



ENGINEERING PHYSICS

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- Class #35
- Rates of absorption and emission and thermal equilibrium
- Planck's expression for Energy density
- Einstein A and B Coefficients

Unit IV : Review of concepts leading to Quantum Mechanics: LASERS

➤ *Suggested Reading*

1. *Concepts of Modern Physics, Arthur Beiser, Chapter 9.6*
2. *Optical Electronics, A. Yariv*
3. *Course material developed by the department*

➤ *Reference Videos*

1. <https://ocw.mit.edu/courses/physics/8-06-quantum-physics-iii-spring-2018/video-lectures/time-dependent-perturbation-theory/l13.3-einsteins-b-and-a-coefficients-determined.-lifetimes-and-selection-rules/>
2. *Unit I Class # 4 Video*

$$R_{Ab} = B_{12} N_1 E(v)$$

$$R_{SpEm} = A_{21} N_2$$

$$R_{StEm} = B_{21} N_2 E(v)$$

*As the total number of atoms is constant,
under thermal equilibrium*

$$R_{Ab} = R_{SpEm} + R_{StEm}$$

$$B_{12} N_1 E(v) = A_{21} N_2 + B_{21} N_2 E(v)$$

$$(B_{12}N_1 - B_{21}N_2) E(v) = A_{21}N_2$$

$$E(v) = \frac{A_{21}N_2}{(B_{12}N_1 - B_{21}N_2)} \quad \text{--- (2)}$$

Planck's Expression for Energy Density

$$E(v) = \frac{\frac{8\pi h v^3}{c^3}}{\left(e^{\frac{hv}{kT}} - 1\right)} \quad \text{--- (3)}$$

$$E(v) = \frac{\frac{A_{21}}{B_{21}}}{\left(\frac{B_{12}}{B_{21}} \frac{N_1}{N_2} - 1 \right)} \quad \dots \dots \dots \quad (4)$$

To obtain the above expression we have divided the numerator and denominator of Eq(2) by $B_{21}N_2$

We know

$$\frac{N_1}{N_2} = e^{\frac{hv}{kT}} \quad (\text{i.e., the Boltzmann equation})$$

$$E(v) = \frac{\frac{A_{21}}{B_{21}}}{\left(\frac{B_{12}}{B_{21}} e^{\frac{hv}{kT}} - 1 \right)} \quad \text{--- (4)}$$

Planck's Energy density expression

$$E(v) = \frac{\frac{8\pi h v^3}{c^3}}{\left(e^{\frac{hv}{kT}} - 1 \right)} \quad \text{--- (3)}$$

Comparing (3) and (4) we get

$$\frac{A_{21}}{B_{21}} = \frac{8\pi h\nu^3}{c^3} \text{ and } \frac{B_{12}}{B_{21}} = 1 \text{ or } B_{12} = B_{21} = B$$

So there are only two constants A (= A_{21}) and B called Einstein's coefficients

Planck's Energy density expression

$$E(\nu) = \frac{A/B}{\left(e^{h\nu/kT} - 1\right)} \quad \text{--- --- --- --- --- (5)}$$

$$\frac{A}{B} = \frac{8\pi h\nu^3}{c^3}$$

Check Your Understanding (True/False)

- 1. The rate of spontaneous emission is the inverse of the life time of the excited state***

- 2. The absorption rate is equal to the sum of the emission rates***

- 3. In equilibrium, the rate of absorption is equal to the rate of stimulated emission***

- 4. The coefficient of absorption is equal to the coefficient of stimulated emission***



THANK YOU

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