Lecture 7

Light - Matter Interactions
A metallic cavity with dilute gas

- Excited atom
- Ground state atom

$N$

Excitation and deexcitation processes:

$e^{-\Delta E/kT}$

$E_1$, $n_1$

$E_2$, $n_2$
Light-Atom Interaction

Absorption

$E_2 \rightarrow n_2$

Spontaneous Emission

$E_1 \rightarrow n_1$

$h\nu = E_2 - E_1$
Available Processes

Rate it happens is: \( B_{12} n_1 u \)
This is equal to: \(-dn_1/dt\)
as well as: \(dn_2/dt\)
\( A_{21} n_2 \)
\( dn_1/dt \)
\(-dn_2/dt\)

In thermal equilibrium ....
Thermal Equilibrium Rate Equations

\[ \frac{dn_1}{dt} = -B_{12} n_1 u + A_{21} n_2 = 0 \]

\[ \frac{A_{21}}{B_{12}} = \frac{n_1}{n_2} u \]

\[ \frac{A_{21}}{B_{12}} = \exp(\Delta E/(k T)) \quad 8 \pi h \frac{v^3}{c^3} x \frac{1}{(\exp(\Delta E/(k T)-1))] \]

How can this be???????????
All Processes

Rate it happens is: \( B_{12} n_1 u \)
This is equal to: \( -\frac{dn_1}{dt} \)\nAs well as: \( \frac{dn_2}{dt} \)
\( -\frac{dn_2}{dt} \)

In thermal equilibrium ....
Thermal Equilibrium Rate Equations

\[ \frac{dn_1}{dt} = -B_{12} n_1 u + A_{21} n_2 + B_{21} n_2 u = 0 \]

As \( T \to \infty \),
\[ -B_{12} \frac{N}{2} u + B_{21} \frac{N}{2} u = 0 \]

\[ B_{12} = B_{21} \quad **** FIRST LAW \]

Resubstituting:
\[ \frac{A_{21}}{B_{12}} = \left( \exp\left(\frac{\Delta E}{k T}\right) - 1 \right) \times \frac{8 \pi h \nu^3/c^3}{1/(\exp(\Delta E/(k T)-1))} \]

\[ \frac{A_{21}}{B_{12}} = 8 \pi h \nu^3/c^3 \quad **** SECOND LAW \]
Single Atom Light Interaction

http://www.colorado.edu/physics/2000/lasers/lasers2.html
Stimulated Emission

Ask Q.4-5
Stimulated Light

Outgoing generated photon shares every property with the incoming (generating photon):

- Frequency
- Phase
- Polarization
- Direction
Is the light we see around us generated by stimulated or spontaneous processes?

\[ \frac{A_{21}}{B_{21}} = \frac{8 \pi \hbar \nu^3}{c^3} \]

\[ B_{21} n_2 u / (A_{21} n_2) = u \frac{c^3}{(8 \pi \hbar \nu^3)} = \frac{u}{(\hbar \nu)} \frac{1}{N(\nu)} \]

How many photons per mode for a thermal source? i.e. \( T \sim 1000K \), and visible photons \( \sim 3 \times 10^{14} \text{Hz} \)

\[ E_{eq} = \frac{1}{(\exp(\hbar \nu/kT) - 1)} \sim 10^{-6} \]

So almost all photons are generated by thermal processes in normal circumstances. Once get more than unity occupation number then situation completely changes.