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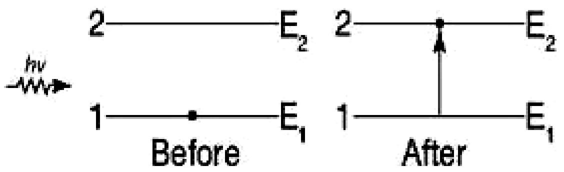
Absorption of Radiation



At low temperatures, most of the atom stay in lower energy states. If an atom is initially in the lower energy state E_1 it can be raised to the higher energy state E_2 by the absorption of a photon of energy hv, as
This is know as absorption of radiation and is represented by

$$E_2 = E_1 + hv$$

$$\Rightarrow E_2 - E_1 = \Delta E = hv \qquad \text{(i)}$$

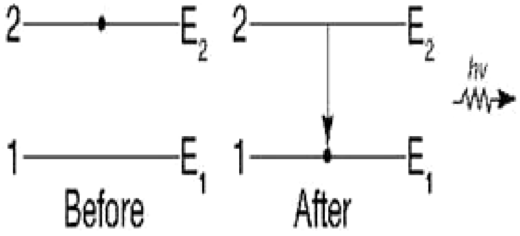
The probability of occurrence of this absorption from state 1 to state 2 is proportional to the energy density $u(\nu)$ of the radiation

$$P_{12} = B_{12}\, u(\nu) \qquad \text{(ii)}$$

Where the proportionality constant B_{12} is known as the *Einstein's coefficient of absorption of radiation.*

Take an example of electron transition associated with visible and ultraviolet interactions with matter. Here the absorption of a photon occurs only when the quantum energy of the photon precisely matches the energy gap between the initial and final states. In such interaction of radiation with matter, if there is no pair of energy state such that the photon energy can elevate the system from the lower to upper state, then the matter will be transparent to that radiation.

Spontaneous Emission



If an atom is initially in the upper state E_2, it can come down to lower state E_1 by emitting a photon of energy $h\nu$

This is known as *spontaneous emission*. This is the natural radiation decay process that is inherent in all excited states of all materials. However, such emission is not always the dominant decay process.

The probability of occurrence of this spontaneous emission transition from state 2 to state 1 depends only on the properties of states 2 and 1 and is given by

$$P'_{12} = A_{21} \quad \text{(iii)}$$

Where A_{21} is known as the *Einstein's coefficient of spontaneous emission of radiation.*

Stimulated (induced) Emission

Einstein was the first to a point out a third possibility of induced emission, in which an incident photon of energy

$h\nu$ causes a transition from upper state E_2 to the lower state E_1, as shown in Fig. 4.3. This occurs when

$$h\nu = \Delta E = E_2 - E_1$$

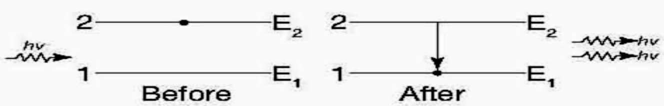


Figure 4.3

In a system of atoms in thermal equilibrium, the number of atoms in the ground state is generally much greater than in a higher energy state. This is known as *normal population* of atoms among the available energy states. A state in which the number of atoms in higher energy state is greater than that of lower energy state is known *population inversion*.

Therefore, the incoming photon stimulates the transition to the lower state and produces a second photon of the same energy, when a sizable population of electrons resides in upper level (Fig. 4.4). In this condition is called a population inversion. This population inversion sets the stage for stimulated emission of multiple photons. This is the precondition for the light amplification in a laser. Since the emitted photons have a definite time and phase relation to each other, the light has a high degree of coherence. If these emitted photons are passed through an assembly of atoms, which fulfil the condition of population inversion, these are amplified. This amplification is very much clear from Fig. 4.4, which shows multiplication of photons emitted during the process of stimulated emission.

(energy of each photon is $h\nu$)

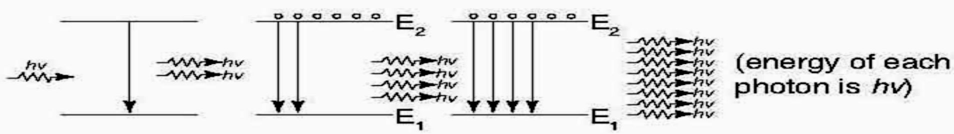


Figure 4.4

The probability of occurrence of stimulated emission transition from the upper level 2 to the lower level 1 is proportional to the energy density $u(\nu)$ of the radiation and is expressed as

$$P''_{21} = B_{21}\, u(\nu) \qquad \text{(iv)}$$

Where B_{21} is the *Einstein's coefficient of stimulated emission of radiation.*

Thus, the total probability of emission transition from the upper level 2 to the lower level 1 is given by

$$P_{21} = P'_{21} + P''_{21}$$

$$\text{or } P_{21} = A_{21} + B_{21}\, u(\nu) \qquad \text{(v)}$$