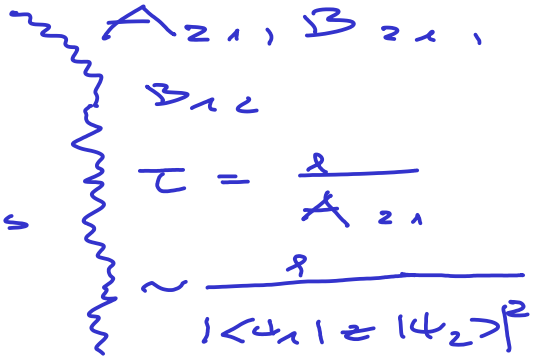
Selection rules

1) Electric dipol transition

$H_{nm} = |\langle \psi_m | \vec{x} | \psi_n \rangle|^2$

if $H_{mn} \neq 0$ transition occurs

$H_{mn} = 0$ is forbidden



a) $[L_z, z] = 0$ $|n \ell m\rangle$

$\langle n' \ell' m' | L_z \cdot z - z L_z | n \ell m \rangle =$

$= \hbar (m' - m) \langle n' \ell' m' | z | n \ell m \rangle = 0$

$m' - m = 0$ for polarized in z direction

π - transition

b) $[L_z, x \pm iy] = \pm \hbar (x \pm iy)$

$\langle n' \ell' m' | L_z (x \pm iy) - (x \pm iy) L_z | n \ell m \rangle =$

$= \hbar (m' - m) \langle n' \ell' m' | x \pm iy | n \ell m \rangle$

$= \pm \hbar \langle n' \ell' m' | x \pm iy | n \ell m \rangle$

$\Rightarrow m' - m = \pm 1$ for light polarized transverse to z

σ - transition

$\Leftrightarrow \quad [L^2, [L^2, x]] = 2\hbar^2 (x L^2 + L^2 x)$

$(l+l')(l+l'+2)\left[(l-l')^2 - 1\right] \langle n l' m' | x | n l m \rangle = 0$

$l, l' > 0$

$$l - l' = \pm 1$$

Wigner - Eckart Theorem //

2) magnetic dipol transition

$\langle n l' m' | \mu | n l m \rangle$

$\mu \sim L$ — even parity

the states have the same parity

1) & 2)

21cm line → lifetime 10 millions years