

Atomic spectra and selection rules

GRE undergraduate preparation · local supported objectives

Choose the physical question

Reasoning

Not every energy difference produces a strong electric-dipole line. Relate atomic energies to spectral lines Apply angular-momentum quantum numbers Distinguish allowed and forbidden electric-dipole transitions

Choose the system and model

Reasoning

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

Reasoning

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

Reasoning

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

Reasoning

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 reasoning 1

Reasoning

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

Worked relation 2

Reasoning

Apply this relation only under the conditions just stated.

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

Worked reasoning 3

Reasoning

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

Worked relation 4

Reasoning

Apply this relation only under the conditions just stated.

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

Worked relation 6

Reasoning

Apply this relation only under the conditions just stated.

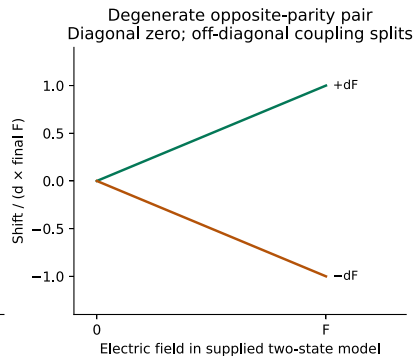
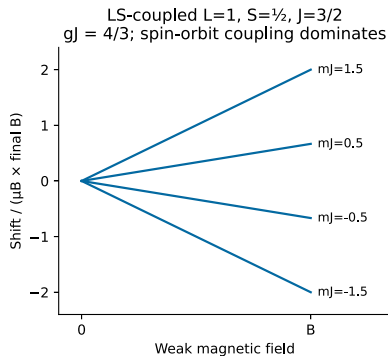
$$\lambda = hc/E_\gamma = (1240 \text{ eV nm})/(7.56 \text{ eV}) = 164 \text{ nm}.$$

Worked reasoning 7

Reasoning

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

Read the original diagram



- Original GRE teaching diagram: Atomic spectra and selection rules
- Identify the axes, units, directions and the stated model.

Independent transfer · attempt

Reasoning

A hydrogenic electron is in a 3d state. Under the electric-dipole approximation, which lower principal-level orbital states can it reach in one emission? Explain why the $n = 1$ level is excluded. Ignore fine structure and spin changes. **[4]**

Independent transfer · reasoning

Reasoning

A 3d state has $l = 2$. Electric-dipole emission requires $\Delta l = \pm 1$, and a lower n for positive photon energy. At $n = 2$ only $l = 0, 1$ exist, so 2p is allowed (with magnetic sublevels obeying $\Delta m = 0, \pm 1$). At $n = 1$ only 1s exists; $\Delta l = -2$ forbids that direct electric-dipole transition. Award initial l , rule, 2p and exclusion of 1s. Higher-order transitions are outside this approximation.

Check assumptions and limits

Reasoning

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

Keep the technical distinctions

Reasoning

selection rule : A restriction on transitions for a specified interaction mechanism. Zeeman splitting : Magnetic-field splitting of atomic energy levels.

Check yourself

- Define selection rule and give its condition of use.
- Define Zeeman splitting and give its condition of use.
- Redo the original transfer with a changed parameter; check a limiting case.