Electric Dipole (Resonance) Transitions

- Only 1 e\textsuperscript{−} changes its (nl) state with \( \Delta l = -1 \) or +1
- Parity MUST change
- \( \Delta L = -1, 0, \) or +1 (\( 0 \rightarrow 0 \), no S \( \rightarrow \) S term transitions)
- \( \Delta J = -1, 0, \) or +1 (\( 0 \rightarrow 0 \) NOT allowed)
- \( \Delta S = 0 \) (spin multiplicity does NOT change)

\text{NII 1084.0A } ^3P_0 \rightarrow ^3D_1^o
Spin Forbidden (Semi-forbidden, Intercombination or Intersystem) Transitions

- Only 1 e\(^-\) changes its (nl) state with \(\Delta l = -1\) or +1
- Parity MUST change
- \(\Delta L = -1, 0,\) or +1 (0 \(\rightarrow\) 0, no S \(\rightarrow\) S term transitions)
- \(\Delta J = -1, 0,\) or +1 (0 \(\rightarrow\) 0 NOT allowed)

- \(\Delta S = 0\) (spin multiplicity does change)

\[\text{NII] 2143.4Å}\]

\[\text{3P}_2 \text{ - } \text{5S}_2^0\]

Notation – single right-side bracket

\(\Delta S = +2\) but otherwise follows rules 1-4
Forbidden Transitions

At least 1 of the following 4 rules is broken:

- Only 1 $e^-$ changes its (nl) state with $\Delta l = -1$ or $+1$
- Parity MUST change
- $\Delta L = -1, 0, \text{ or } +1$ ($0 \rightarrow 0$, no S $\rightarrow$ S term transitions)
- $\Delta J = -1, 0, \text{ or } +1$ ($0 \rightarrow 0$ NOT allowed)
- $\Delta S = \text{may or may not change}$

$[\text{NII}] 6549.9 \text{A } ^3P_1 - ^1D_2$

Parity does not change
- breaks rule 2
Figure 6.1 First nine energy levels of NII. Forbidden transitions are indicated by broken lines, and allowed transitions by solid lines; forbidden decays are not shown from levels that have permitted decay channels. Fine-structure splitting is not to scale.

### Multipole Transition Rules

<table>
<thead>
<tr>
<th>Allowed transitions</th>
<th>Electric dipole (E1)</th>
<th>Magnetic dipole (M1)</th>
<th>Electric quadrupole (E2)</th>
<th>Magnetic quadrupole (M2)</th>
<th>Electric octupole (E3)</th>
<th>Magnetic octupole (M3)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Rigorous rules</strong></td>
<td></td>
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<tr>
<td>(1)</td>
<td>$\Delta J = 0, \pm 1$</td>
<td>$\Delta J = 0, \pm 1, \pm 2$</td>
<td></td>
<td></td>
<td>$\Delta J = 0, \pm 1, \pm 2, \pm 3$</td>
<td></td>
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<tr>
<td></td>
<td>$(J = 0, \phi = 0)$</td>
<td>$(J = 0, \phi = 0, 1, \frac{1}{2}, \phi \frac{1}{2}, \frac{1}{2})$</td>
<td></td>
<td></td>
<td>$(0, \phi = 0, 1, 2, \frac{1}{2}, \phi \frac{1}{2}, 1, \phi = 1)$</td>
<td></td>
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<tr>
<td>(2)</td>
<td>$\Delta M_J = 0, \pm 1$</td>
<td>$\Delta M_J = 0, \pm 1, \pm 2$</td>
<td></td>
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<td>$\Delta M_J = 0, \pm 1, \pm 2, \pm 3$</td>
<td></td>
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<tr>
<td><strong>Parity</strong></td>
<td>$\pi_f = -\pi_i$</td>
<td>$\pi_f = \pi_i$</td>
<td></td>
<td></td>
<td>$\pi_f = -\pi_i$</td>
<td>$\pi_f = \pi_i$</td>
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<tr>
<td><strong>LS coupling</strong></td>
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<tr>
<td>(4)</td>
<td>One electron jump</td>
<td>No electron jump</td>
<td>None or one electron jump</td>
<td>One electron jump</td>
<td>One electron jump</td>
<td>One electron jump</td>
</tr>
<tr>
<td></td>
<td>$\Delta J = s_1$</td>
<td>$\Delta J = 0, s_2$</td>
<td>$\Delta J = s_1, s_3$</td>
<td>$\Delta J = s_1, s_3$</td>
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<td>(5)</td>
<td>$\Delta L = 0, \pm 1$</td>
<td>$\Delta L = 0, \pm 1, \pm 2$</td>
<td>$\Delta L = 0, \pm 1, \pm 2$</td>
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<td><strong>Intermediate coupling</strong></td>
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<td>(6)</td>
<td>$\Delta L = 0, \pm 1, \pm 2$</td>
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</table>
Helium

Figure 14.3: Radiative decay pathways for He\(^0\) (see text). Selected lines are labeled by vacuum wavelength.

Breakdown of LS coupling

He\(^0\) Singlet States

He\(^0\) Triplet States

Lithium

Configuration: (3s)\(^2\) (3p)\(^2\)

\(E\) (cm\(^{-1}\))

\(\nu\) 
\(P\) 
\(D\) 
\(F\) 
\(E\) (\(\AA\))

5.37

4.0

3.0

2.0

1.0

0.0

10000

20000

30000

40000

50000

60000

\(n = 3\)

\(n = 3\)

\(n = 2\)

\(n = 3\)

\(n = 4\)

\(n = 4\)

\(n = 5\)

\(n = 5\)

\(n = 6\)

\(n = 6\)
Lithium-like Ions

Beryllium-like Ions
Carbon “Grotrian Diagram”

Energy (eV)

Triplets

Singlets

Nitrogen-like Ions

7 electrons

Fabbian+ 2006
Oxygen-like Ions

Fluorine-like Ions