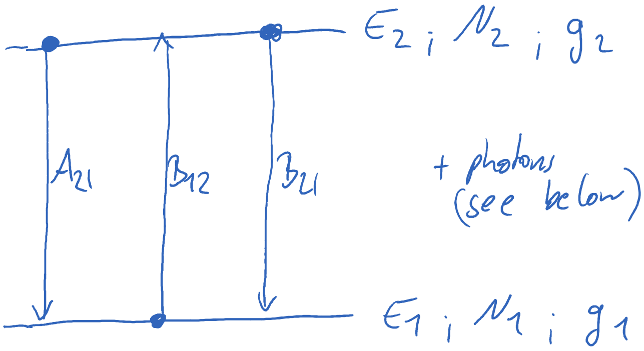
1) Structure of Atoms (✓)
2) Light-atom interaction

Einstein A & B coefficients

Foot: Atomic physics

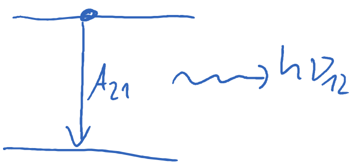
2 level system (toy atom) & electromagnetic radiation

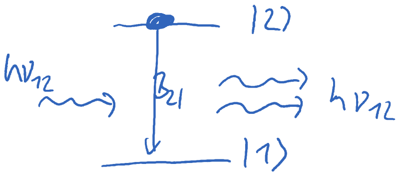


+ photons (see below)

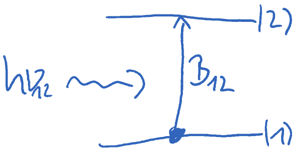
$g_{1,2}$ = degeneracy = # of sublevels with same energy

spontaneous emission   absorption





stimulated emission



interaction of atom with radiation field

$\rho(\omega)$ = energy density per unit frequency interval

$$B_{12} \propto \rho(\omega_{12})$$

resonance frequency: $\omega_{12} = \frac{E_2 - E_1}{\hbar}$ (1)

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$B_{21} \propto \rho(\omega_{12})$ by symmetry

A_{21} spontaneous emission even without $\rho(\omega_{12})$
$\hat{=}$ with $\rho(\omega_{12}) = 0$

rate equations: abs. stim. em. spont. em.

- $\frac{dN_2}{dt} = N_1 \cdot B_{12} \cdot \rho(\omega_{12}) - N_2 B_{21} \rho(\omega_{12}) - N_2 A_{21}$ (2)

- $\frac{dN_1}{dt} = - \frac{dN_2}{dt}$ $(N_1 + N_2 = 1 = \text{const})$ (3)

1st case: laser = off $\hat{=}$ $\rho(\omega) = 0$
but $N_2(t=0) \neq 0$ (some excited state population @ $t=0$)

$\overset{(2)}{\Rightarrow}$ $N_2(t) = N_2(0) \cdot e^{-A_{21} \cdot t}$ exponential decay (4)

mean lifetime $\boxed{\frac{1}{\tau} = A_{21}}$ (5)

- Einstein's argument to relate A and B's

put atom into heated box
→ black-body radiation

$\rho(\omega) d\omega$ depends only on temperature

↳ radiation density in angular frequ. interval $[\omega, \omega+d\omega]$

Planck's law

$$\rho(\omega) = \frac{\hbar \omega^3}{\pi^2 c^3} \frac{1}{\exp\left(\frac{\hbar\omega}{kT}\right) - 1} \qquad (6)$$

eventually the atom will get into equilibrium with field

$$\rightarrow \frac{dN_i}{dt} = 0$$

from (2): $$\rho(\omega_{12}) = \frac{A_{21}}{B_{12}} \frac{1}{\frac{N_1}{N_2} \cdot \frac{B_{12}}{B_{21}} - 1} \qquad (7)$$

populations in thermal equilibrium are given by Boltzmann factor

$$\frac{N_2}{g_2} = \frac{N_1}{g_1} \exp\left(-\frac{\hbar\omega_{12}}{kT}\right)$$

(6)...(8) holds for each temperature

→ 2 equations, for T independant part & $e^{-\frac{\hbar\omega_{12}}{kT}}$ part

$$\boxed{\begin{aligned} A_{21} &= \frac{\hbar \omega_{12}^3}{\pi^2 c^3} B_{21} \\ B_{12} &= \frac{g_2}{g_1} B_{21} \end{aligned}} \qquad (9)$$

Einstein coeff are properties of the atom

- hold for all types of radiation
  (black body, broadband, monochromatic)

Strong absorption is associated with strong emission