$$\mathcal{H} = H_0 + \underline{\mu_B (\vec{L} + g\vec{S}) \cdot \vec{B}}$$

$$+ \frac{e^2}{8m} \sum_i \underline{(\vec{B} \times \vec{r}_i)}^2 + \lambda \sum_i \vec{L}_i \cdot \vec{S}_i$$

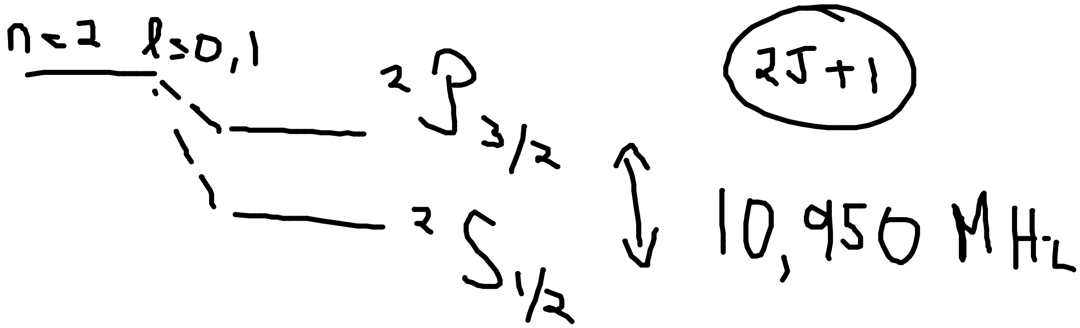
1er ordre $\quad \chi \propto \frac{1}{T} \mu_B^2$

2ième ordre $\quad$ Diamagn

Paramagn.

Hund:
1) S max
2) L max
3) $J = |L - S|$
$J = L + S$

$2J+1$



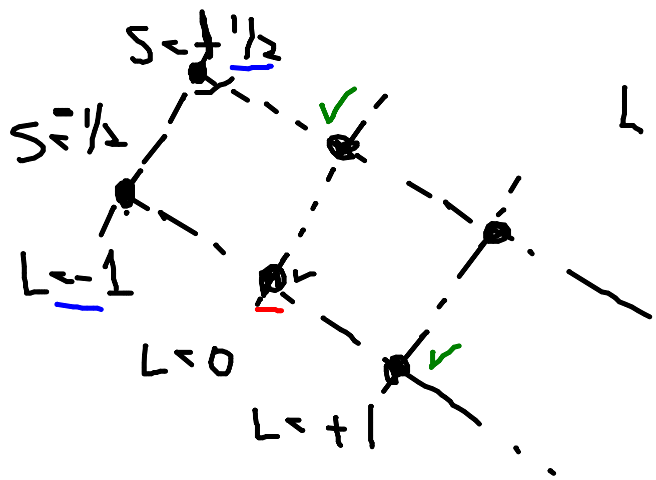
Addition des moments cinétiques.

$$L \rightarrow (2L+1)$$

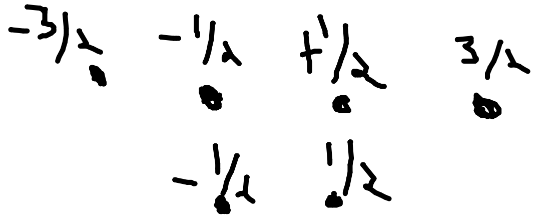
$$S \rightarrow (2S+1)$$

$$\text{Tot } (2L+1)(2S+1)$$

$L = 1 \qquad S = 1/2$



$L + S \geq J \geq L - S$



$J = 3/2$

$J = 1/2$

$$\frac{1}{r}\frac{\partial V}{\partial r} \qquad \lambda \sim \frac{1}{r^3} \times Z \sim Z^4$$

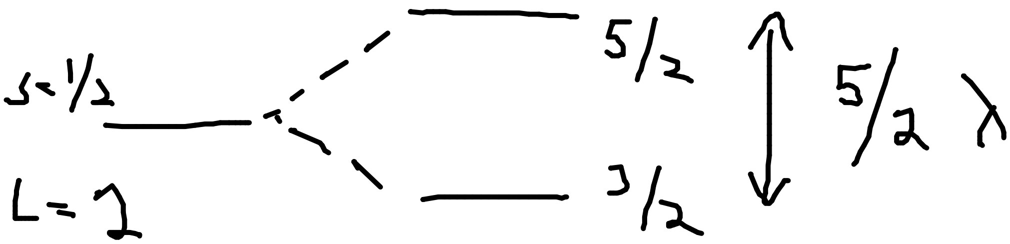
$$V = \frac{Ze^2}{r}$$

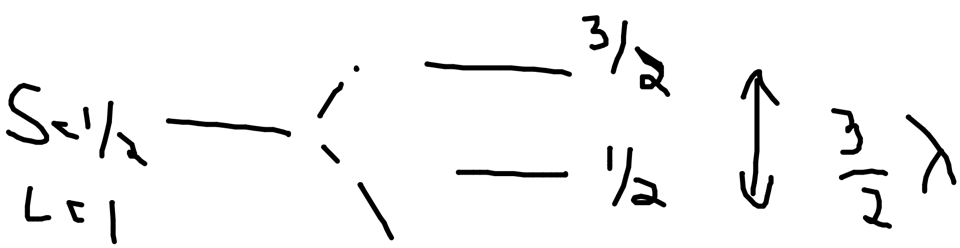
$$\frac{\hbar^2}{2m r^2} = \frac{Ze^2}{r} \qquad \frac{1}{r} \sim Z$$

$$\lambda_{Pb} \sim 10^5 \lambda_c$$

~~[illegible]~~

Intervalle de Landé





$$(\vec{L}+\vec{S})^2 = J^2 = L^2 + S^2 + 2\vec{L}\cdot\vec{S}$$

$$\boxed{2\langle \vec{L}\cdot\vec{S}\rangle = \langle J^2 - L^2 - S^2 \rangle = J(J+1) - L(L+1) - S(S+1)}$$

$$[J^2, \vec{L}\cdot\vec{S}] = 0 \qquad [L_z, \vec{L}\cdot\vec{S}] \neq 0$$

$$[L^2, \vec{L}\cdot\vec{S}] = 0$$

$$[S^2, \vec{L}\cdot\vec{S}] = 0 \qquad [S_z, \vec{L}\cdot\vec{S}] \neq 0$$

$$|L, L_z, S, S_z\rangle$$

$$= \sum_{J=L-S}^{L+S} |J, J_z, L, S\rangle$$

$$\Rightarrow \langle J, J_z, L, S | L, L_z, S, S_z\rangle$$

$E(J) - E(J-1)$

$$\frac{\lambda}{2}\left[J(J+1) - (J-1)(J)\right] = \lambda J$$

$$\lambda \langle \vec{L} \cdot \vec{S} \rangle$$

$$\lambda \propto Z^4 \qquad \lambda_{Pb} \sim 10^5 \lambda_c$$

Chaque électron

mis dans un état j

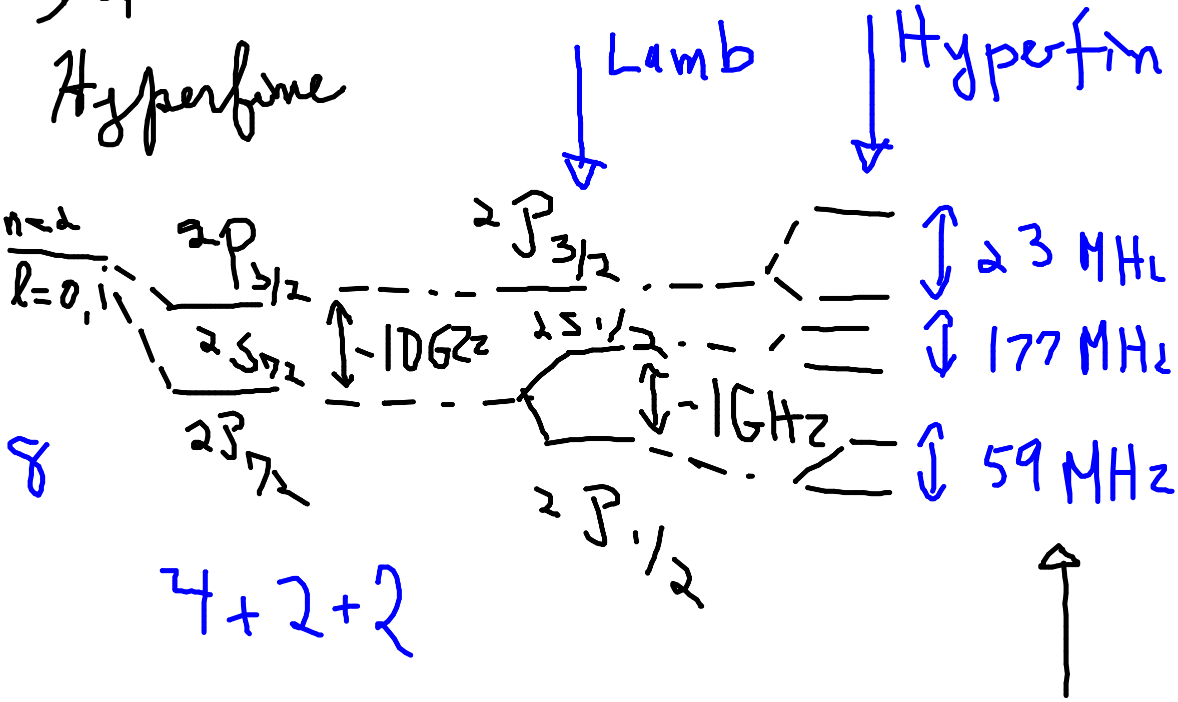
Russel-Sanders

3d 4f

Couplage $j \cdot j$

Deplacent du Lamb

Hyperfine



$$\mathcal{H} = \boxed{\mathcal{H}_m} + \boxed{\mathcal{H}_{lumière}} + \mathcal{H}_{m-l}$$

Jusqu'à maintenant

$$|\psi\rangle_m |0\rangle_l + \frac{\mathcal{H}_{l-m}}{\Delta} |\psi^{ex}\rangle |1\rangle$$

$$\Delta E = \sum_n \frac{\langle 0 | \mathcal{H}_{e-m} | n\rangle\langle n | \mathcal{H}_{l-m} | 0\rangle}{E_n - E_0 + i\gamma}$$

$$\mathcal{H}_{l-m} \sim \vec{j} \cdot \vec{A}$$

$$\begin{array}{ccc} X & \longleftrightarrow & A \\ \downarrow & & \downarrow \\ a + a^{+} & & a + a^{+} \end{array}$$

analogue

photon

$$\frac{\langle 0| \mathcal{H}_{\ell-m} |n\rangle\langle \underset{\approx}{n}| \mathcal{H}_{\ell m} |\underline{0}\rangle}{E_0 - E_n}$$

$$\frac{\cdot\ \cdot\ |1\rangle\ {}_\ell\langle 1| \langle\Psi_n| \mathcal{H}_{\ell-m} |\Psi_m\rangle |0\rangle_\ell}{E_0 - E_n}$$

$$\langle\Psi_n| j |\Psi_m\rangle\ {}_\ell\langle 1| A |0\rangle_\ell$$

$${}_\ell\langle 0|A|1\rangle_\ell\ {}_\ell\langle 1|A|0\rangle_\ell$$

$$\sum_n \langle 0|A|n\rangle_\ell\ {}_\ell\langle n| A |0_\ell\rangle$$

$${}_{l}\langle 0| A^2 |0\rangle_{l} \neq 0$$

$$A = 0 \qquad A^2 = 0$$

$$\underset{(a+a^\dagger)}{{}_{l}\langle 0| A |0\rangle_{l}} = 0$$

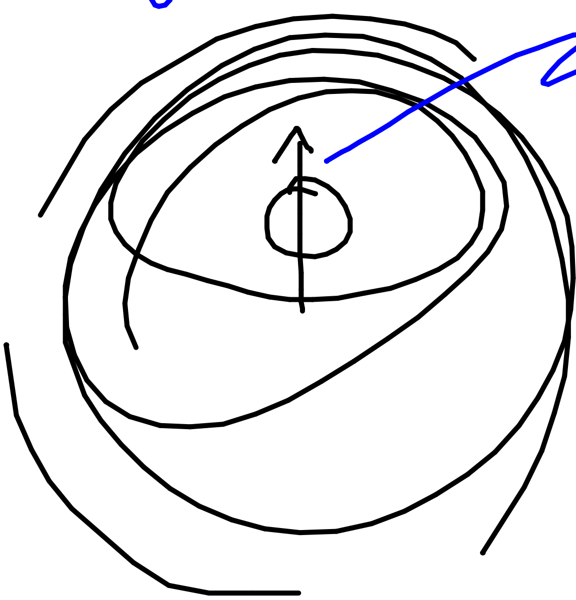
$$\ell \quad \langle 0|(a+a^\dagger)(a+a^\dagger)|0\rangle \quad \ell$$

$$\langle 0| a a^\dagger |0\rangle$$

$$= \langle 0| 1 + a^\dagger a |0\rangle$$

$$= \langle 0|0\rangle \neq 0$$

Hyperfine



$$\mu_N = \frac{e\hbar}{2M_N}$$

$$M_N \sim 2000\, M_e$$

$$-\vec{\mu}_N \cdot \vec{B}_{electron}$$

$\vec{B}_{electron}$

$\uparrow$

Champ dipolaire créé par μ_{el}

Si $\vec{L} = 0$

$\vec{S} \cdot \vec{I}\, \delta(\vec{r})$

Contact Fermi

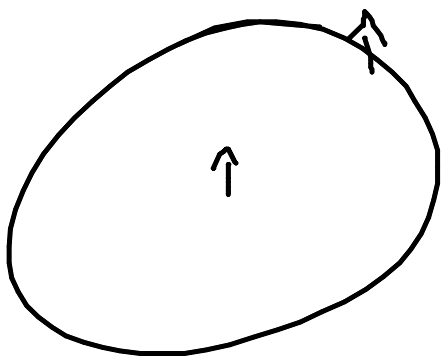
$$\frac{(\vec{p}+e\vec{A})^2}{2m}$$

$\vec{A}$ dipôle

$$\lambda_h \vec{I} \cdot \vec{J}$$

Couramé

$$\vec{F} = \vec{I} + \vec{J}$$



$F = 0$ — 1

$F = 1$ — 1, 0, -1