40.1 Atomic field shifts and spectral differences

Name: _____ Class: _____ Date: _____ **Total: 11 marks**

KEY WORDS Landé factor • Stark splitting

Objective

Calculate orbital and spin magnetic shifts in the appropriate coupling regime; Find photon-energy shifts from allowed upper-minus-lower level changes; Contrast parity cancellation with degenerate electric-field splitting. Original public practice; not an ETS paper.

1 Key knowledge and worked examples

For B along z, electron H_Z=μ_B B(L_z+2S_z)/$\hbar$. In the uncoupled regime, ΔE=μ_B B(m_l+2m_s). Compare magnetic energy with spin-orbit and orbital gaps.

Weak LS-coupled fields use ΔE=μ_B B g_J m_J and the Landé factor . For L=1,S=1/2: g_(3/2)=4/3, g_(1/2)=2/3. J=0 needs separate treatment.

Photon shift is upper minus lower shift, subject to transition selection rules. A spin-neglected L=1→0 model has three photon shifts −μ_B B,0,+μ_B B.

A nondegenerate parity state has zero first-order electric dipole expectation. A degenerate opposite-parity pair with supplied dipole matrix [[0,d],[d,0]] has shifts ±dF. Higher-order and near-degenerate corrections remain possible.

■ Worked method

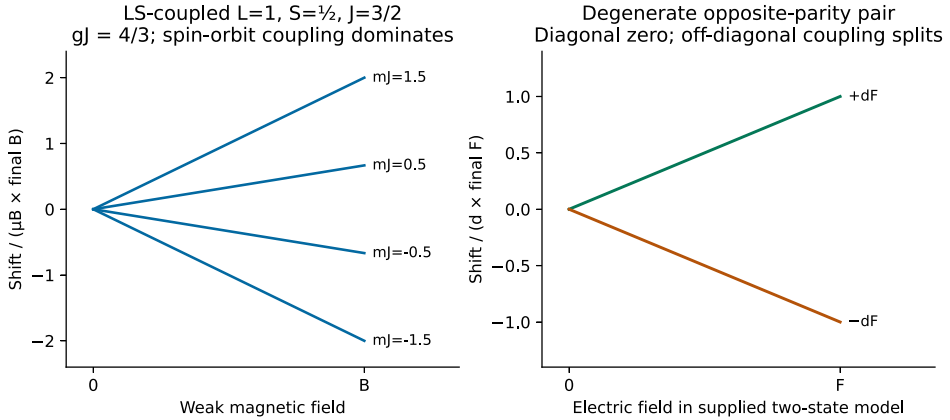
In weak LS-coupled magnetic fields, the Zeeman effect uses J, not uncoupled ml and ms.

$$\Delta E = \mu_B B g_J m_J, \quad g_J = 1 + \frac{J(J+1) + S(S+1) - L(L+1)}{2J(J+1)}.$$

For L = 1, S = 1/2 and J = 3/2, $g_J = 4/3$.

$$\Delta E = \mu_B B g_J m_J = (5.788 \times 10^{-5}\,\text{eV/T})(2\,\text{T})(4/3)(1/2) = 7.72 \times 10^{-5}\,\text{eV}.$$

Select the field regime before inserting quantum numbers. Photon shifts subtract the lower-level shift.



2 Practice

2.1 Choose one answer. In the uncoupled electron approximation, m_l=1,m_s=−1/2 and B along +z give a linear magnetic shift: [1]

- **A** −2μ_B B
- **B** −μ_B B
- **C** 0
- **D** +μ_B B
- **E** +2μ_B B

2.2 Choose one answer. An upper level shifts by +2u and a lower level by −u. An allowed emitted photon shifts by: [1]

- **A** −3u
- **B** −u
- **C** 0
- **D** +u
- **E** +3u

2.3 For L=1,S=1/2,J=1/2, the Landé factor in the g_s=2 approximation is _____ (use a fraction). Show your relation and units. [2]

2.4 Decide whether this claim is true. Justify it: A nondegenerate parity eigenstate's zero first-order Stark shift guarantees no electric-field response at any order. [2]

3 Exam-style questions

3.1 Two opposite-parity degenerate states have dipole perturbation matrix $\begin{pmatrix} 0 & dF \\ dF & 0 \end{pmatrix}$. Find energies and eigenstates to first order. Compare with two such states separated by a large unperturbed gap Delta. [5]