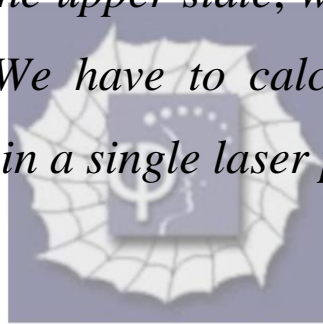


782.

Problem 52.31 (RHK)

An atom has two energy levels with a transition wavelength of 582 nm. At 300 K, 4.0×10^{20} atoms are in the lower state. (a) We have to find the number of atoms that occupy the upper state, under conditions of thermal equilibrium. (b) Suppose, instead, that 7.0×10^{20} atoms are pumped into the upper state, with 4.0×10^{20} atoms in the lower state. We have to calculate the energy that could be released in a single laser pulse.



Solution:

(a)

As the transition wavelength corresponding to the two levels is 582 nm, their energy difference is

$$\begin{aligned} E_2 - E_1 &= \frac{hc}{\lambda} = \frac{6.63 \times 10^{-34} \times 3 \times 10^8}{582 \times 10^{-9}} \text{ J} \\ &= 3.42 \times 10^{-19} \text{ J} . \end{aligned}$$

It is given that at 300 K, 4.0×10^{20} atoms are in the lower state. From the Boltzmann distribution, we note that at equilibrium the number of atoms in the upper state when

4.0×10^{20} atoms are in the lower state will be given by the relation

$$\frac{n(E_2)}{n(E_1)} = \exp\left(-\frac{(E_2 - E_1)}{kT}\right),$$

$$\begin{aligned}\therefore n(E_2) &= 4.0 \times 10^{20} \times \exp\left(-\frac{3.42 \times 10^{-19}}{1.38 \times 10^{-23} \times 300}\right) \\ &= 4.0 \times 10^{20} \times \exp(-82.6) = 4.0 \times 10^{20} \times 1.32 \times 10^{-36} \\ &= 5.3 \times 10^{-16}.\end{aligned}$$

This is an incredibly small number. For all purposes there are no atoms in the upper state.

(b)

We consider the situation when 7.0×10^{20} atoms are pumped in the upper state. Because of the laser action the energy that could be released in a single laser pulse will be

$$\begin{aligned}(E_2 - E_1) \times 7.0 \times 10^{20} &= 3.42 \times 10^{-19} \times 7.0 \times 10^{20} \text{ J} \\ &= 2.4 \times 10^2 \text{ J}.\end{aligned}$$