ZEEMAN EFFECT FOR N = 3: STRONG FIELD

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References: Griffiths, David J. (2005), Introduction to Quantum Mechanics, 2nd Edition; Pearson Education - Problem 6.26 (strong field).

To continue our analysis of the $n=3$ line in hydrogen, we'll look at the Zeeman effect in the strong field limit. In this case, the energies are given by

$$\begin{aligned} E_{n1} &= E_{n0}+E_{fs1}+E_{Z1} && (1)\\ &= -\frac{13.6\text{ eV}}{n^2}+\frac{13.6\text{ eV}}{n^2}\frac{\alpha^2}{n}\left(\frac{3}{4n}-\frac{\ell(\ell+1)-\ell_z s_z}{\ell\left(\ell+\frac{1}{2}\right)(\ell+1)}\right)+\mu_B B_{ext}\left(\ell_z+2s_z\right) && (2)\end{aligned}$$

For $n=3$, we get

$$\begin{aligned} E_{fs1} &= \frac{13.6\text{ eV}}{27}\alpha^2\left(\frac{1}{4}-\frac{\ell(\ell+1)-\ell_z s_z}{\ell\left(\ell+\frac{1}{2}\right)(\ell+1)}\right)\equiv 4\gamma\left(\frac{1}{4}-\frac{\ell(\ell+1)-\ell_z s_z}{\ell\left(\ell+\frac{1}{2}\right)(\ell+1)}\right) && (3)\\ E_{Z1} &= \mu_B B_{ext}\left(\ell_z+2s_z\right)\equiv\beta\left(\ell_z+2s_z\right) && (4)\end{aligned}$$

This time, the relevant quantum numbers are ℓ, ℓ_z and s_z, so by plugging in the values we get (remember that for $\ell=0$, the second term in parentheses for E_{fs1} is 1):

ℓ	ℓ_z	s_z	$E_{fs1}+E_{Z1}$
0	0	$-\frac{1}{2}$	$-3\gamma-\beta$
0	0	$\frac{1}{2}$	$-3\gamma+\beta$
1	-1	$-\frac{1}{2}$	$-\gamma-2\beta$
1	-1	$\frac{1}{2}$	$-\frac{7}{3}\gamma$
1	0	$-\frac{1}{2}$	$-\frac{5}{3}\gamma-\beta$
1	0	$\frac{1}{2}$	$-\frac{5}{3}\gamma+\beta$
1	1	$-\frac{1}{2}$	$-\frac{7}{3}\gamma$
1	1	$\frac{1}{2}$	$-\gamma+2\beta$
2	-2	$-\frac{1}{2}$	$-\frac{1}{3}\gamma-3\beta$
2	-2	$\frac{1}{2}$	$-\frac{13}{15}\gamma-\beta$
2	-1	$-\frac{1}{2}$	$-\frac{7}{15}\gamma-2\beta$
2	-1	$\frac{1}{2}$	$-\frac{11}{15}\gamma$
2	0	$-\frac{1}{2}$	$-\frac{3}{5}\gamma-\beta$
2	0	$\frac{1}{2}$	$-\frac{3}{5}\gamma+\beta$
2	1	$-\frac{1}{2}$	$-\frac{11}{15}\gamma$
2	1	$\frac{1}{2}$	$-\frac{7}{15}\gamma+2\beta$
2	2	$-\frac{1}{2}$	$-\frac{13}{15}\gamma+\beta$
2	2	$\frac{1}{2}$	$-\frac{1}{3}\gamma+3\beta$

The total energy for each level is

$$E_{n1} = -\frac{13.6\text{ eV}}{9}+E_{fs1}+E_{Z1} \tag{5}$$

$$= -1.51\text{ eV}+E_{fs1}+E_{Z1} \tag{6}$$

There are 14 energies with degeneracy 1 and 2 energies with degeneracy 2 (the four states that don't depend on B_{ext}).

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