# 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=$\mu$_B B(L_z+2S_z)/$\hbar$. In the uncoupled regime, $\Delta$E=$\mu$_B B(m_l+2m_s). Compare magnetic energy with spin-orbit and orbital gaps.

Weak LS-coupled fields use $\Delta$E=$\mu$_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 −$\mu$_B B,0,+$\mu$_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

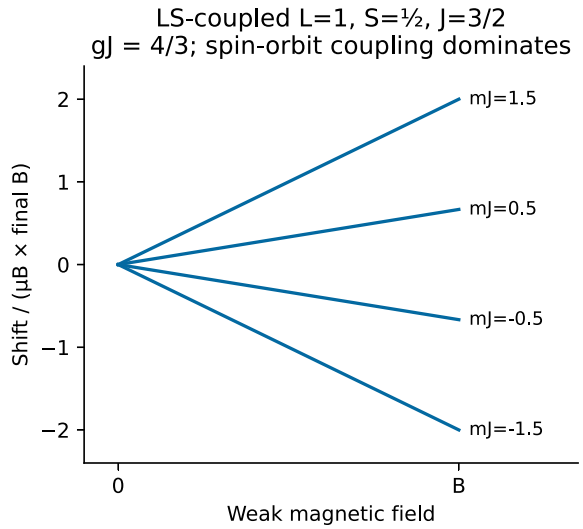
In weak LS-coupled magnetic fields, the Zeeman effect uses J, not uncoupled ml and ms.

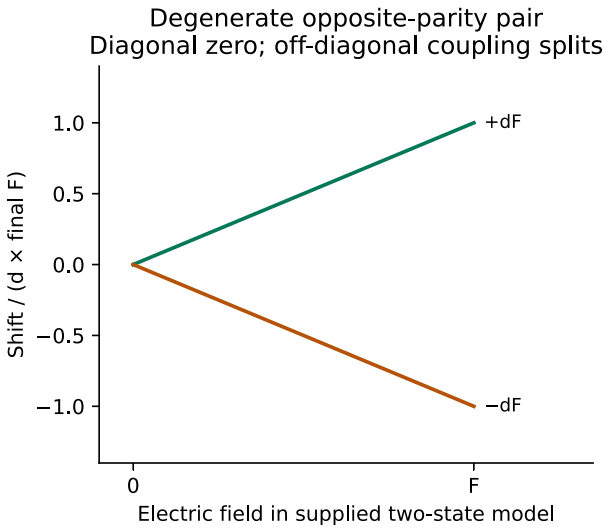
$$\Delta E = \mu_B B g_J m_J, \quad g_J = 1 + \frac{J(J+1) + S(S+1) - L(L+1)}{2J(J+1)}.$$

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** $-2\mu$_B B
- **B** $-\mu$_B B
- **C** 0
- **D** $+\mu$_B B
- **E** $+2\mu$_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]

## Solutions

**2.1 C** m_l+2m_s=1−1=0. This statement uses the uncoupled regime.

Compare the rejected options: $-2\mu$_B B; $-\mu$_B B; $+\mu$_B B; $+2\mu$_B B. Use the stated model and conditions.

**2.2 E** Photon energy is E_upper−E_lower, so the change is 2u−(−u)=3u.

Compare the rejected options: −3u; −u; 0; +u. Use the stated model and conditions.

**2.3** 2/3. 1+[3/4+3/4−2]/(2 · 3/4)=2/3.

**2.4** False. Off-diagonal dipole couplings can produce a quadratic shift; degeneracy changes the leading-order treatment.

**3.1** Degenerate shifts are $\pm dF$, with eigenstates $(1, \pm 1)/\sqrt{2}$; splitting is $2|dF|$. With a large gap, each parity state's first-order diagonal shift is zero. Off-diagonal coupling instead gives ground shift approximately $-(dF)^2/\Delta$. Award shifts, states, splitting, vanishing nondegenerate first order and quadratic correction/condition.