Tutorial - 7

1) i) Normally the excited state is an unstable state where the life time of an atom is very short around 10^{-8} sec. Hence the atom is in excited state, E_2 returns to the ground state spontaneously by releasing one photon of energy $h\nu$. This process is called spontaneous emission

ii) In this process an incident photon is absorbed by an excited atom as a result of which atom becomes unstable in state E_2 and makes a transition to ground state releasing two photons. This process is called stimulated emission

iii) Meta stable state is an excited state of an atom or other system with a longer lifetime than other excited states. However, it has shorter lifetime than other excited states.

iv) Population inversion is the redistribution of atomic energy level that takes place in a system so that laser action can occur.

v) Optical pumping is a process in which light is used to raise electrons from a lower energy level in an atom or molecule to a higher one.

2) a) Energy of each photon, $E = nh\nu$, $n = \frac{E}{h\nu} = \frac{E\lambda}{hc}$

$$\Rightarrow n = \frac{1 \times 694 \times 10^{-9} m}{6.62 \times 10^{-34} \times 3 \times 10^{8}} = 3.5 \times 10^{18} \text{ ions}$$

b) Energy of the laser = Total no. of ions $(n) \times$ energy of each photon

$$E = nh\nu = \frac{nhc}{\lambda}$$

$$E = \frac{2.8 \times 10^{19} \times 6.62 \times 10^{-34} \times 3 \times 10^{8}}{7 \times 10^{-7}} = 7.94 \, J$$

3) Ratio of the population $\frac{N_2}{N_1} = e^{-(E_2 - E_1)/kT}$

$$E_2 - E_1 = \frac{hc}{\lambda} = 1.96 eV$$

$$\text{so, } \frac{N_2}{N_1} = \exp\left[\frac{-1.96 eV}{8.61 \times 10^{-5} \times 300}\right] = e^{-75.88} = 1.1 \times 10^{-33}$$

4) Ratio of spontaneous to stimulated emission is given as

$$R = [e^{h\nu/kT} - 1] = [e^{hc/\lambda kT} - 1]$$

$$\lambda = 10^{-5} m, \; T = 50K$$

Then $R = e^{28.78} - 1 = 3.16 \times 10^{12}$

5) Efficiency of laser = 1% = 0.01, efficiency = $\frac{P_{out}}{P_{in}}$

So, $P_{in} = \frac{P_{out}}{\text{Efficiency}}$ = 1 watt = 1 J/sec

∴ No. of atoms excited in one second = $\frac{1\,J}{20\,eV}$

$= \frac{1\,J}{20 \times 1.6 \times 10^{-19}\,J} = 3.12 \times 10^{17}$

6) i) $\lambda = 5890\,Å$, so $\nu = \frac{c}{\lambda} = \frac{3 \times 10^{8}}{5890}$

$[\nu = 5.09 \times 10^{14}\,Hz]$

ii) no. of oscillations $n = \frac{l_c}{\lambda} = \frac{2.945 \times 10^{-2}}{589 \times 10^{-7}}$

$[n = .5 \times 10^{4}]$

iii) Coherence time $\tau_c = l_c/c = \frac{2.945 \times 10^{-2}}{3 \times 10^{8}}$

$[\tau_c = 9.82 \times 10^{-11}\,sec]$

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

$E_2 - E_1 = \frac{hc}{\lambda} = 1.77\,eV$

at $27°C = 27 + 273 = 300\,K$.

$\left(\frac{N_2}{N_1}\right)_{300\,k} = e^{-68.5}$

Scanned with CamScanner

at $227^\circ C = 227 + 273 = 500\,K$, $\left(\frac{N_2}{N_1}\right)_{500K} = e^{-47.1}$

Now Ratio $\dfrac{(N_2/N_1)_{300K}}{(N_2/N_1)_{500K}} = 1.25 \times 10^{-12}$