

Atomic spectra and selection rules

GRE · GRE Subject Test · GRE Physics

Not every energy difference produces a strong electric-dipole line.

Prerequisites: 23, 40, 41.

- Relate atomic energies to spectral lines
- Apply angular-momentum quantum numbers
- Distinguish allowed and forbidden electric-dipole transitions

Choose the system and model

For hydrogen-like one-electron ions, the bound energies scale as $-13.6 Z^2/n^2$ eV in the simplest nonrelativistic model. Emission requires a downward transition and positive photon energy.

Use the governing relation

Orbital angular momentum has $l=0,\dots,n-1$ and $m_l=-l,\dots,l$. Electron spin adds $s=1/2$; total angular momentum combines orbital and spin contributions.

Apply the conditions

Electric-dipole selection rules include $\Delta l=\pm 1$ and $\Delta m=0,\pm 1$. These rules concern a specific transition mechanism; forbidden does not mean impossible by every mechanism.

Check the conclusion

Fine structure, spin-orbit effects and Zeeman splitting refine the simplest hydrogen picture. In many-electron atoms, shielding and electron interactions invalidate direct hydrogen-energy substitution.

Worked method

For a nonrelativistic one-electron ion, neglecting fine structure,

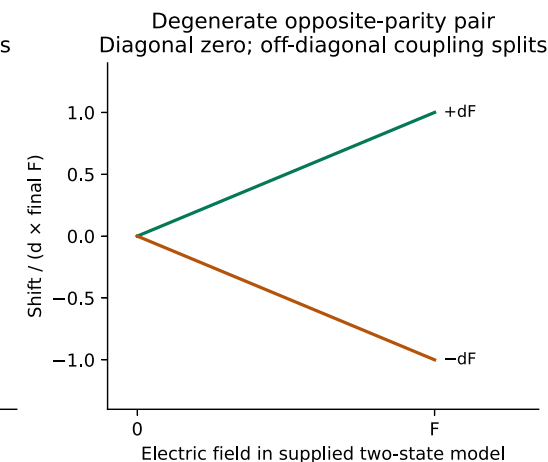
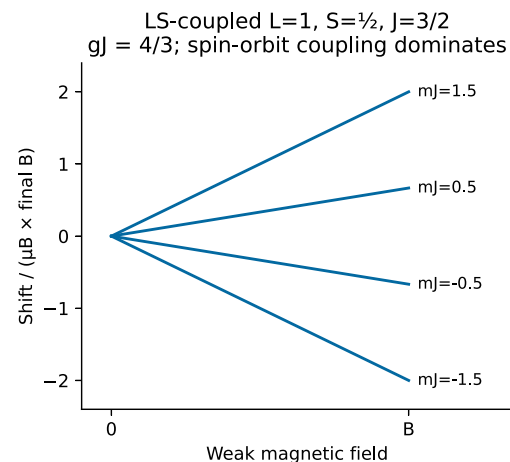
$$E_n = -13.6 \text{ eV } Z^2/n^2.$$

For $Z = 2$, an emission from $n = 3$ to $n = 2$ gives positive photon energy:

$$E_\gamma = E_3 - E_2 = (13.6 \text{ eV})(2^2)(1/2^2 - 1/3^2) = 7.56 \text{ eV}.$$

$$\lambda = hc/E_\gamma = (1240 \text{ eV nm})/(7.56 \text{ eV}) = 164 \text{ nm}.$$

An energy difference alone does not guarantee an electric-dipole transition; the participating orbital states must satisfy the selection rules.



Atomic spectra and selection rules: original GRE teaching diagram.

Check conditions and vocabulary

Do not make the final-state energy minus initial-state energy negative for an emitted photon.

selection rule : A restriction on transitions for a specified interaction mechanism.

Zeeman splitting: Magnetic-field splitting of atomic energy levels.