(1) $\frac{N_2}{N_1} = \frac{e^{-E_2/kT}}{e^{-E_1/kT}} = e^{-(E_2-E_1)/kT}$

∵ $\lambda = 550$ nm & $E_2 - E_1 = \frac{hc}{\lambda}$

$\Rightarrow E_2 - E_1 = \frac{6.626\times10^{-34}\times3\times10^{8}}{550\times10^{-9}}$

$\Rightarrow E_2 - E_1 = 3.16\times10^{-19}$ J

∴ $\frac{N_2}{N_1} = \exp\left(\frac{-3.16\times10^{-19}}{1.38\times10^{-23}\times300}\right)$

$\Rightarrow \frac{N_2}{N_1} = 1.1577\times10^{-38}$

(2) $\frac{A_{21}}{B_{21}} = \frac{8\pi h\nu^3}{c^3}$

$A_{21} = \frac{1}{\tau_{sp}} = \frac{1}{10^{-6}} = 10^{6}$

$\nu = \frac{c}{\lambda} = \frac{3\times10^{8}}{600\times10^{-9}} = 5\times10^{14}$ Hz

$\Rightarrow B_{21} = \frac{A_{21}c^3}{8\pi h\nu^3} = \frac{10^{6}\times(3\times10^{8})^3}{8\times3.14\times6.626\times10^{-34}\times(5\times10^{14})^3}$

$\Rightarrow B_{21} = 1.3\times10^{19}$ m/kg

(3) No. of spontaneous to stimulated emissions, $R = (e^{h\nu/kT} - 1)$

$\frac{h\nu}{kT} = \frac{6.626\times10^{-34}}{1.38\times10^{-23}\times1000}\times\left(\frac{3\times10^{8}}{500\times10^{-9}}\right)$

$\frac{h\nu}{kT} = 28.8$

$\Rightarrow R = (e^{28.8} - 1) \approx e^{28.8} = 5\times10^{12}$

(4) $A_{21} = \frac{1}{\tau_{sp}} = \frac{1}{1.6\times10^{-9}} = 6.25\times10^{8}\ s^{-1}$

$B_{21} = \frac{A_{21}c^3}{8\pi h\nu^3} = \frac{A_{21}\lambda^3}{8\pi h}$ (∵ $\frac{c}{\nu} = \lambda$)

$\Rightarrow B_{21} = \frac{6.25\times10^{8}\times(121.5\times10^{-9})^3}{8\times3.14\times6.626\times10^{-34}}$ [redacted] $= 1.73\times10^{19}$ m/kg

Q5. $l_c = \frac{\lambda^2}{\Delta\lambda} \Rightarrow \Delta\lambda = 0.0183$ Å

(6) $\Delta\nu = 10^{9}$ Hz, $\frac{\Delta\nu}{\nu} \approx \frac{\Delta\lambda}{\lambda} \approx 2\times10^{-6}$

(7) $\theta = 32' \approx 0.009$ radian,

spatial coherence l_s or l_t

$\lambda = 500$ nm $\quad = \frac{\lambda}{\theta} = 0.00555$ cm

$\approx 55.5\ \mu m$

(8) $\Delta\lambda = \lambda_2 - \lambda_1 = 300$ nm

$\lambda = \frac{\lambda_1 + \lambda_2}{2} = 550$ nm

$l_c = \frac{\lambda^2}{\Delta\lambda} = \frac{(550\ nm)^2}{300\ nm} = 10^{-6}$ m ≈ 1008 nm

(9) $\lambda = 720$ nm, $d = 5\times10^{-3}$ m

$r = 4\times10^{8}$ m

(i) Angular spread $\Rightarrow d\theta$

for circular aperture

~~$d\theta = \frac{\lambda}{d} = 1.44\times10^{-4}$ radian.~~

If $d\theta = 1.22\times\frac{\lambda}{d} = 1.7568\times10^{-4}$ rad

(ii) Axial (or Aerial spread)

$= \pi(r\,d\theta)^2$

$= 3.1416\times[4\times10^{8}\times1.7568\times10^{-4}]^2$

$= 155.13\times10^{8}$

$= 1.5513\times10^{10}\ m^2$

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