

PHY2005

Atomic Physics

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(10) Transitions and selection rules

Learning goals

1. To qualitatively understand the processes of *spontaneous emission*, *absorption* and *stimulated emission* for transitions between bound states of atoms/ions.
2. To become familiar with the *Einstein coefficients*.
3. To know the *selection rules* that are obeyed by *permitted* (electric dipole) transitions.

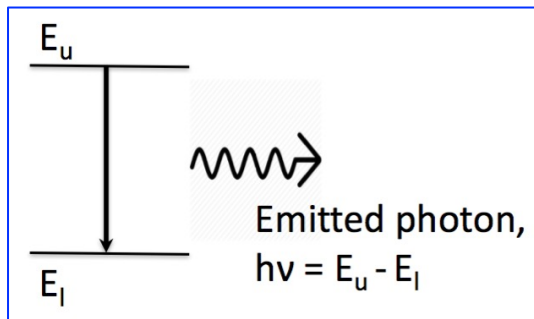
Photon processes

Three distinct photon processes associated with atoms changing their state:

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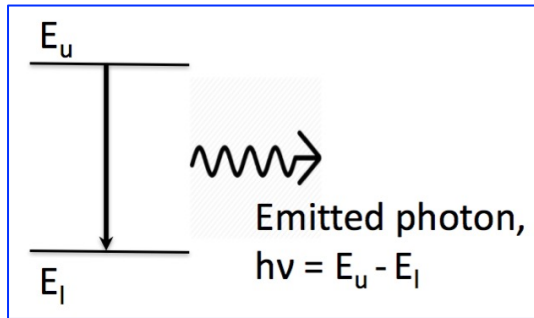
Spontaneous
Emission



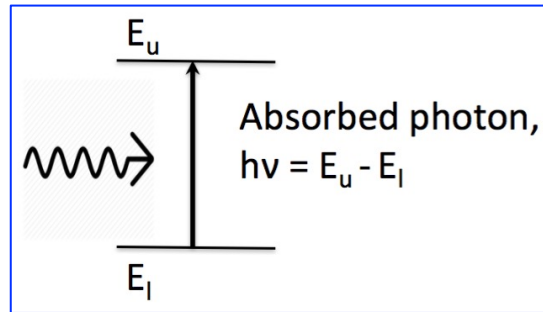
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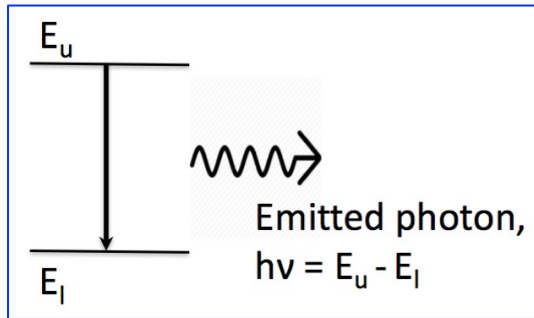
Absorption



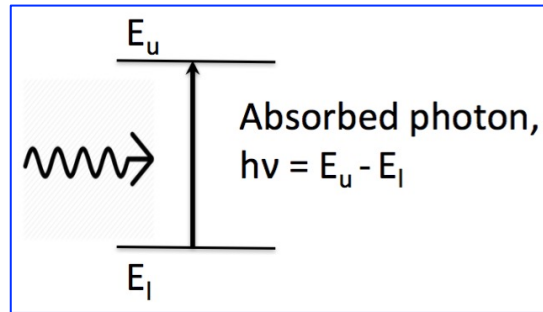
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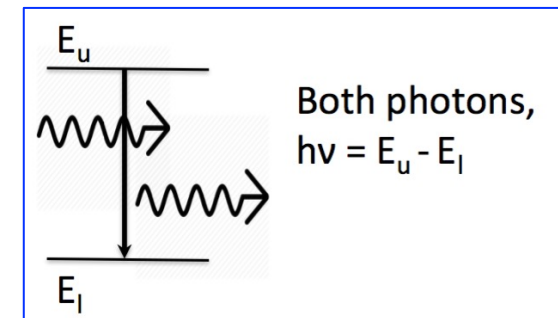
Spontaneous
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Absorption



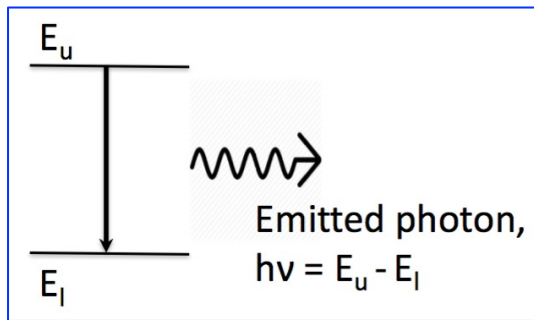
Stimulated
Emission



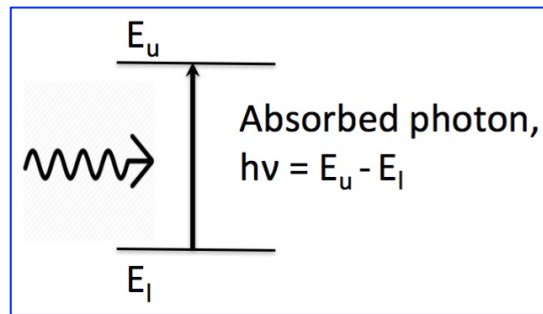
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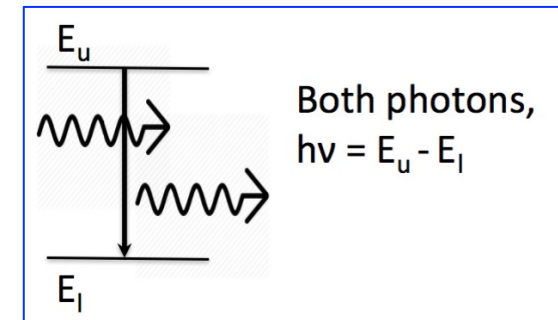
Spontaneous
Emission



Absorption



Stimulated
Emission



Rates characterized by Einstein coefficients (three are related):

$$A_{ul}$$

$$B_{lu}$$

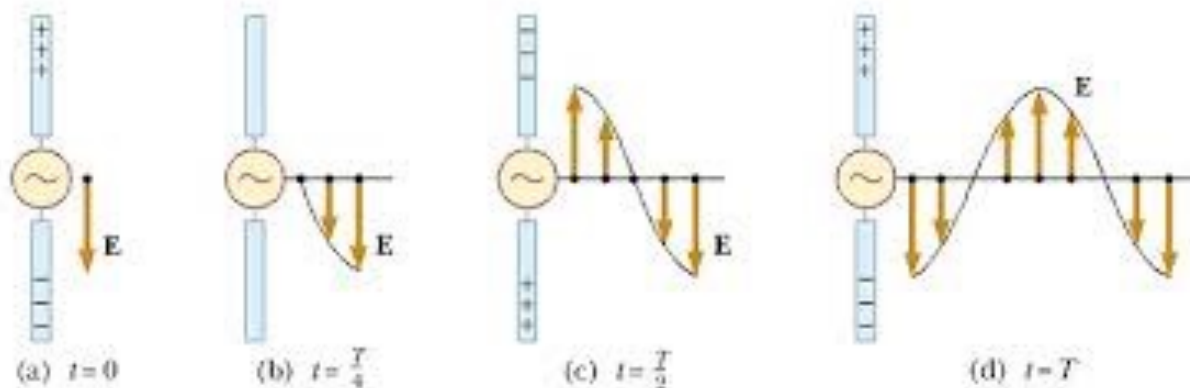
$$B_{ul}$$

Selection rules (permitted electric dipole transitions)

There are restrictions on which transitions (i.e. change in level) of an atom are “allowed” when emitting / absorbing a photon.

“Permitted” transitions require that the electric dipole moment of the atom changes

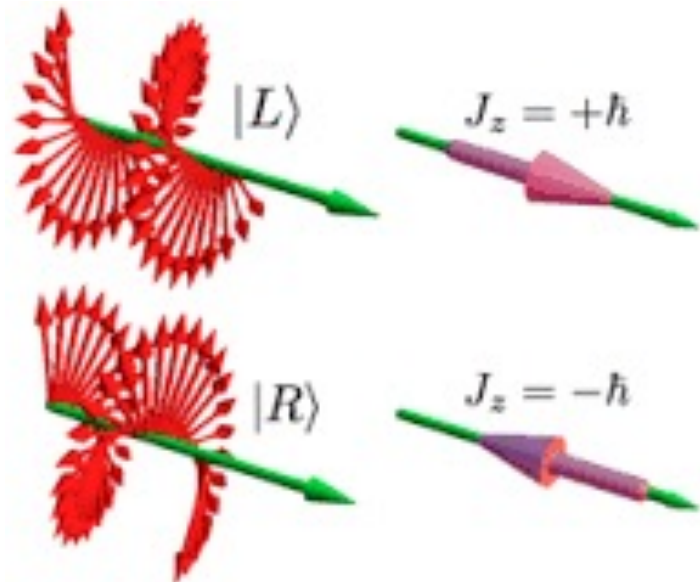
- Can be understood semi-classically: an oscillating electric dipole is an efficient source of electromagnetic radiation



Selection rules (permitted electric dipole transitions)

“Permitted” transitions must also respect the angular momentum of the photon:

- Change in angular momentum quantum numbers of atom relates to angular momentum of emitted photon



Selection rules

These considerations give rise to set of “**selection rules for permitted transitions**”:

1. **Single electron jump**: the transition must involve a change in the configuration that corresponds to a single electron changing its shell (or sub-shell).
2. $\Delta l = \pm 1$: the change in the electron configuration must involve the angular momentum quantum number of the “jumping” electron changing by one.
3. $\Delta L = 0, \pm 1$ **but** $L = 0 \rightarrow L = 0$ **is forbidden**.
4. $\Delta S = 0$.
5. $\Delta J = 0, \pm 1$ **but** $J = 0 \rightarrow J = 0$ **is forbidden**.
6. $\Delta M_J = 0, \pm 1$.

Summary / Revision

- Transitions between atomic states involving photons have three types: *spontaneous emission*, *absorption* and *stimulated emission*.
- The rates of these three classes of transition depend on the corresponding *Einstein coefficients*.
- Permitted transitions must obey *selection rules* that govern the changes in the quantum numbers that occur during the transition. **Students are expected to know the selection rules.**