11.29) For two $e^-$ in He with antiparallel spins, upper in $l=2$ $S$ state, lower in $l=3$ $F$ state in a B field.

a) Sketch the levels for all $m$.

b) Calculate the possible transitions and the number of distinct energy changes.

c) Show allowed transitions.

d) How many distinct photon energies will result?

\[ \Delta \ell = \pm 1, \quad \Delta m = \pm 1, 0 \]

\[ \Rightarrow \text{In principal, there are } (5) \times (7) = 35 \text{ transitions} \]

\[ \ell = 2 \quad \ell = 3 \]

\[ \Delta E = m \mu_B B, \quad E = E_\ell + m \mu_B B \]

\[ E_{\ell=2} = E_2 + m \mu_B B \quad E_{\ell=3} = E_3 + m \mu_B B \]

\[ \Delta E = E_{\ell=2} - E_{\ell=3} = E_2 - E_3 + (m_2 - m_3) \mu_B B \]

\[ (m_2 - m_3) = 2 - 3 = -1 \quad \text{and} \quad 2 - 3 = -5 \]

\[ \begin{align*}
2 - 2 &= 0 \\
2 - 1 &= 1 \\
2 - 0 &= 2 \\
2 - (-1) &= 3 \\
2 - (-2) &= 4 \\
2 - (-3) &= 5 \\
-2 - 2 &= -4 \\
-2 - 1 &= -3 \\
-2 - 0 &= -2 \\
-2 - (-1) &= -1 \\
-2 - (-2) &= 0 \\
-2 - (-3) &= 1 \\
\end{align*} \]

\[ \Rightarrow 11 \Delta E's \]

\[ \text{Selecting selection rules, there are} \]

\[ (m_2 - m_3) = 2 - 3 = -1 \quad \text{and} \quad 2 - 3 = -5 \]

\[ \Delta E = \begin{cases} 
-2 & (m_2 - m_3) = 2 - 3 = -1 \\
-2 & (m_2 - m_3) = 2 - 3 = -5 \\
-2 & (m_2 - m_3) = 2 - 3 = -1 \\
-2 & (m_2 - m_3) = 2 - 3 = -5 \\
\end{cases} \]

\[ \Rightarrow 11 \Delta E's \]

\[ \text{Selection rules only allow } (m_2, m_3) = 0, \pm 1 \text{ so only 3 photons can be produced} \]