Magnetska svojstva metala

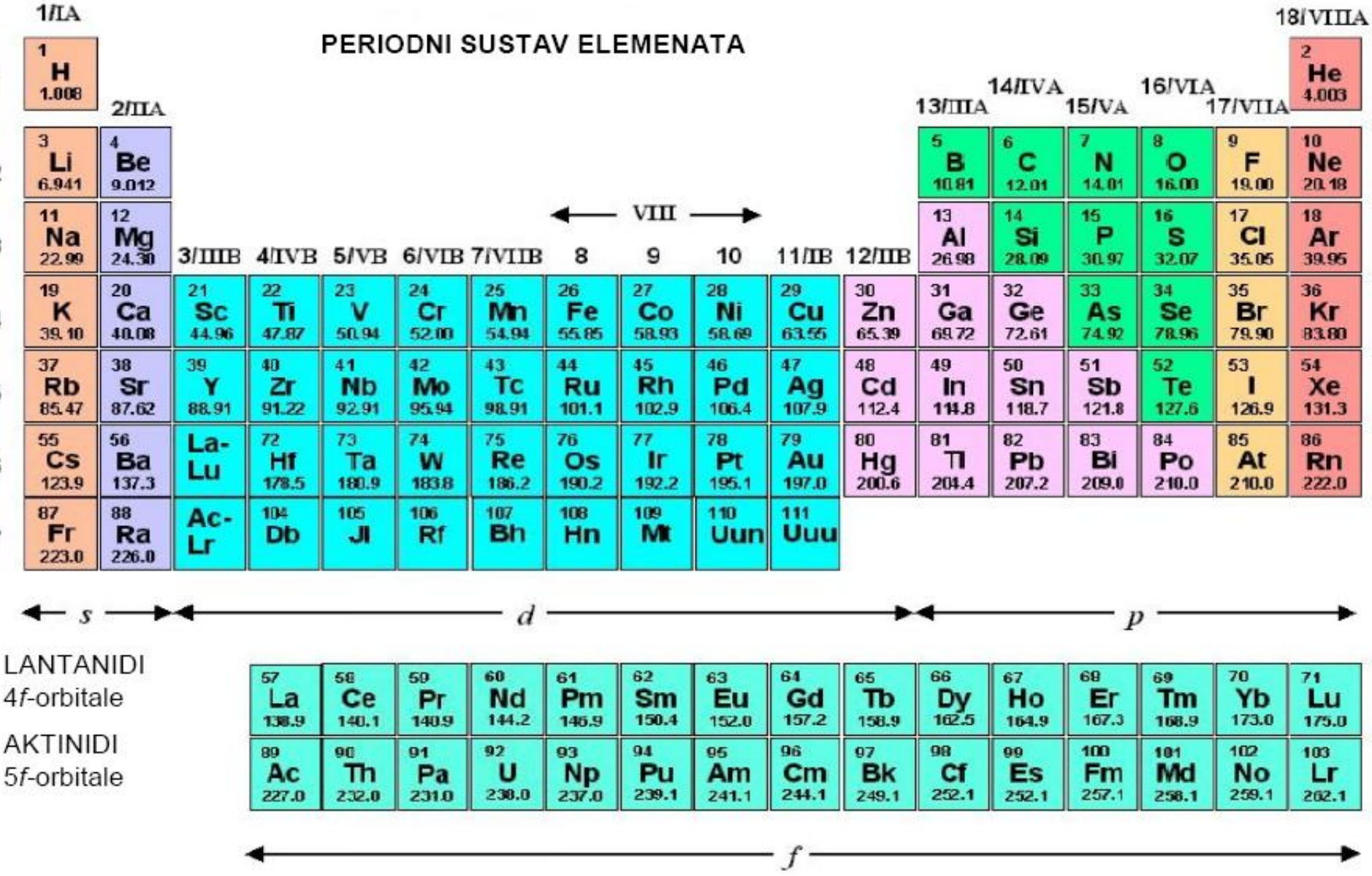
- U magnetskom polju sustav se magnetizira
- Ukupna magnetizacija u materijalu:

$$M = \frac{\text{Rezultantni dipolni moment}}{\text{Jedinični volumen}}$$

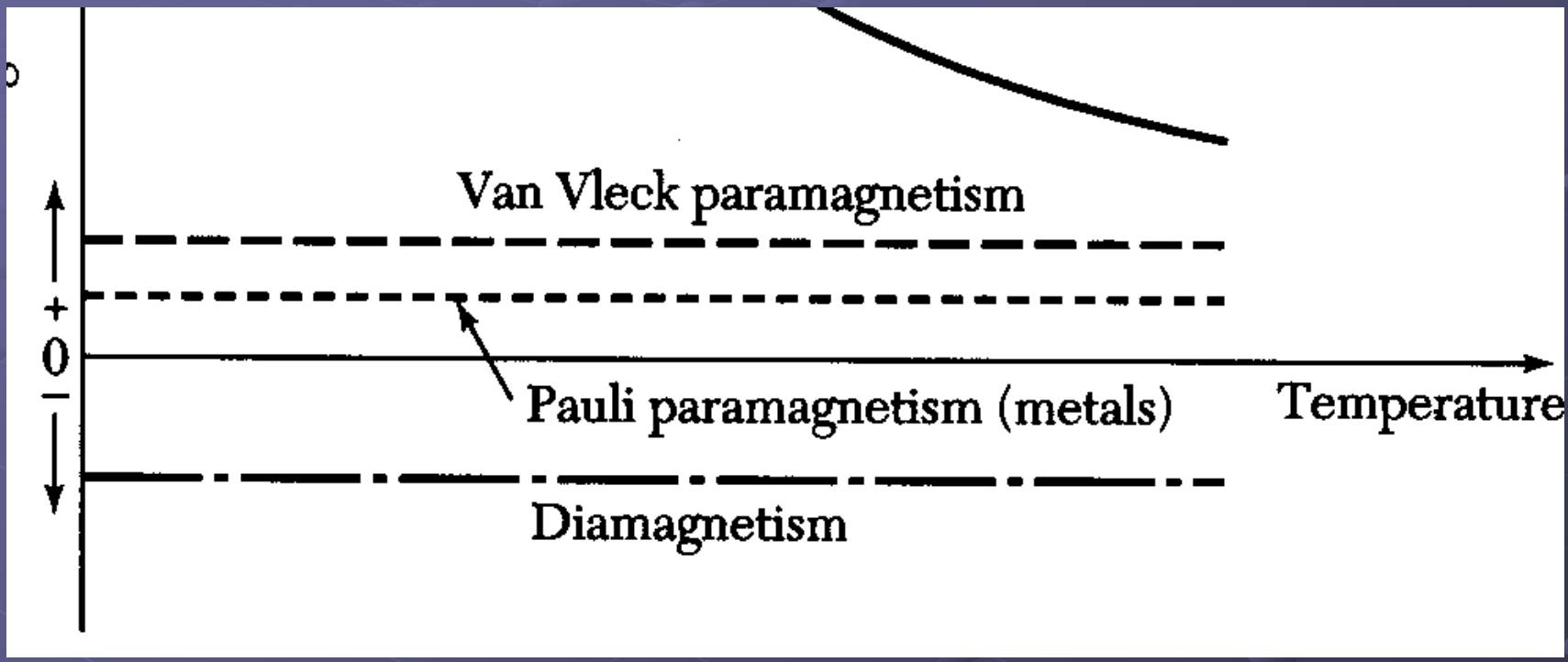
- Izotropni kristali: $\vec{M} = \chi \vec{H}$

- Susceptibilnost sustava - χ

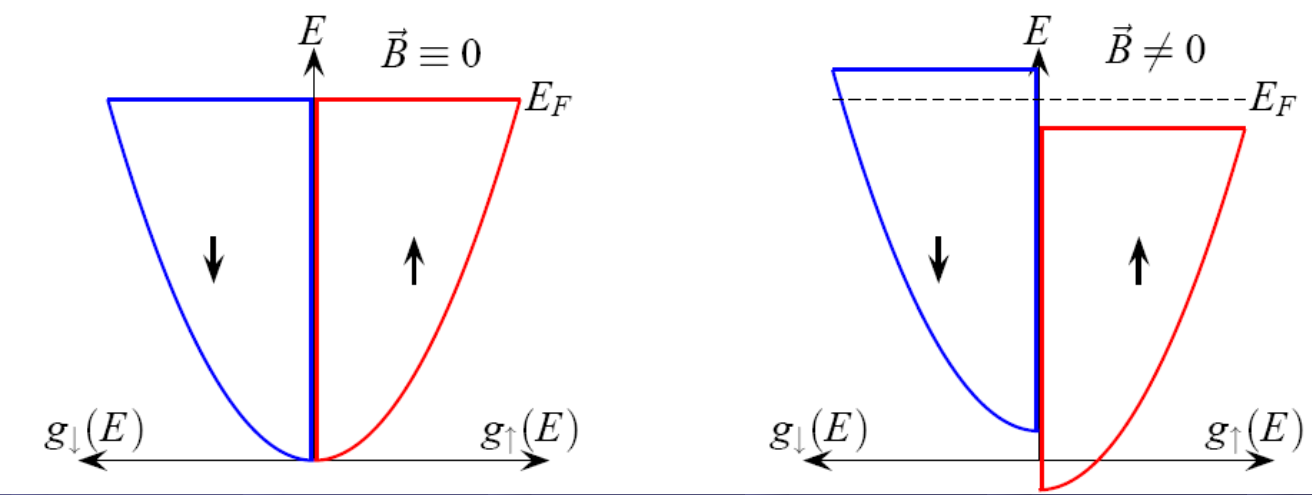
PERIODNI SUSTAV ELEMENATA

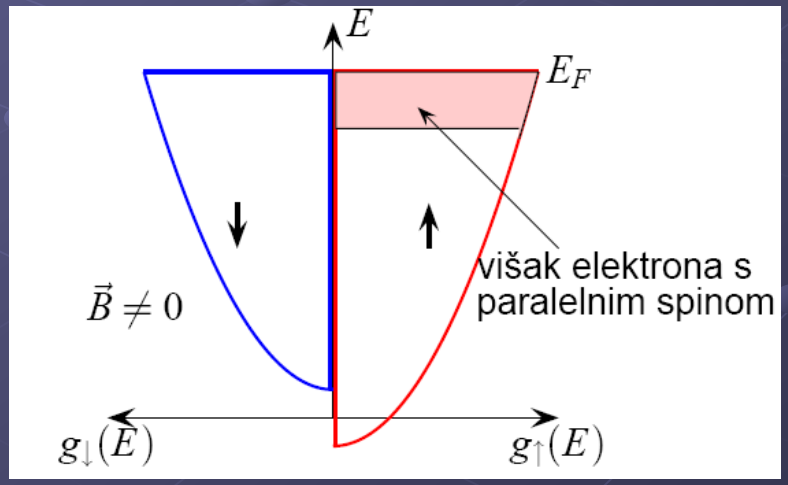


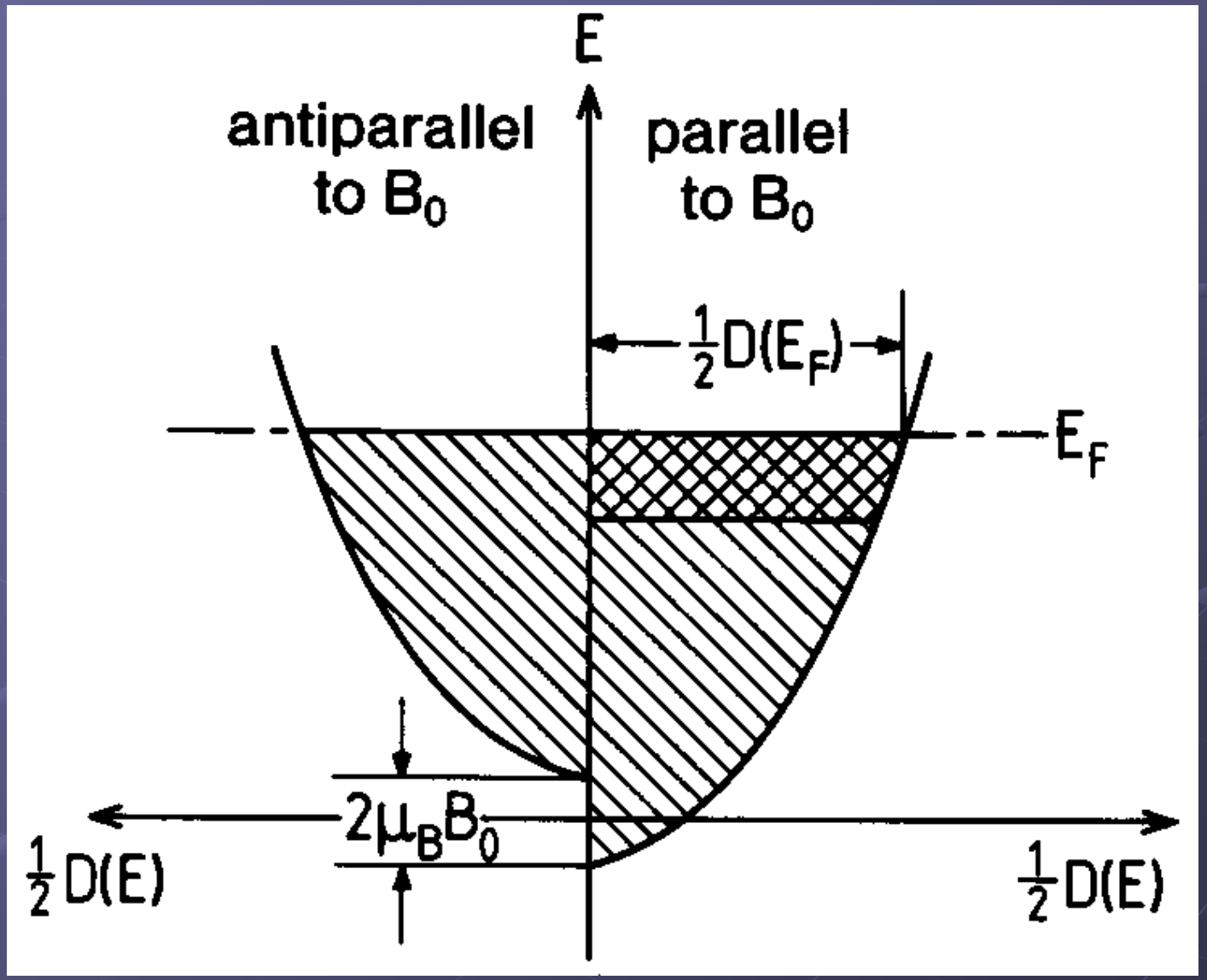
- Razlikujemo:
  - Slabe magnete
    - Dijamagneti
    - Paramagneti
  - Jake magnete
    - Feromagneti
    - Antiferomagneti
    - Ferimagneti


Van Vleck paramagnetism
+
0
−
Pauli paramagnetism (metals)
Temperature
Diamagnetism

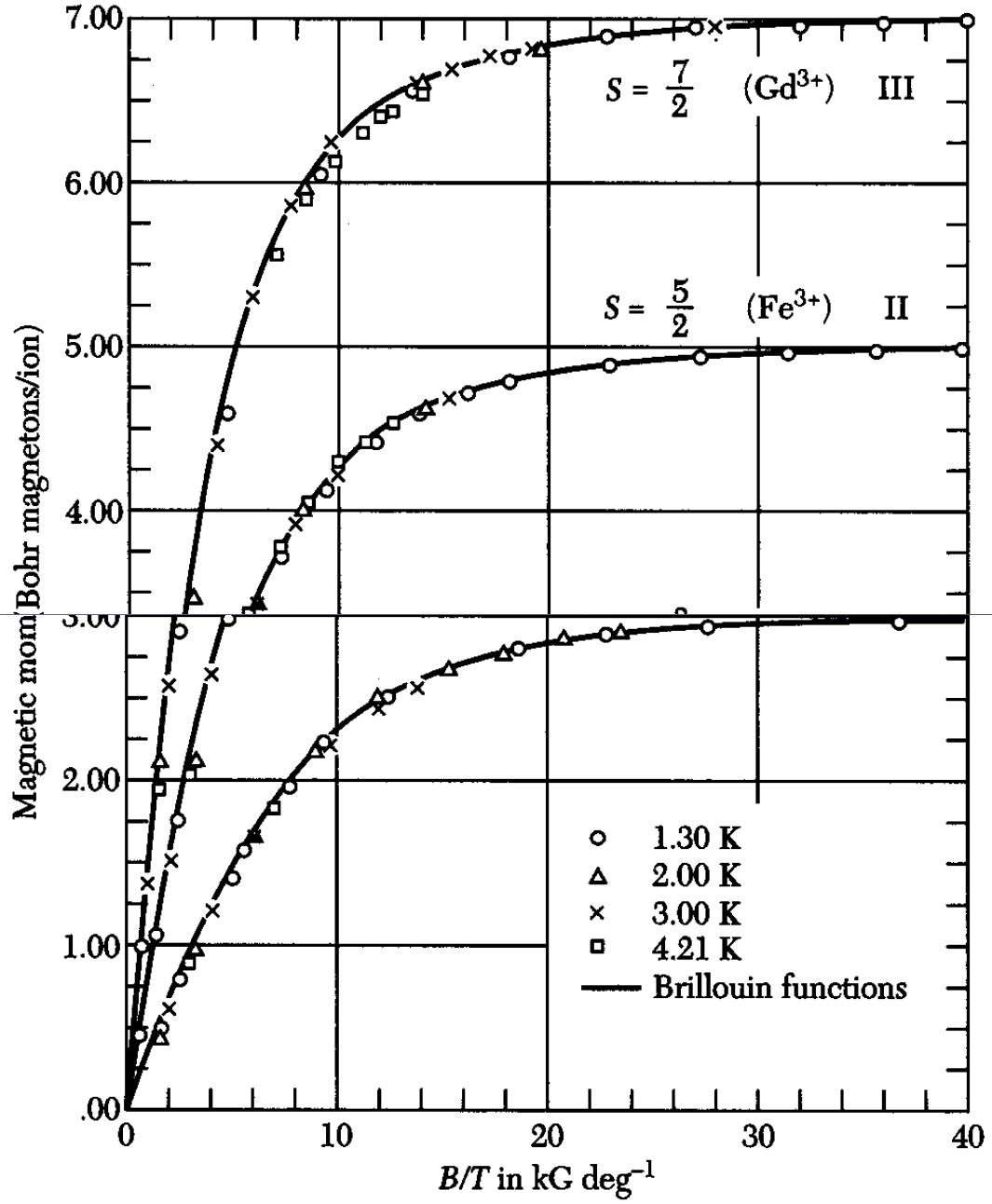
Paulijev paramagnetizam






E
antiparallel
to B_0
parallel
to B_0
$\frac{1}{2}D(E_F)$
E_F
$2\mu_B B_0$
$\frac{1}{2}D(E)$
$\frac{1}{2}D(E)$

ELEMENT (AND IONIZATION)	BASIC ELECTRON CONFIGURATION	GROUND-STATE TERM	CALCULATED[b] p		MEASURED[c] p
			$(J = S)$	$(J = \|L \pm S\|)$	
Ti^{3+}	$3d^1$	$^2D_{3/2}$	1.73	1.55	—
V^{4+}	$3d^1$	$^2D_{3/2}$	1.73	1.55	1.8
V^{3+}	$3d^2$	$^3F_2$	2.83	1.63	2.8
V^{2+}	$3d^3$	$^4F_{3/2}$	3.87	0.77	3.8
Cr^{3+}	$3d^3$	$^4F_{3/2}$	3.87	0.77	3.7
Mn^{4+}	$3d^3$	$^4F_{3/2}$	3.87	0.77	4.0
Cr^{2+}	$3d^4$	$^5D_0$	4.90	0	4.8
Mn^{3+}	$3d^4$	$^5D_0$	4.90	0	5.0
Mn^{2+}	$3d^5$	$^6S_{5/2}$	5.92	5.92	5.9
Fe^{3+}	$3d^5$	$^6S_{5/2}$	5.92	5.92	5.9
Fe^{2+}	$3d^6$	$^5D_4$	4.90	6.70	5.4
Co^{2+}	$3d^7$	$^4F_{9/2}$	3.87	6.54	4.8
Ni^{2+}	$3d^8$	$^3F_4$	2.83	5.59	3.2
Cu^{2+}	$3d^9$	$^2D_{5/2}$	1.73	3.55	1.9


7.00
6.00
5.00
4.00
2.00
1.00
.00
0
10
20
30
40
Magnetic mom (Bohr magnetons/ion)
B/T in kG deg⁻¹
S = 7/2 (Gd3+) III
S = 5/2 (Fe3+) II
1.30 K
2.00 K
3.00 K
4.21 K
Brillouin functions

Hundova Pravila
J=L+S

d-shell ($l = 2$)

n	$l_z = 2,\ 1,\ 0,\ -1,\ -2$	S	$L = \lvert\Sigma l_z\rvert$	J	SYMBOL
1	↓	1/2	2	3/2	$^2D_{3/2}$
2	↓ ↓	1	3	2	$^3F_2$
3	↓ ↓ ↓	3/2	3	3/2	$^4F_{3/2}$
4	↓ ↓ ↓ ↓	2	2	0	$^5D_0$
5	↓ ↓ ↓ ↓ ↓	5/2	0	5/2	$^6S_{5/2}$
6	⇵ ↑ ↑ ↑ ↑	2	2	4	$^5D_4$
7	⇵ ⇵ ↑ ↑ ↑	3/2	3	9/2	$^4F_{9/2}$
8	⇵ ⇵ ⇵ ↑ ↑	1	3	4	^3F

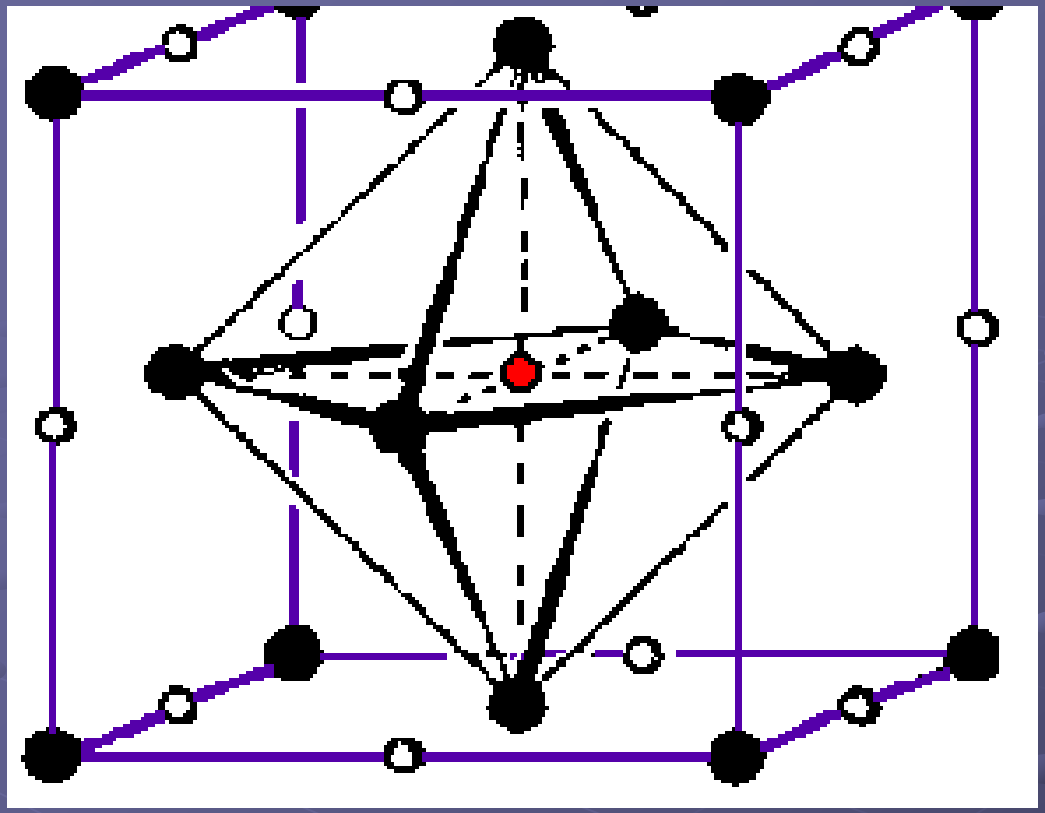
$J = |L - S|$ (rows 1–5); $J = L + S$ (rows 6–8)

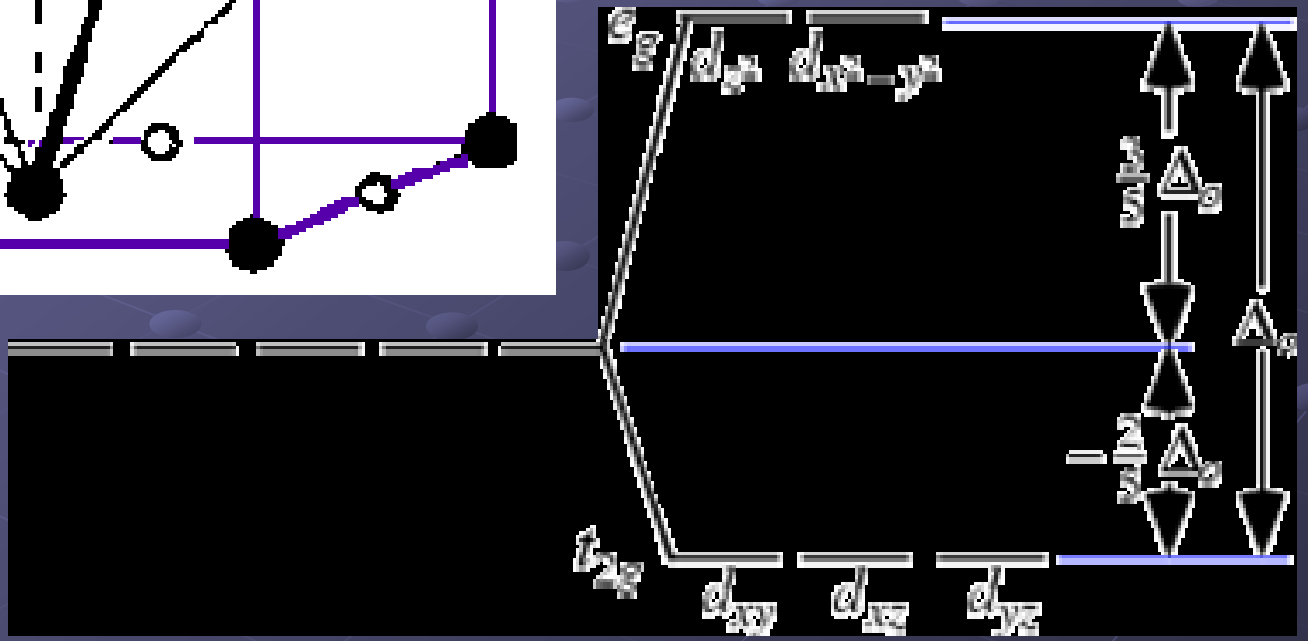
f-shell ($l = 3$)

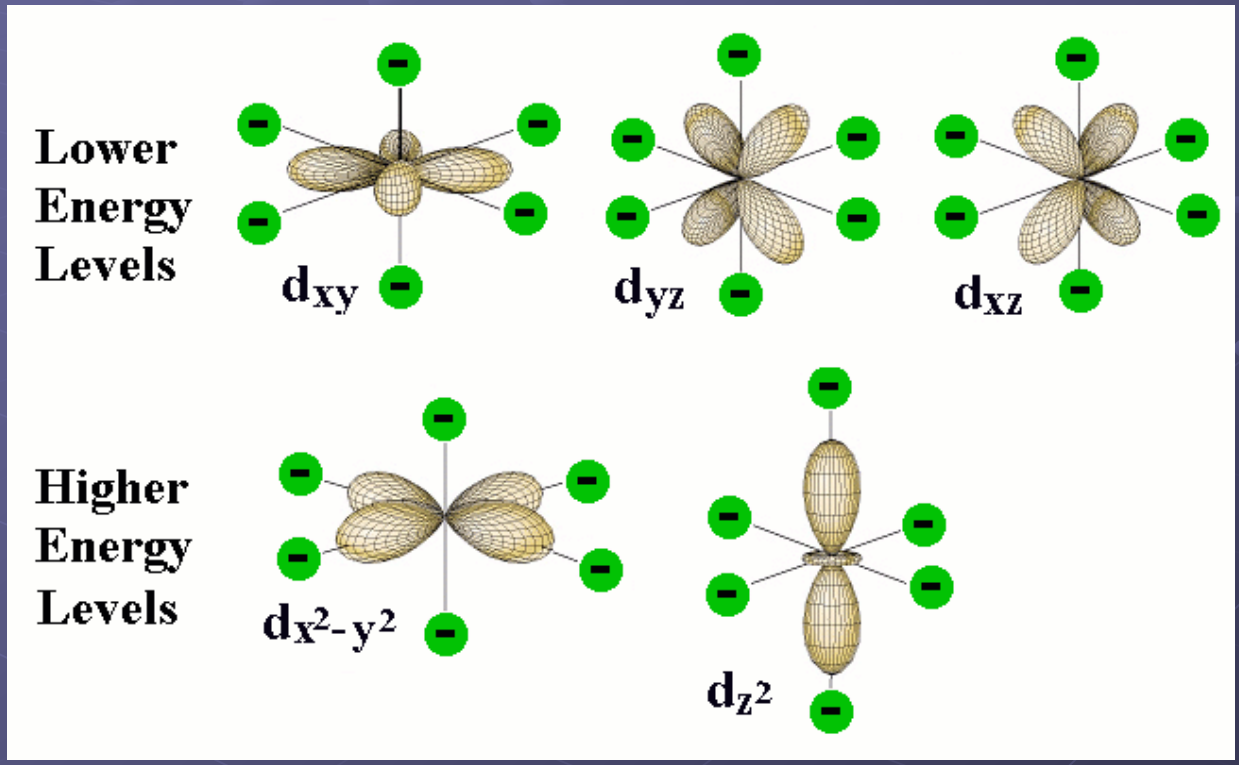
n	$l_z = 3,\ 2,\ 1,\ 0, -1, -2, -3$	S	$L = \lvert\Sigma l_z\rvert$	J	
1	↓	1/2	3	5/2	$^2F_{5/2}$
2	↓ ↓	1	5	4	$^3H_4$
3	↓ ↓ ↓	3/2	6	9/2	$^4I_{9/2}$
4	↓ ↓ ↓ ↓	2	6	4	$^5I_4$
5	↓ ↓ ↓ ↓ ↓	5/2	5	5/2	$^6H_{5/2}$
6	↓ ↓ ↓ ↓ ↓ ↓	3	3	0	$^7F_0$
7	↓ ↓ ↓ ↓ ↓ ↓ ↓	7/2	0	7/2	$^8S_{7/2}$
8	⇵ ↑ ↑ ↑ ↑ ↑ ↑	3	3	6	$^7F_6$
9	⇵ ⇵ ↑ ↑ ↑ ↑ ↑	5/2	5	15/2	$^6H_{15/2}$
10	⇵ ⇵ ⇵ ↑ ↑ ↑ ↑	2	6	8	$^5I_8$
11	⇵ ⇵ ⇵ ⇵ ↑ ↑ ↑	3/2	6	15/2	$^4I_{15/2}$
12	⇵ ⇵ ⇵ ⇵ ⇵ ↑ ↑	1	5	6	$^3H_6$
13	⇵ ⇵ ⇵ ⇵ ⇵ ⇵ ↑	1/2	3	7/2	$^2F_{7/2}$
14	⇵ ⇵ ⇵ ⇵ ⇵ ⇵ ⇵	0	0	0	$^1S_0$

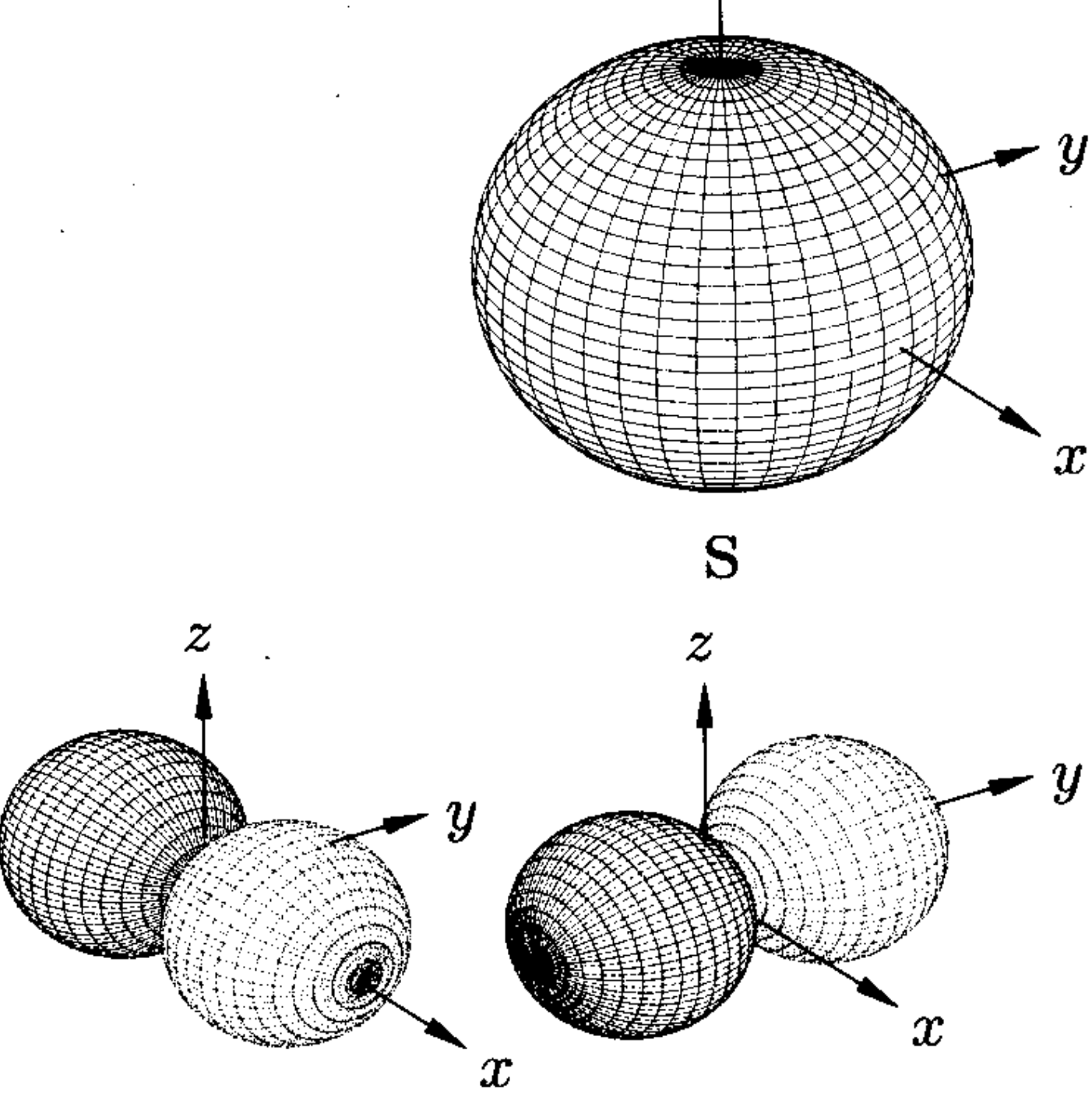
$J = |L - S|$ (rows 1–5); $J = L + S$ (rows 6–14)

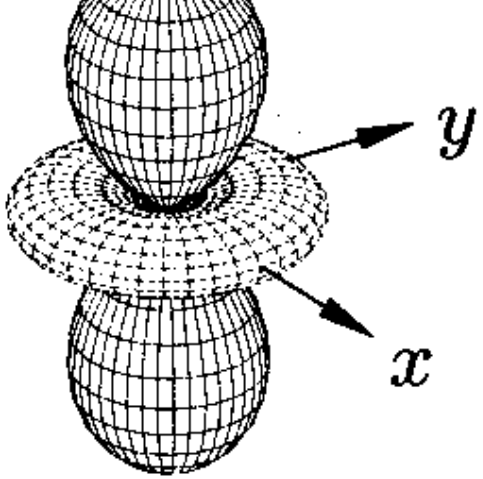
*↑ = spin $\frac{1}{2}$; ↓ = spin $-\frac{1}{2}$.



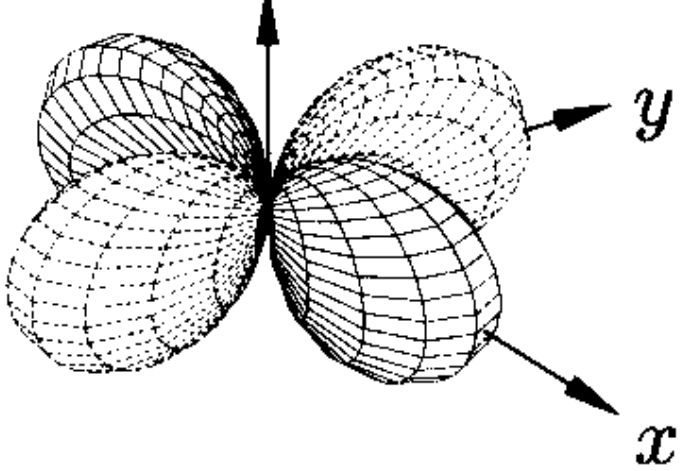

e_g
d_{z^2}
$d_{x^2-y^2}$
$\frac{3}{5}\Delta_o$
Δ_o
$-\frac{2}{5}\Delta_o$
t_{2g}
d_{xy}
d_{xz}
d_{yz}


Lower Energy Levels
dxy
dyz
dxz
Higher Energy Levels
dx2-y2
dz2

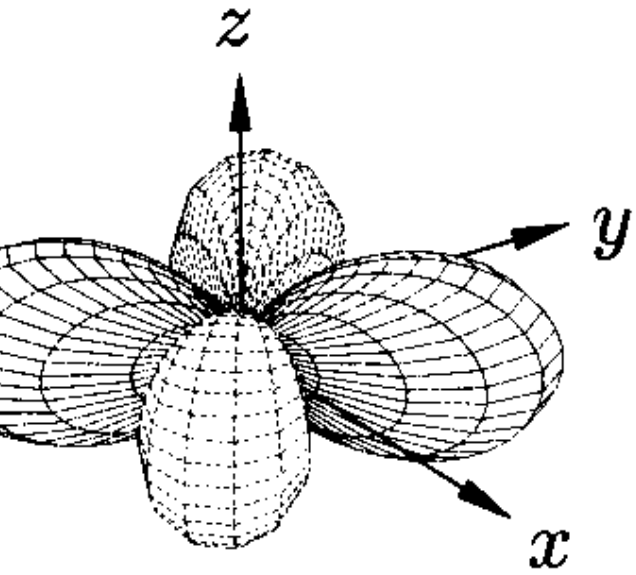

y
x
S
z
y
x
z
y
x
z
y
x



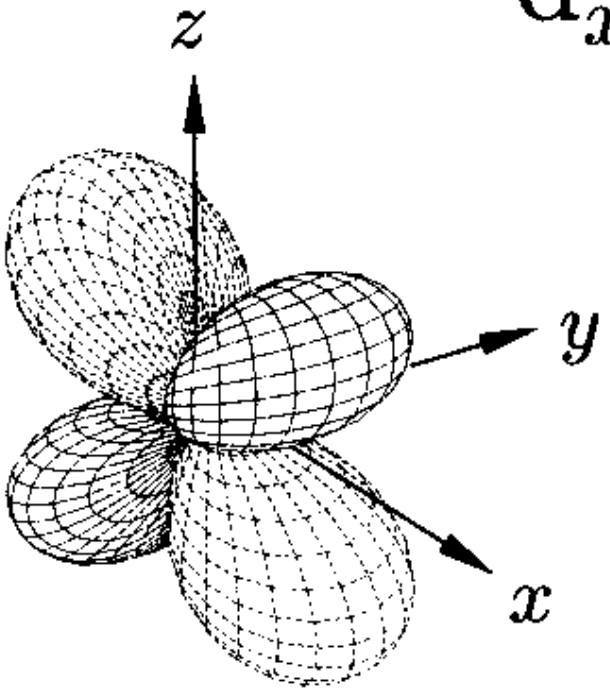
d_{z^2}



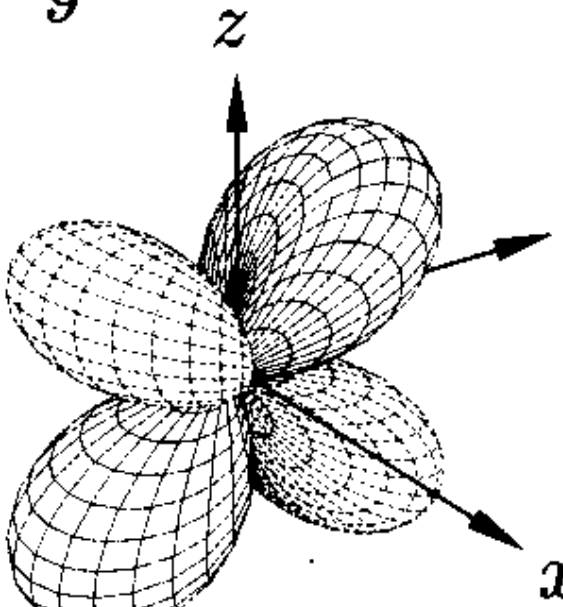
$\mathrm{d}_{x^2-y^2}$



d_{xy}



d_{xz}



d_{yz}

- Za $\vec{H} \neq 0$
  - $X < 0$ dijamagnetizam
  - $X > 0$ paramagnetizam

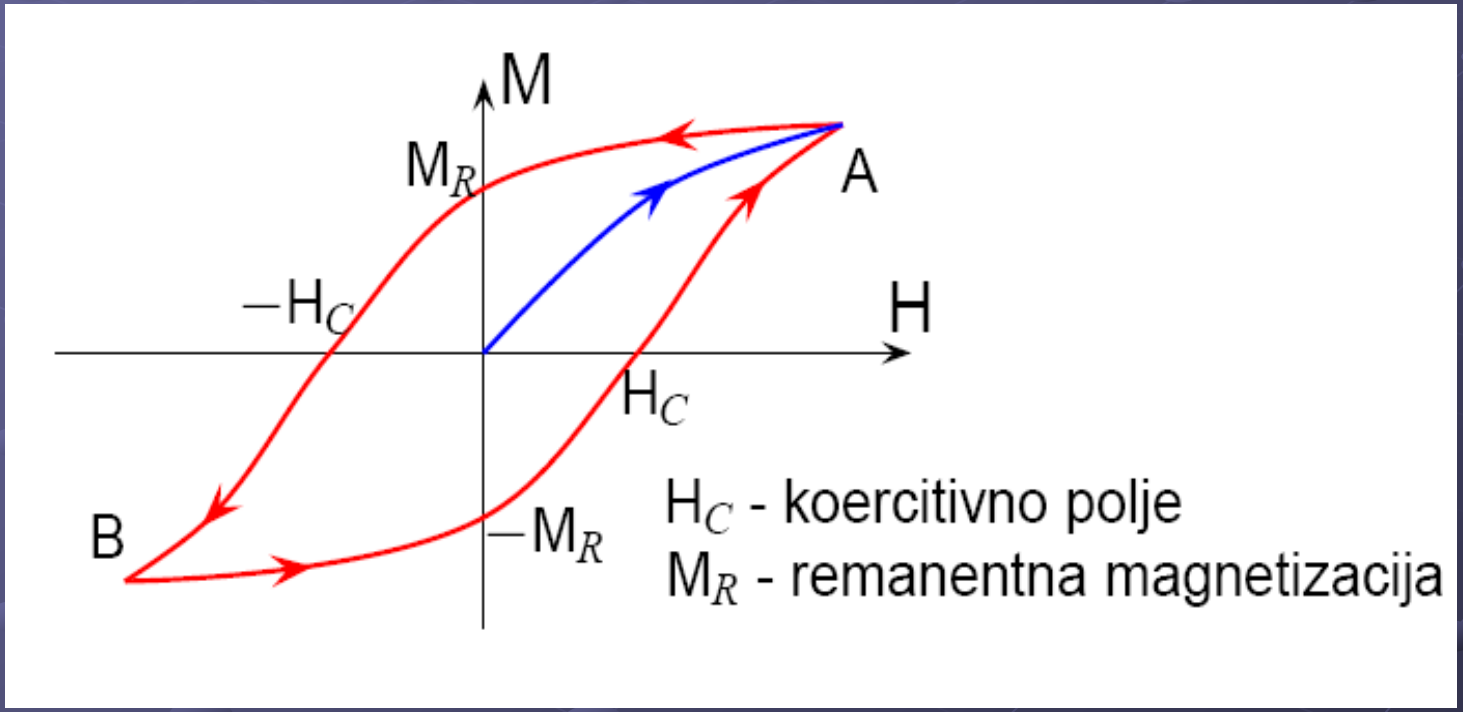
- $\vec{M} \neq 0$ i $\vec{H} = 0$ feromagnetizam

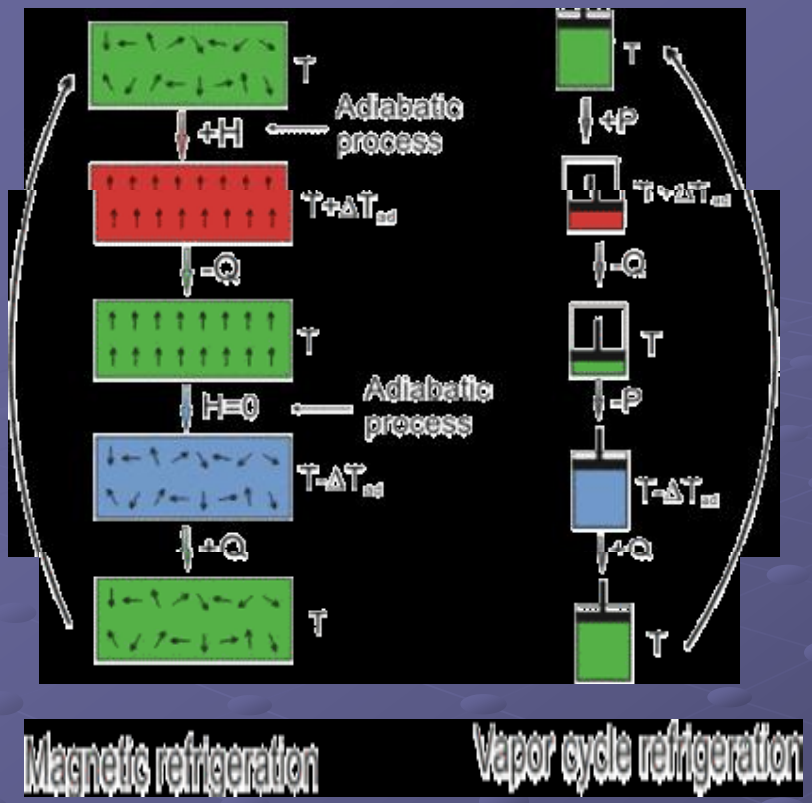
- $< \vec{M} > = 0$, $\vec{M}$ pravilno oscilira u prostoru antiferomagnetizam

- $< \vec{M} > \neq 0$, $\vec{M}$ pravilno oscilira u prostoru ferimagnetitam

Krivulja histereze

- Proces magnetiziranja makroskopskog uzorka





[K (kelvin)]

- 1G (10^9) — Interior of the hottest star
- 100M — Nuclear fusion
- 10M — Solar interior
- 1M (10^6) — Atomic explosion (~300,000 K)
- 100k
- 10k — Luminous nebulae
- Tungsten melts (3683 K)
- 1k (10^3) — Superconductors reacted (~1000 K)
- Ice point (273 K= 0°C)
- 100 — LN_2 boils (77 K) HTS operation feasible
- 10 — LHe boils (4.2 K) LTS operation
- 1 — Upper limit (~0.5 K) by dilution refrigerators and by the "adiabatic demagnetization" technique
- 100m
- 10m — Lower limit by dilution refrigerators
- 1m (10^{-3})
- 100μ
- 10μ — Adiabatic demagnetization, 1956 (16 μK)
- 1μ (10^{-6})
- 100n — Bose-Einstein condensation, 1995 (150 nK)
- 10n
- 1n (10^{-9}) — Lower limit by adiabatic demagnetization?