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Batch: F2

PHYSICS-II

Tutorial-7

1. (i) Spontaneous Emission

It is the process in which a quantum mechanical system such as atom transits from an excited energy state to a lower energy state and exits a quantised amount of energy in the form of photon.

(ii) Stimulated Emission

It is the process by which an incoming photon of a specific frequency, can interact with an excited atomic electron, causing it to drop to a lower energy level.

(iii) Population Inversion

The redistribution of atomic energy levels that take place in a system so that laser action can occur.

(iv) Metastable state

It is an excited state of an atom or other system with a longer lifetime than the other excited states. However it has a shorter lifetime than the stable ground state.

(v) Optical Pumping

It 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. commonly used in Laser construction.

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

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

b) Energy of laser pulse = Total no. of ions(n) x Energy of each photon

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

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

3.

Ratio of population $= \frac{N_2}{N_1} = e^{-(E_2-E_1)/kT}$, $E_2 - E_1 = \frac{hc}{\lambda} = 1.96\ eV$

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

$$= \boxed{1.1 \times 10^{-33}}$$

4. Ratio of spontaneous to stimulated emission is given as $\rightarrow R = [e^{h\nu/kT} - 1] = [e^{\frac{hc}{\lambda kT}} - 1]$

At $T = 50k$, $\lambda = 10^{-5} m$

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

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

so $P_{in} = \frac{P_{out}}{\text{Efficiency}} = 1\ W = 1\ J/sec$

No. of atoms excited in one second $= 1J/20eV$

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

6. (i) $\lambda = 5890 Å$ so $\nu = \frac{c}{\lambda} = \boxed{5.09 \times 10^{14} Hz}$

(ii) No. of oscillations $= n = \frac{l_c}{\lambda} = \frac{2.945 \times 10^{-2}}{5.89 \times 10^{-7}} = \boxed{5 \times 10^4}$

(iii) Coherence Time $\tau = \frac{l_c}{c} = \frac{2.945 \times 10^{-2}}{3 \times 10^8} = \boxed{9.82 \times 10^{-11} \text{ sec. Am}}$

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

$T = 27 + 273 = 300K$

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

At 227°C → $T = 227 + 273 = 500K$

$$\left(\frac{N_2}{N_1}\right)_{500K} = e^{-41.1}$$

Now, $$\frac{(N_2/N_1)_{300K}}{(N_2/N_1)_{500K}} = \frac{e^{-68.5}}{e^{-41.1}}$$

$$= \boxed{1.25 \times 10^{-12}}$$