

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

$$E_{n1} = E_{n0} + E_{fs1} + E_{Z1} \quad (1)$$

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

For $n = 3$, we get

$$E_{fs1} = \frac{13.6 \text{ eV}}{27} \alpha^2 \left(\frac{1}{4} - \frac{\ell(\ell+1) - \ell_z s_z}{\ell(\ell + \frac{1}{2})(\ell+1)} \right) \equiv 4\gamma \left(\frac{1}{4} - \frac{\ell(\ell+1) - \ell_z s_z}{\ell(\ell + \frac{1}{2})(\ell+1)} \right) \quad (3)$$

$$E_{Z1} = \mu_B B_{ext} (\ell_z + 2s_z) \equiv \beta (\ell_z + 2s_z) \quad (4)$$

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

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

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

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

PINGBACKS

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