

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

(1)

$$E_{n1} = E_{n0} + E_{fs1} + E_{Z1}$$

(2)

$$= -\frac{13.6 \text{ eV}}{n^2} + \frac{13.6 \text{ eV}}{n^2} \frac{\alpha^2}{n} \left(\frac{3}{4n} - \frac{\ell(\ell+1) - \ell_z s_z}{\ell(\ell + \frac{1}{2})(\ell+1)} \right) + \mu_B B_{ext} (\ell_z + 2s_z)$$

For $n = 3$, we get

(3)

$$E_{fs1} = \frac{13.6 \text{ eV}}{27} \alpha^2 \left(\frac{1}{4} - \frac{\ell(\ell+1) - \ell_z s_z}{\ell(\ell + \frac{1}{2})(\ell+1)} \right) \equiv 4\gamma \left(\frac{1}{4} - \frac{\ell(\ell+1) - \ell_z s_z}{\ell(\ell + \frac{1}{2})(\ell+1)} \right)$$

(4)

$$E_{Z1} = \mu_B B_{ext} (\ell_z + 2s_z) \equiv \beta (\ell_z + 2s_z)$$

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

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

$$(6) \quad = -1.51 \text{ eV} + E_{fs1} + E_{Z1}$$

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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