1. √Al: $p^1 \Rightarrow \underbrace{L=1,\ S=1/2}_{J=\frac{3}{2},\ \frac{1}{2}} \Rightarrow {}^2P_{1/2}$

√Cl: $p^5 \Rightarrow {}^2P_{3/2}$

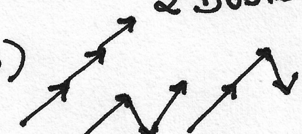
√Mn: ↑ ↑ ↑ ↑ ↑ ; $S = 5/2,\ L = 0, \Rightarrow {}^6S_{5/2}$

---

2. $J_1 = 1,\ J_2 = \frac{1}{2} \Rightarrow J = \frac{3}{2}, \frac{1}{2} \Rightarrow \boxed{\langle J^2 \rangle = J(J+1) = \begin{cases} 15/4 \\ 3/4 \end{cases}}$

---

3. $S = 3/2$ é o maior valor possível: ↑↑↑   S possíveis: 1 Quarteto, 2 Dubletos



$\left|\frac{3}{2}, \frac{3}{2}\right\rangle = \left|\frac{1}{2}, \frac{1}{2}\right\rangle\left|\frac{1}{2}\ \frac{1}{2}\right\rangle\left|\frac{1}{2}\ \frac{1}{2}\right\rangle$ ou $\alpha(1)\alpha(2)\alpha(3)$

$S_+\left|\frac{3}{2}, \frac{3}{2}\right\rangle = 0$; $S_z\left|\frac{3}{2}, \frac{3}{2}\right\rangle = \left(S_z(1) + S_z(2) + S_z(3)\right)\alpha(1)\alpha(2)\alpha(3)$

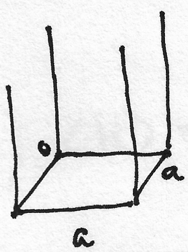
$= \left(3 * \frac{1}{2}\right)\hbar\left|\frac{3}{2}\ \frac{3}{2}\right\rangle = \frac{3\hbar}{2}\left|\frac{3}{2}, \frac{3}{2}\right\rangle$

Então como

$S^2 = S_z^2 + \hbar S_z + S_- S_+$ então $S^2\left|\frac{3}{2}, \frac{3}{2}\right\rangle = \left(\frac{9}{4} + \frac{6}{4}\right)\hbar^2\left|\frac{3}{2}\ \frac{3}{2}\right\rangle$

De fato $\boxed{S^2\left|\frac{3}{2}, \frac{3}{2}\right\rangle = \frac{15}{4}\hbar^2\left|\frac{3}{2}\ \frac{3}{2}\right\rangle}$

---

4. 

$E_n^{(0)} = \frac{n^2\pi^2\hbar^2}{2ma^2}$, $n^2 = n_x^2 + n_y^2$, est. fundamental $|1\,1\rangle$

$E_0^{(1)} = \langle 1 1 | xy | 1 1 \rangle = \underbrace{\langle 1 | x | 1 \rangle}_{a/2} \underbrace{\langle 1 | y | 1 \rangle}_{a/2} = \frac{a^2}{4}$

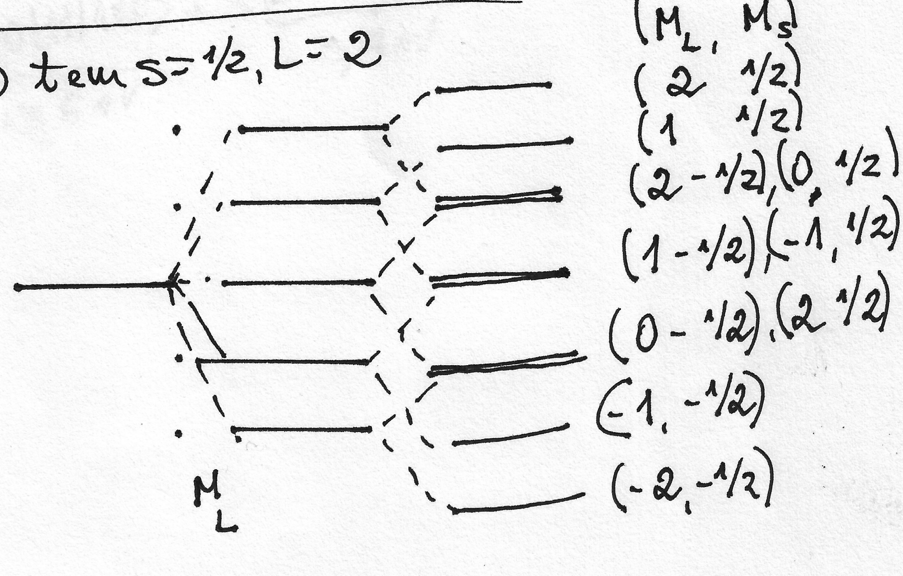
---

5. Paschen-Back ${}^2D$ tem $S = 1/2,\ L = 2$

$M_L = 2, 1, 0, -1, -2$

$M_S = 1/2, -1/2$

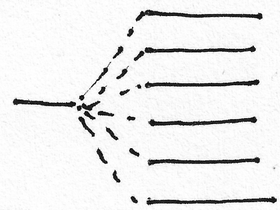
$\Delta E = \mu_0 B(M_L + 2M_S)$



5ª. $L=2, S=\frac{1}{2} \Rightarrow J_m = 5/2$, Zeeman p/ $^2D_{5/2}$

$g(J=\frac{5}{2}, L=2, S=\frac{1}{2}) = 6/5$

$\Delta E = \mu_0 B g M_J \longrightarrow$



Separação entre níveis vizinhos $= 6\mu_0 B/5$

---

6. $|0\rangle = \frac{1}{\sqrt{2}}\left[|100\rangle + |210\rangle\right]$ $E_{100} = -13{,}6\,eV \equiv E_1$

$E_{210} = -3{,}4\,eV \equiv E_2$

a) $|\psi(t)\rangle = \frac{1}{\sqrt{2}}\left[|100\rangle e^{-E_1 t/\hbar} + |210\rangle e^{-E_2 t/\hbar}\right]$

b) $\langle r\rangle \Rightarrow$ não há termos cruzados por causa da ortogonalidade dos harmônicos esféricos Y_{00} e Y_{10}. Então

$$\langle r\rangle = \frac{1}{2}\Big[\underbrace{\langle R_{10}|r|R_{10}\rangle}_{1{,}5a_0} + \underbrace{\langle R_{21}|r|R_{21}\rangle}_{5a_0}\Big] = 3{,}25a_0$$

c) $\langle H\rangle \Rightarrow$ não há termos cruzados por causa da ortogonalidade das autofunções. Então

$$\langle H\rangle = \frac{1}{2}\Big[\underbrace{\langle 100|H|100\rangle}_{-13{,}6\,eV} + \underbrace{\langle 210|H|210\rangle}_{-3{,}4\,eV}\Big] = -8{,}5\,eV$$