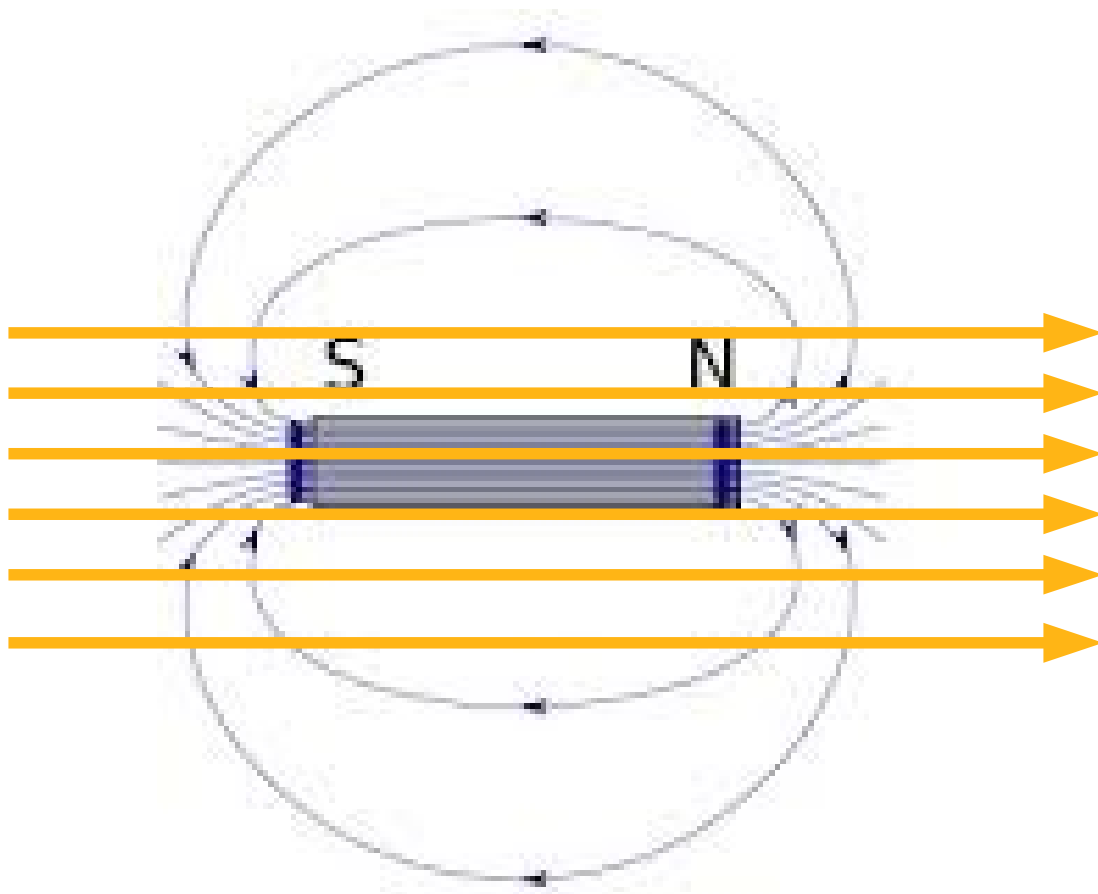
Momento de dipolo magnético médio

Meio linear: $\vec{M} = \frac{\chi}{\mu_0} \vec{B}_0$

χ : Suscetibilidade magnética



Campo magnético total no interior da amostra



$$\vec{B} = \vec{B}_0 + \mu_0 \vec{M}$$

Meio linear: $\vec{M} \parallel \vec{B}_0$

$$\vec{B} = K_m \vec{B}_0$$

$$\mu = K_m \mu_0$$

Permeabilidade magnética e permeabilidade relativa

$$\chi = (K_m - 1)$$

Suscetibilidade magnética de alguns materiais

Tabela 28.1 Suscetibilidades magnéticas de materiais paramagnéticos e diamagnéticos para $T = 20\text{ °C}$

TOTAL

$\vec{\mu}_J \neq 0$

Material

$\chi_m = K_m - 1 (\times 10^{-5})$

Paramagnético

Alúmen de ferro e amônio

66

Urânio

40

Platina

26

Alumínio

2,2

Sódio

0,72

Gás oxigênio

0,19

>0

$\vec{\mu}_J = 0$

Diamagnético

Bismuto

-16,6

Mercúrio

-2,9

Prata

-2,6

Carbono (diamante)

-2,1

Chumbo

-1,8

Cloreto de sódio

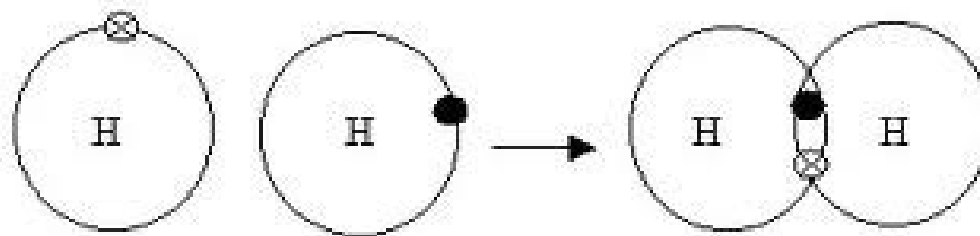
-1,4

Cobre

-1,0

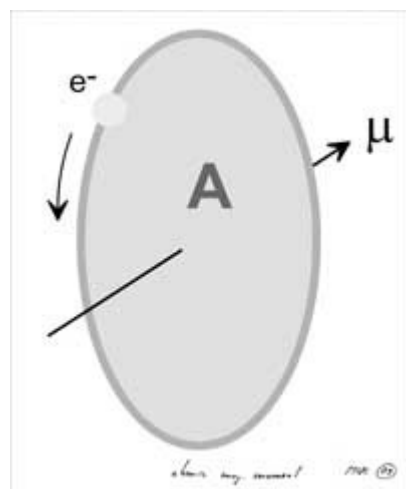
<0

Diamagnetismo ($J=0$)

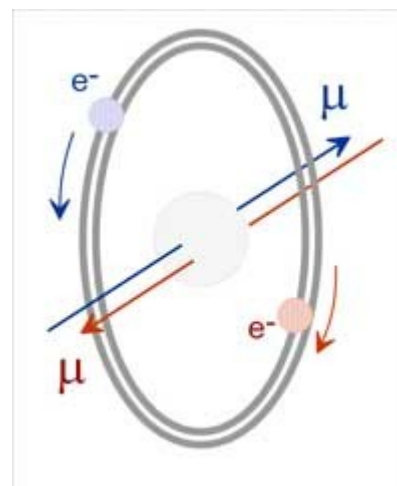


H^2

H



He



Total

$$\vec{\mu}_J = 0$$

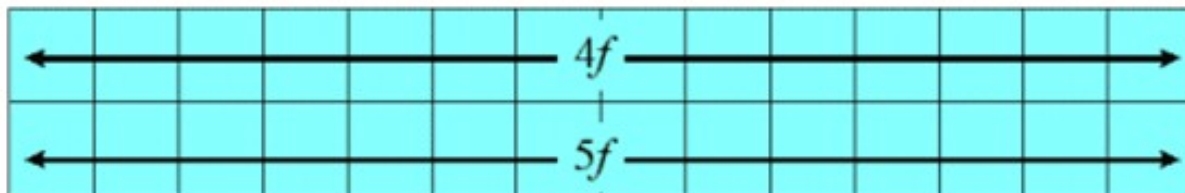
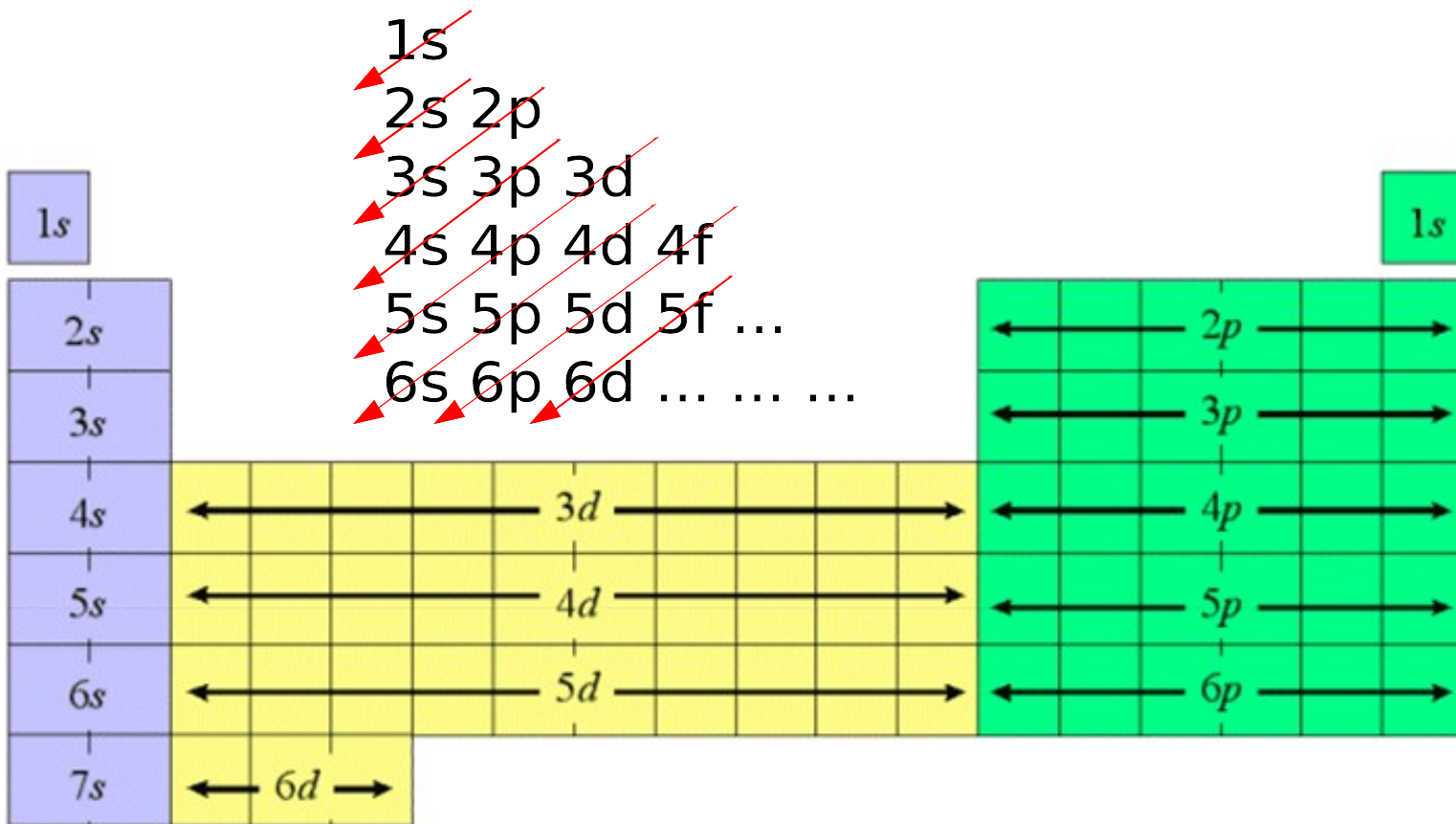
Campo externo -
Indução de Faraday

$$\vec{\mu}_m \neq 0$$

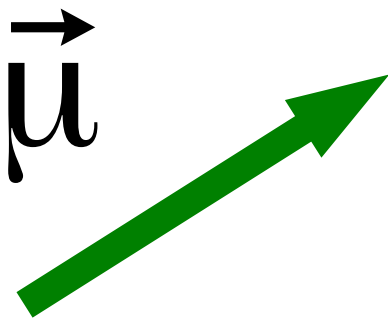
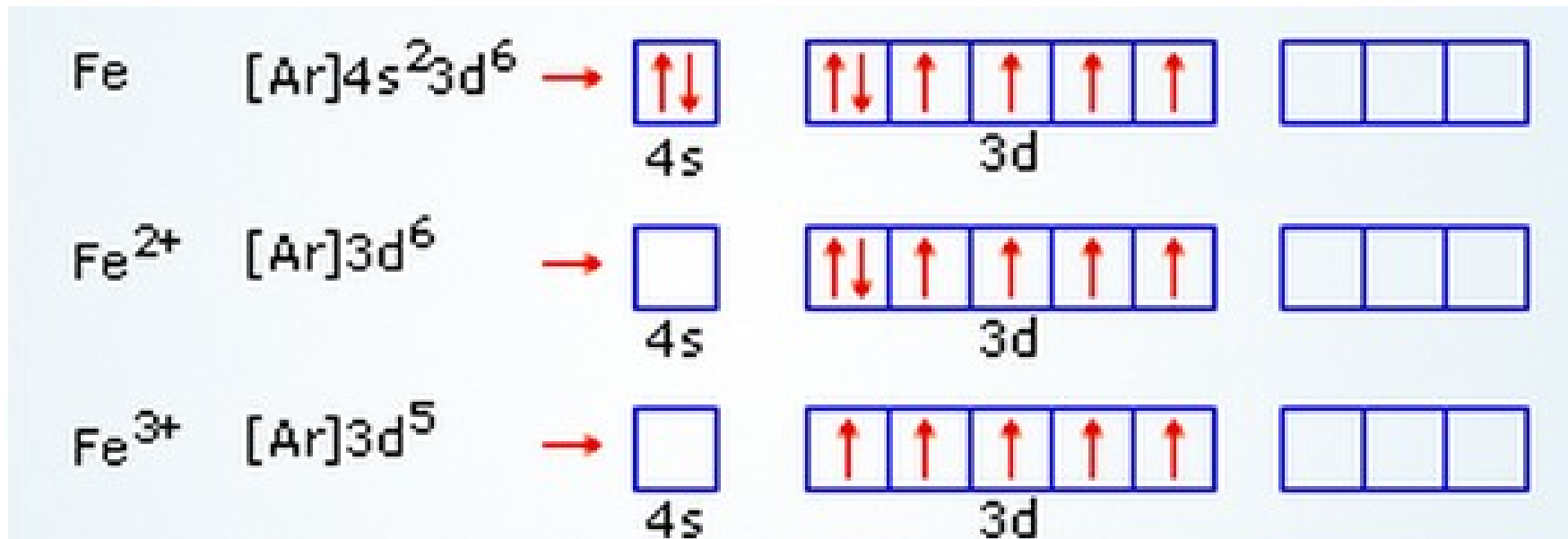
Tabela periódica

1 H																	2 He						
		<input checked="" type="checkbox"/> Ferromagnetic <input checked="" type="checkbox"/> Antiferromagnetic																					
		<input type="checkbox"/> Paramagnetic <input checked="" type="checkbox"/> Diamagnetic																					
3 Li	4 Be																	5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg																	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr						
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe						
55 Cs	56 Ba	57 La	58	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn					
87 Fr	88 Ra	89 Ac	↓																				
			58 Ce	59 Pr	60 Nd	61 Pm	62 Sm	63 Eu	64 Gd	65 Tb	66 Dy	67 Ho	68 Er	69 Tm	70 Yb	71 Lu							

Preenchimento dos orbitais

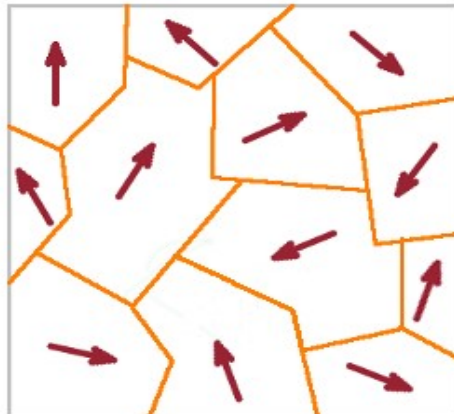
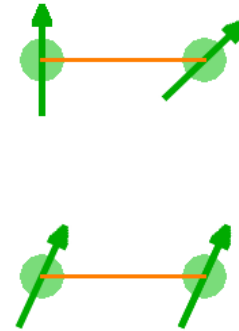
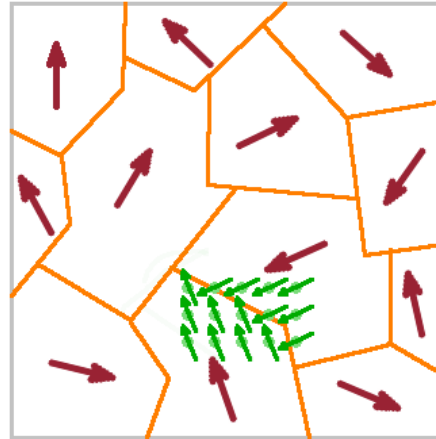


Orbital 3d - Fe

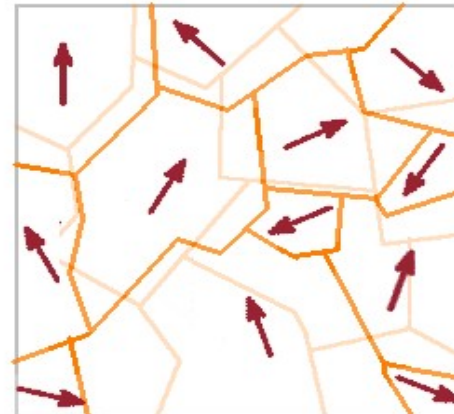


$$K_m \gg 10$$

Ferromagnetismo - domínios

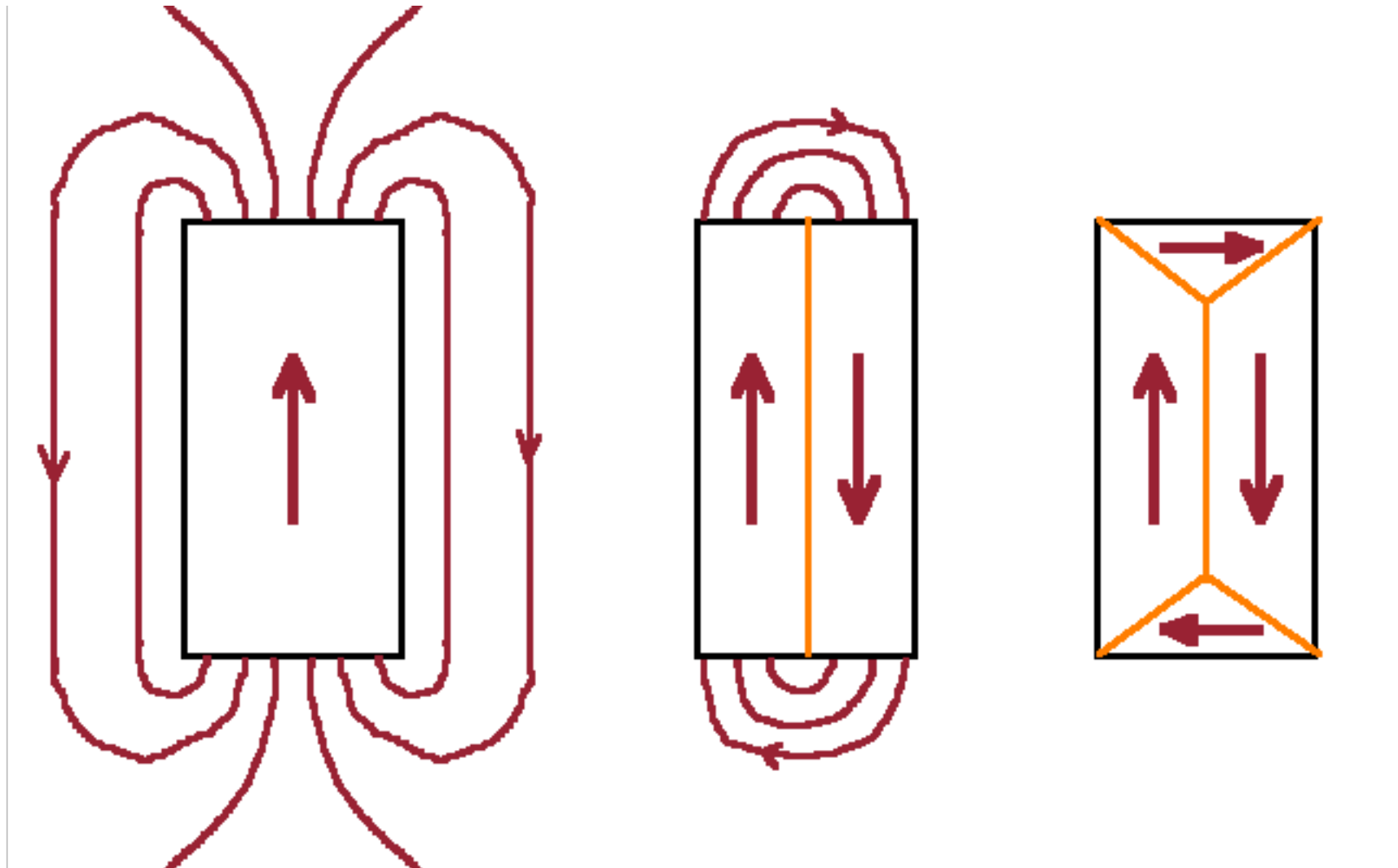


$B=0$

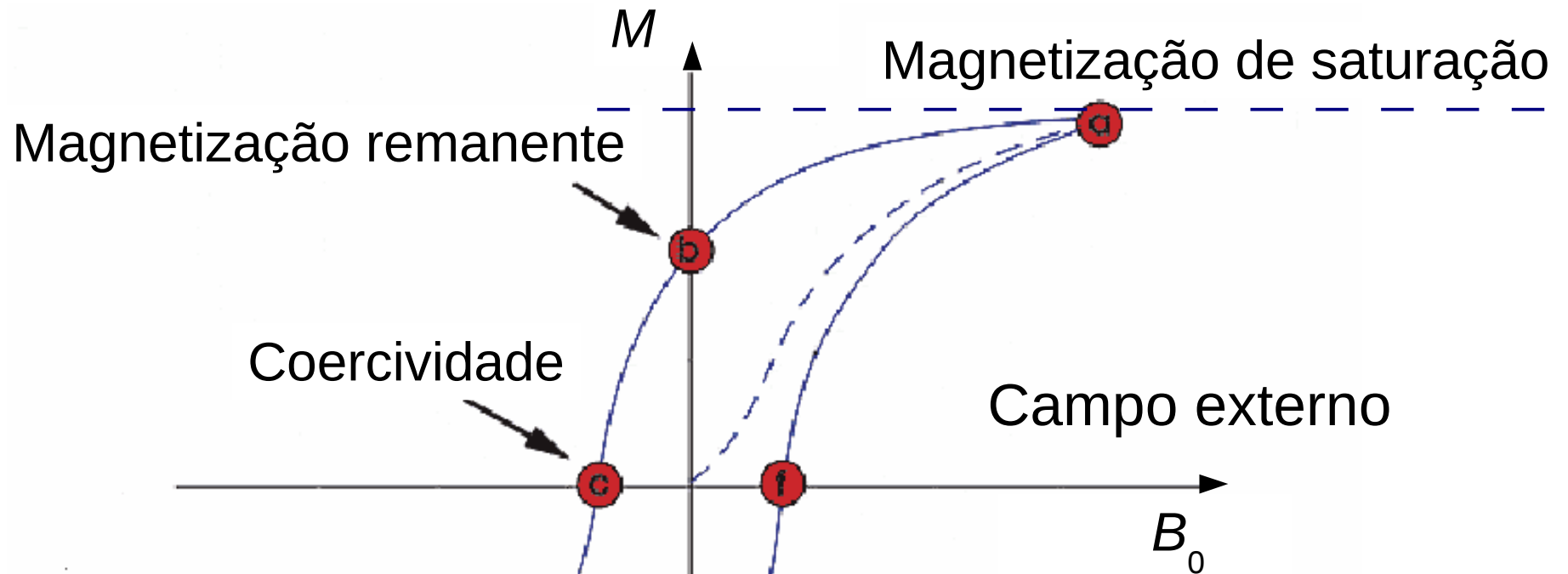


$\uparrow B > 0 \uparrow$

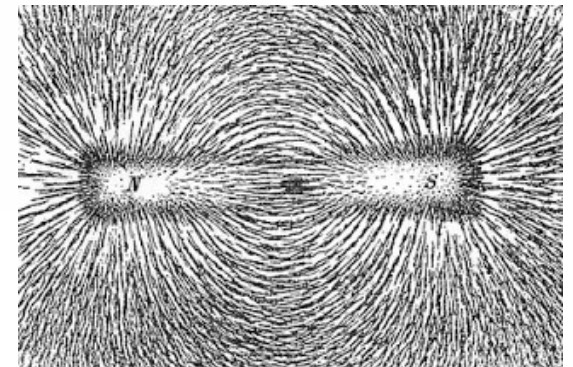
Desmagnetização



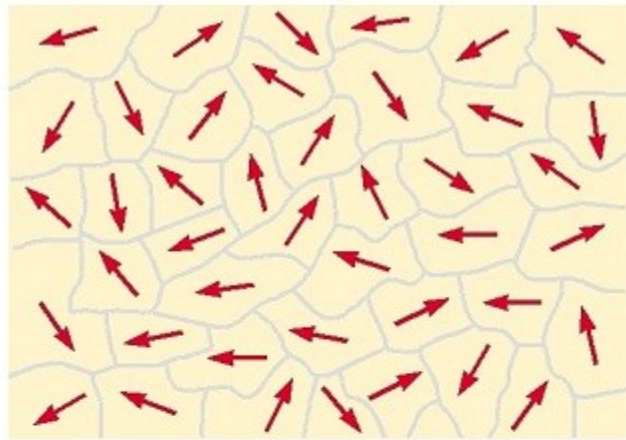
Histerese



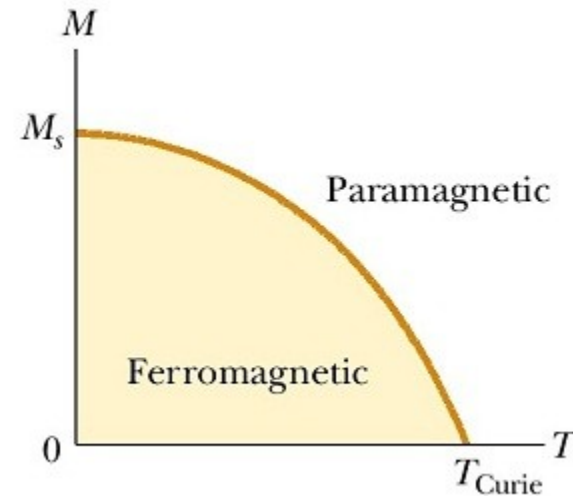
Imã permanente



Ponto de Curie (Trans. de fase)

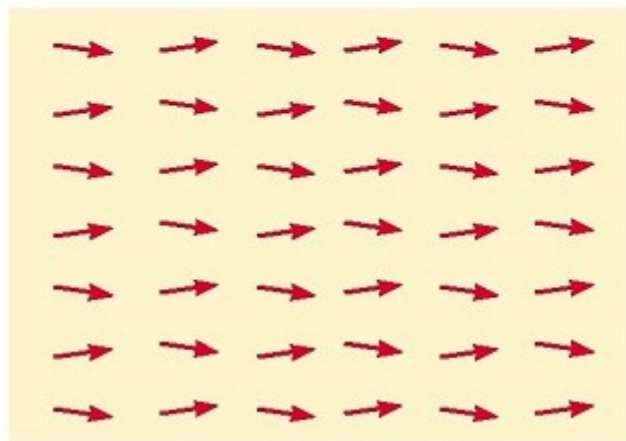


(a)



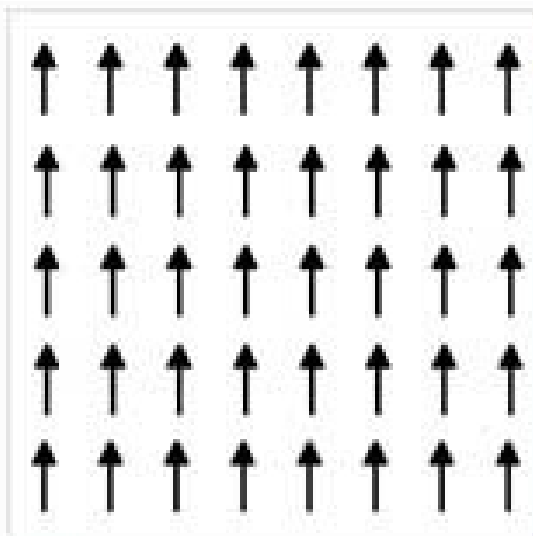
Sat.

M_s



B_0

Substance	T_{Curie} (K)
Iron	1 043
Cobalt	1 394
Nickel	631
Gadolinium	317
Fe_2O_3	893

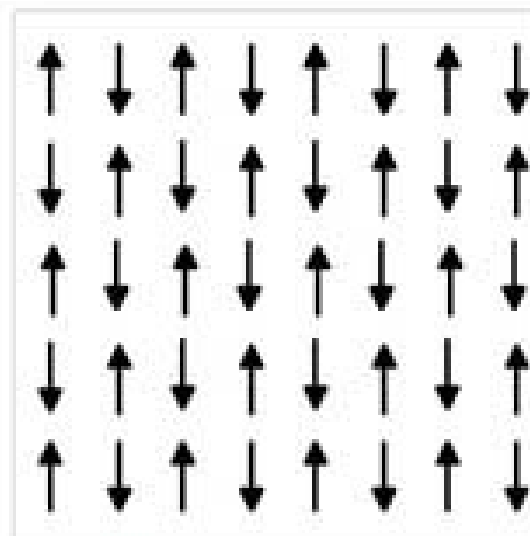


μ_{net}



ferromagnet

a)



$\mu_{\text{net}} = 0$

b)

antiferromagnet

