X-rays:

The radiation which consists of distinct spectral lines whose frequencies are characteristic of the material of the target is known as X-ray spectrum.

Most elements in their X-ray spectra consists of two lines, known as K-series and L-series. Each series consists of a number of lines designated as K_α, K_β .... and L_α, L_β, ...
The wavelengths of K-series is about 1 Å, whereas those of L series is about ten-times higher.

Properties of X-rays:

(1) X-rays are a part of electromagnetic waves and hence they have no charge and mass.

(2) They travel in a straight line unless deflected or scattered.

(3) They have no charge, hence they are unaffected by electric and magnetic field.

(4) X-rays have very short wavelength ranging from 0.01 nm to 10 nm.

(5) They have high penetrating power.

(6) They have high ionising power.

(7) They can produce fluorescence in materials like ZnS.

Applications of X-rays:

(a) Industrial applications:

(i) X-rays are used in security scanners at airports to detect weapons, explosives and illegal items.

(2) They are used to inspect internal defects in manufacturing.

(3) They are used in crystal structure analysis.

(4) They are also used in food inspection to detect contaminants like metal, glass and bone fragments.

(5) They are also used in material analysis to determine the composition of metals, ceramics and other materials.

(3) Medical applications:

(1) X-rays are used in medical imaging to scan and diagnose fractures, lung infections, dental issues and bone diseases.

(2) They are used in dental imaging to detect cavities, root infections and jawbone abnormalities

(3) They are also used in cancer treatment.

LASER:

LASER stands for Light Amplification by Stimulated Emission of Radiation

Properties:

- Laser is monochromatic in nature.
- The emitted light waves in laser are in phase with each other.
- They have very high intensity.
- The Laser light is polarised.

Applications of laser:

(a) Medical applications:

- Laser is used in LASIK Eye Surgery to cure eye diseases like myopia and hypermetropia.

(2) Laser is used to remove tumours and abnormal tissues and hence are used in cancer treatment.

(3) Laser is also used in dentistry mainly in gum surgery and teeth whitening.

(b) Industrial application:

(1) Lasers are used in metalworking, electronics and automobile industries.

(2) They are used in 3-D printing.

(3) They are also known as barcode scanners.

(c) Communication and technology:

(1) Laser enables high-speed internet and telecommunication.

(2) Lasers are used in high-quality printing.

(d) Lasers are used in military and security.

(e) Lasers are also used in scientific research and space.

Interaction of radiation with matter:

An atomic system is characterised by discrete energy states and usually the atoms occupy the lowest state, known as the ground state. An atom in a lower energy state may be excited to a higher energy state by a number of different processes. The processes are as follows:

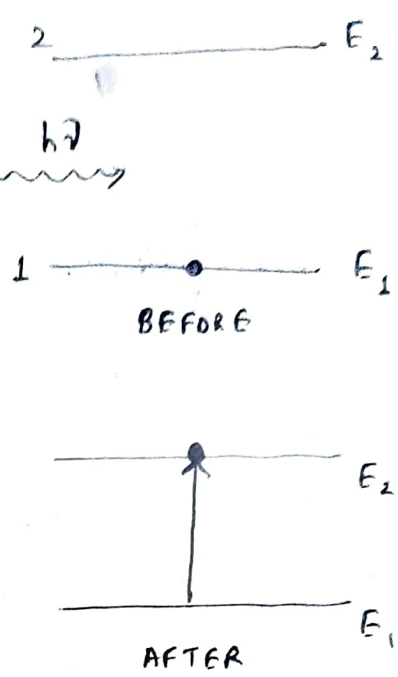
(a) Absorption of Radiation (stimulated): An atom, initially in a lower state 1 rises to a higher state 2 by absorbing a

quantum of radiation (photon) of frequency ν given by:

$$\nu = \frac{E_2 - E_1}{h}$$

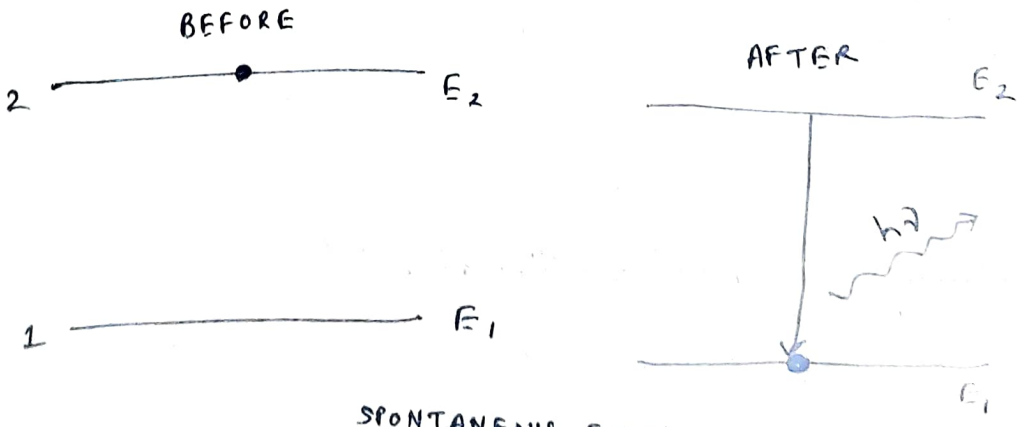
where E_1 and E_2 are the energies of the atom in the states 1 & 2.

This is stimulated (or induced) absorption of radiation, the absorbed photon being the stimulating photon.



(b) Spontaneous Emission of Radiation:

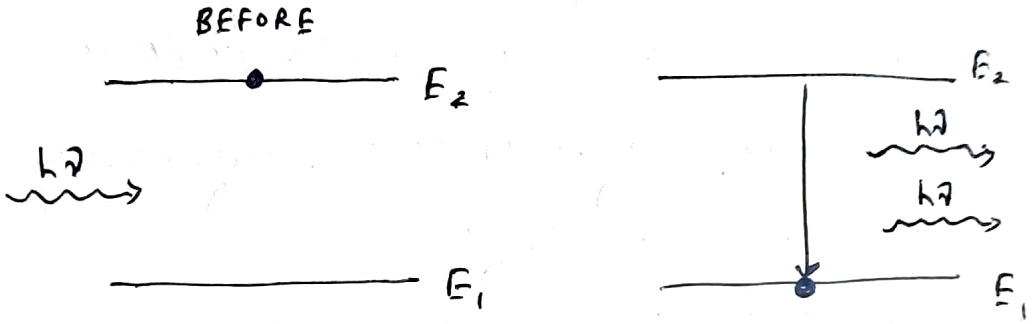
Let us now consider an atom initially in the higher (excited) energy state 2. Observations show that its life-time in higher state is usually very small ($\sim 10^{-8}$ second) and of its own accord decays to the lower energy state 1, emitting a photon of frequency $\nu = \frac{(E_2 - E_1)}{h}$. This is spontaneous emission of radiation. If there is an assembly of atoms, then the radiation emitted spontaneously by each atom has a random direction and a random phase.



SPONTANEOUS EMISSION.

(c) Stimulated emission of radiation:

According to Einstein, an atom in an excited energy state, under the influence of the electromagnetic field of a photon of frequency ν incident upon it decays to a lower energy state, emitting an additional photon of same frequency. Thus two photons of same frequency; one incident and the other emitted more on. This is a stimulated or induced emission.



STIMULATED EMISSION

Principle of laser:

The principle of a laser is based on stimulated emission of radiation. They are as follows:

(a) Energy Absorption (Excitation): Atoms or molecules in a material absorb external energy which excites the electron from a lower energy level to higher energy level.

(b) Spontaneous emission: After a short-time, the excited electrons return to a lower energy level releasing energy in the form of photon. This emission is random in direction and phase.

(c) Stimulated emission: If an external photon of the same energy interacts with an excited atom, it triggers the release of another identical photon. This newly emitted photon has the same energy, phase and direction as the original leading to amplification of light.

(d) Population inversion: For laser action to occur, more atoms must be in the excited state than in the ground state. This is known as population inversion which is a necessary condition for LASER operation. It is achieved mainly through an external energy source and the mechanism is called pumping.

(e) Optical resonance and amplification: The laser setup includes two mirrors: one fully reflective and the other partially. The light bounces between these mirrors, amplifying through repeated stimulated emissions. A portion of the amplified light exits through the partially reflective mirror, forming the LASER beam.

★ **Metastable state:**

The metastable state in a LASER is an excited energy level where electrons remain for a relatively longer time before returning to the lower state. This extended lifetime is crucial for achieving population inversion, which is a necessary condition for laser operation. So the role of metastable state is:

(i) Delays electron transition. (iii) Enhances laser efficiency.

(ii) Enables population inversion.

★ Components of a laser:

A laser consists of three main components:

(1) Active medium (Gain medium): It is the material responsible for Laser light generation. It undergoes excitation and facilitates stimulated emission.

(2) Energy source: The energy source involves the pumping mechanism. It provides energy to excite atoms in the active medium.

(3) Optical resonator (Write description from principle point (2))

★ Different types of laser:

Based on the active medium, lasers are of four types:

(a) Solid-state laser Ex: Ruby Laser,

(b) Gas laser Ex: Helium neon laser, CO_2 laser

(c) Liquid laser Ex: dye laser

(d) Semi-conductor laser Ex: GaAs laser (Gallium-Arsenide laser)

Based on the mode of operation, lasers are of two types:

(a) Continuous wave lasers Ex: He-Ne laser, CO_2 laser.

(b) Pulsed laser Ex: Nd:YAG laser.

Based on the wavelength, lasers are of three types:

(a) Infra-red laser: Ex: CO_2 laser.

(b) Visible laser: Ex: He-Ne laser.

(c) Ultra-violet laser: Ex: Excimer laser.