Zeeman shift

Interaction of Atom with external magn. field

chapter 5: nucleus is only source of E-field but has no nuclear magnetic moment.

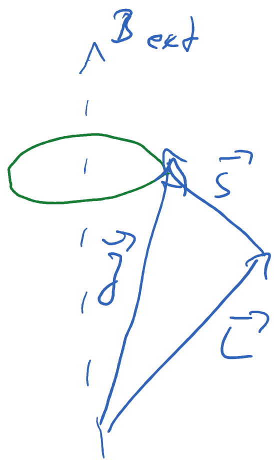
total magn. moment of atom

$$\vec{\mu} = -\mu_B \cdot \vec{L} - g_S \mu_B \vec{S} \qquad (5.9)$$

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

orbital spin contributions

interaction w/ external B-field



$$H_{zeeman} = -\vec{\mu} \cdot \vec{B}_{ext}$$

$\rightarrow$ basis $|L S J M_J\rangle$

small B_{ext}

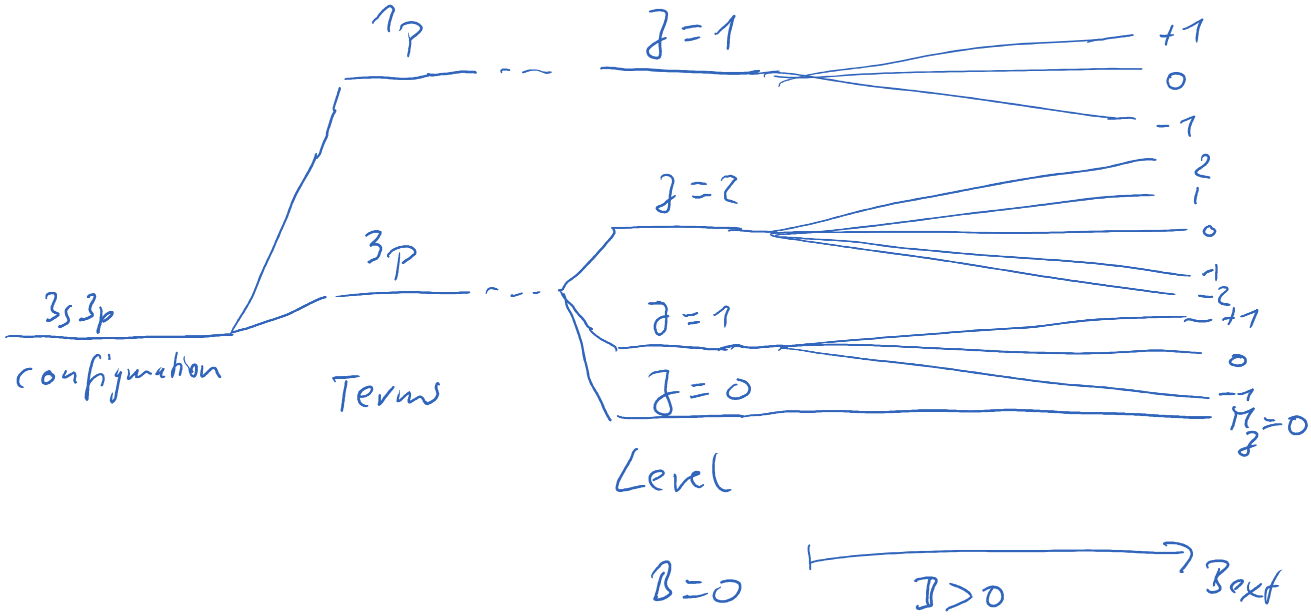
$$E_{zeeman} \ll E_{S-O}$$

$\rightarrow$ perturbation theory

$$E_{zeeman} = g_J \cdot \mu_B \cdot B_{ext} \cdot M_J \qquad (5.11)$$

$$g_J = \frac{3}{2} + \frac{S(S+1) - L(L+1)}{2J(J+1)} \qquad (5.12)$$

Fig. 5.15



complete description for $I = 0$ (^4He, ^{12}C, ...)

Now + nuclear spin $\vec{I}$

① $B = 0$ e^- in orbit creates $\vec{B}_{int}$ field at position of nucleus

→ HFS from alignment of $\vec{I}$ w.r.t. $\vec{B}_{int}$

$$H_{HFS} = -\vec{\mu}_I \cdot \vec{B}_{int} \qquad (68)$$

$$\mu_N = \mu_B \cdot \frac{m_e}{M_N} \approx \frac{1}{2000} \mu_B$$

↳ very small

HFS very small effect

$l = 0$: $\quad H_{HFS} = A \cdot \vec{I} \cdot \vec{J}$ $\quad$ (6.8)

$$E_{HFS} = A \langle \vec{I}\vec{J} \rangle = \frac{A}{2}\left\{F(F+1) - I(I+1) - J(J+1)\right\} \quad (6.9)$$

$l \neq 0$: $\quad E_F - E_{F-1} = A \cdot F$ $\quad$ (6.14)

$+ B_{ext}$

$$\vec{\mu}_{atom} = -g_J \mu_B \vec{J} + \cancel{g_I \mu_N \cdot \vec{I}} \approx -g_J \mu_B \vec{J}$$

total atom $\quad$ electronic $\quad$ nuclear $\quad$ magn. moment

very small, can be neglected when looking at effect of external fields

$$\hat{H} \approx g_J \mu_B \vec{J} \vec{B}_{ext}$$

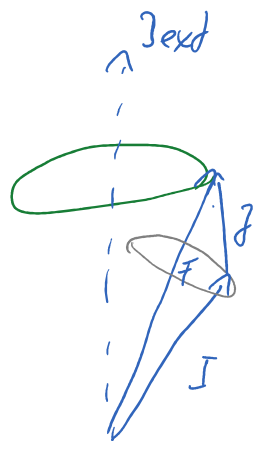
does not depend on I, but
it does depend on HFS

Weak Bext:
$$\underbrace{g_J \mu_B \vec{B}}_{\text{Zeeman}} \ll \underbrace{A \cdot \vec{I} \cdot \vec{J}}_{\text{HFS}}$$

→ treat Zeeman effect as perturbation to HFS

F, M_F remain good quantum numbers

M_I, M_J are not



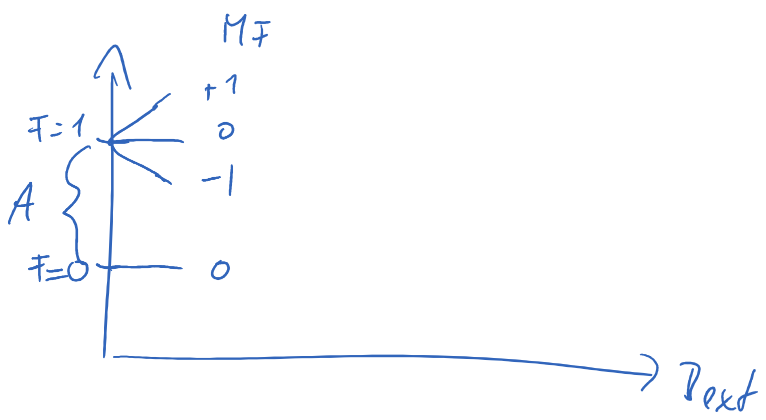
$$H = g_J \mu_B \frac{(\vec{J}\cdot\vec{F})}{F(F+1)} \vec{F}\cdot\vec{B} =$$

$$= g_F \mu_B \vec{F}\cdot\vec{B} = \qquad (6.29)$$

$$= g_F \cdot \mu_B B_{ext} \cdot F_z$$

$$g_F = \frac{F(F+1)+J(J+1)-I(I+1)}{2F(F+1)} \cdot g_J \qquad (6.30)$$

$$E = g_F \mu_B \cdot B_{ext} \cdot M_F$$



<u>strong field</u>:

$$\mu_B \cdot B_{ext} > A$$

interaction with Bext $\gg A \cdot \vec{I}\vec{J}$

$F \neq$ good quantum number

J precesses around $\vec{B}_{ext}$

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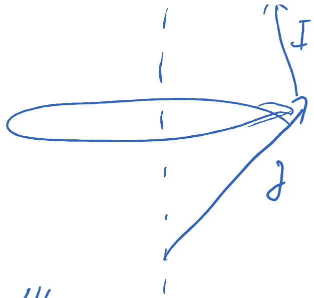
$J, M_J = \text{good}$



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$\vec{I}$ does not precess around $\vec{B}_{ext}$

because $-\underset{\text{small}}{\vec{\mu}_I} \underset{\text{smaller than } \vec{B}_{int}}{\vec{B}_{ext}}$ = negligible

$$E_{Zeeman} = g_J \mu_B B \cdot M_J + A \cdot M_I \cdot M_J \quad (6.37)$$

$\boxed{\text{Fig. 6.10}}$

1s in H

$^1S_{1/2}$

$I = 1/2$

$J = 1/2$