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

$$E_2 - E_1 = \frac{hc}{\lambda} = \frac{6.63\times10^{-34}\times3\times10^{8}}{582\times10^{-9}}\ \text{J}$$

$$= 3.42\times10^{-19}\ \text{J}.$$

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

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

$$\therefore\ n(E_2)=4.0\times10^{20}\times\exp\left(-3.42\times10^{-19}/1.38\times10^{-23}\times300\right)$$

$$=4.0\times10^{20}\times\exp(-82.6)=4.0\times10^{20}\times1.32\times10^{-36}$$

$$=5.3\times10^{-16}.$$

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

$$(E_2-E_1)\times7.0\times10^{20}=3.42\times10^{-19}\times7.0\times10^{20}\ \text{J}$$

$$=2.4\times10^{2}\ \text{J}.$$