ATOMIC PHYSICS:

Atomic physics is the study of atoms, focusing on electron arrangements, interactions, and energy states, primarily using quantum mechanics.

EXCITATION ENERGY:

"The energy needed to move out atom from its ground state to an excited state is called excitation energy. It is generally expressed in eV."

There are many ways by which the electron can be excited to different states:

- By thermal collision.
- By accelerating an electron, that hits gas molecules in an electric discharge tube.
- By illuminating atom of a gas so, that energy from a photon may be observed.

EXCITATION POTENTIAL:

"If an electron of charge 'e' is accelerated by applying a potential difference of 'V' volts to achieve the excitation energy, then the applied voltage V is known as excitation potential."

IONIZATION ENERGY:

"The minimum energy required to ionize an atom, which is in its ground state is called ionization energy of the atom. It is generally expressed in eV."

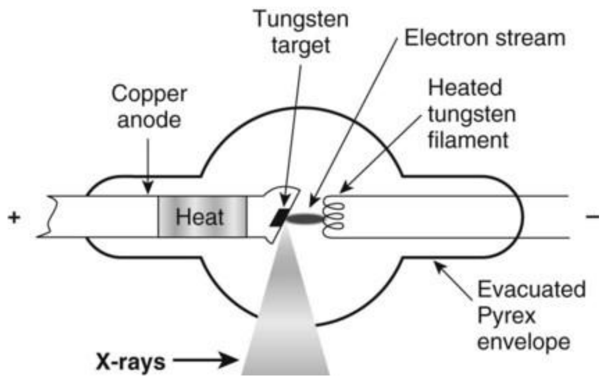
IONIZATION POTENTIAL:

"It is the accelerating potential which removes an electron completely from an atom."

X – RAYS:

Introduction:

When high-energy electrons strike a metal surface, high frequency radiations of extremely high penetrating power are emitted, which are called "X – rays". They are also called "Rontgen rays" as discovered by W.K. Rontgen in 1985).



Wave length range:

The wavelength range is 0.001nm – 1nm corresponding to frequency $10^{16} – 10^{19}$ Hz, which correspond to quantum energies 1 – 100 KeV.

Production of X – rays:

X – rays are generated by:

- Rapid deceleration of fast moving electrons by a metal target-using x – ray tube.
- Change in energy of innermost electrons.

X – RAY TUBE:

Introduction:

The construction of a modern x – ray tube designed by Dr. W Coolidge in 1913.

Construction:

- A cathode C, heated by an adjacent filament, F, through which electric current is passed by a battery B. The cathode surface is made concave so that electrons are concentrated at a single point.
- An anode, made up of copper. It contains a target T of the tungsten or molybdenum. Most of K.E of accelerated electrons goes into the production of heat. The heat is conducted away from the target by

a copper rod in which target material is embedded. The rod is cooled by cooling fins to dissipate the thermal energy. The face of target is inclined at an angle of 45^0.

- A high tension (HT) battery (~ 50 kV) is used. It maintains p.d. between cathode and target and accelerates electrons. Generally, a transformer from a.c. supply with rectifier is used.
- A lead shield with a window is used for protection.

Working:

The cathode, heated by filament supplies electrons copiously by thermionic emission. They are accelerated towards the target – T due to high p.d. When these highly energetic particles are focused on a metallic target, they are accelerated by the atoms and some of the k.e. is converted into electromagnetic energy, known as X – rays.

The intensity of X – rays depends on the filament current. The quality and energy of X – rays depend upon the operating voltage.

Properties of X – rays:

- The electromagnetic radiations have wave length 0.1 to 100 A^0.
- X – rays are not deflected by electric or magnetic fields.
- They possess high penetration power.
- They ionize gases weakly.
- They effect photographic plate.
- They produce fluorescence in ZnS and Ba – platinocyanide.
- They travel in straight line with the speed of light.
- When X – rays falls on metal surface, electrons are ejected. This phenomenon is called photoelectric effect.
- They can be diffracted by a crystal lattice.
- They destroy the living cells and tissues.

Detection:

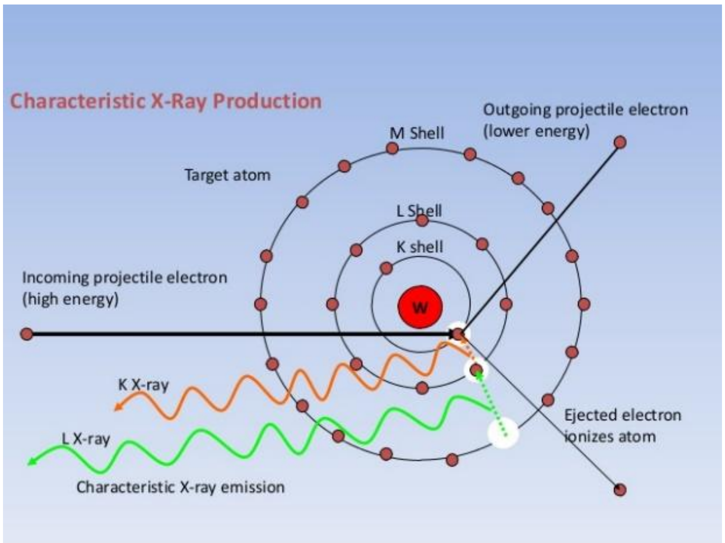
X – rays are detected by:

- Photographic plates or films.
- Ionization chamber.
- Counting tubes.
- Semi – conductor detectors.
- Fluorescence.

Uses of X – rays:

- Survey and diagnostics of human bodies for checking the fractures in bones, location of swallowed foreign bodies, diseases areas of internal organs, condition of teeth and jaws etc.
- It is used for computerized tomography (CT) scan.
- It is used for radiotherapy to destroy cancer cells.
- X – rays are used in non – destructive testing of structure of metals.
- It helps to established authenticity of paintings.
- X – Rays are used at customs and security posts to detect arms, explosives, precious metals and other contraband goods.
- X – Rays satellites has brought us a new view of our universe.
- The diffraction of X – rays is used to investigate the crystal structure and structures of such complex substances as insulin and DNA.

INNER SHELL TRANSITIONS AND CHARACTERISTICS X-RAYS



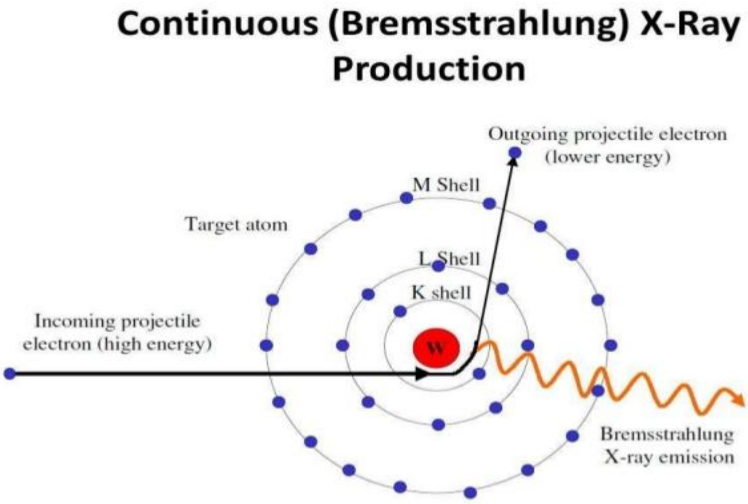
The X Rays are emitted when high energy electrons are bombarded on the metal target. The spectrum of X-Rays consists of a broad continuous band and a series of intense sharp lines which depends on the nature of the target material. These discrete lines are called characteristics X Rays, which are discovered in 1908. We know that electrons are revolving around the nucleus in the circular orbits or shells. These shells are represented by K, L, M, N, O etc. In each shell, there are specific number of electrons. For example, there are two electrons in K-shell, 8 electrons in L-shell and so on. The characteristics X Rays are produced, when a high-energy electron is bombarded on another electron in an inner shell of target atom and knockout it from the atom. Let the electron in K-shell is knockout from the atom due to bombarding electron.
In this way, a vacancy is created in K-shell. Then an electron of L, M or N-shell will jump down quickly to fill the vacancy in K-shell. In doing so the jumping electron emits its excess energy in the form of photons, which is known as characteristics X Rays.

- The photon emitted due to transition of electron from L-shell to K-shell is called $K_\alpha\ Characteristics\ X - Rays$
- The photon emitted due to transition of electron from M-shell to K-shell is called $K_ß\ Characteristics\ X - Rays$
- The photon emitted due to transition of electron from N-shell to K-shell is called $K_\gamma\ Characteristics\ X - Rays$

THE CONTINUOUS X – RAY SPECTRUM:

It is produced due to the deceleration of high velocity electrons when they are deflected, while passing near the positively charged nucleus, in the target material molybdenum.

Principle:
The momentum of high speed electrons is transferred to the nucleus, and the electron lose K.e. The energy lost by the electron appears as the energy hv of an X – ray photon. This process is called bremsstrahlung (German "Braking radiation"). This is an inverse photo – electric effect.



$$Atom + (Fast\ electron) \longrightarrow Atom + (Slow\ electron) + hv$$

LASER:

Introduction:

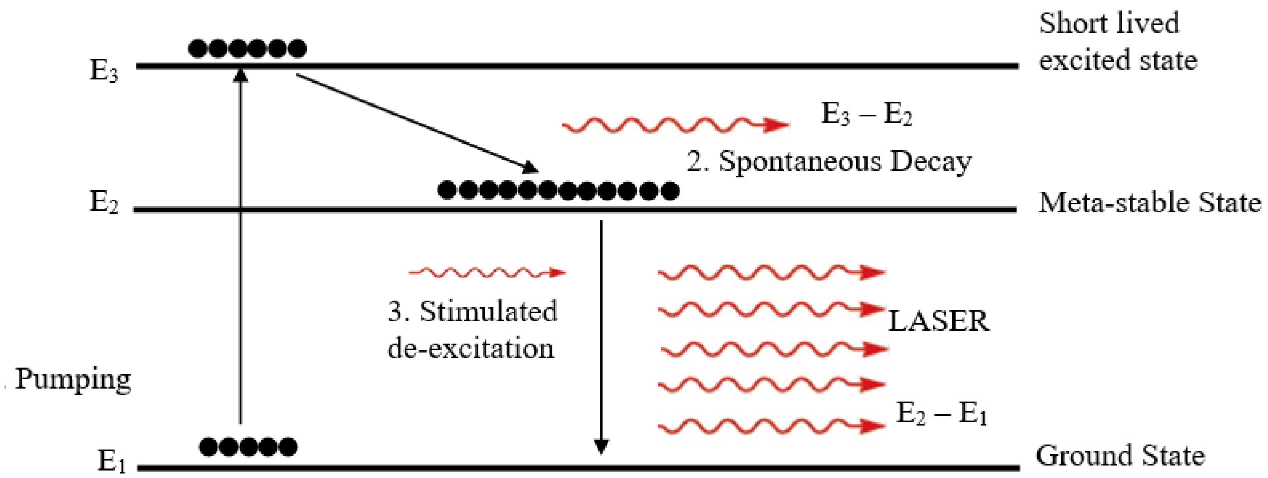
The word laser is an acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation. The laser was first presented by Einstein in 1917.

Definition:

"The laser is a device for producing a very narrow intense beam of monochromatic coherent light"

Principle:

The interaction between matter and radiation involve three process: absorption, spontaneous emission and stimulated emission. When a photon of energy hv is incident on an excited electron in a metastable state, the system is driven to its ground state with the emission of a second photon of the same energy, phase, direction and state of polarization. These two photons can cause another stimulated event, giving a total four of photons which can cause additional stimulated emission and so on. This chain reaction of similar process produce amplification. This produces laser.



Laser operation:

A laser beam can be obtained if all the atoms could be persuaded to emit their waves together in phase. The laser action involves:

1. Metastable state.
2. Population inversion.
3. Stimulated emission.
4. Amplification.

1. Metastable state:

Normally an atom remains in an excited state only for a life time of the order of 10^{-8} sec. However, certain excited states persist for a longer period of time, up to 10^{-13} sec or even more. Such states are known as metastable state. In this state the transitions take place by stimulated emission and not by spontaneous emission. But this requires population inversion.

2. Population inversion:

Consider a lasing material that comprises a three – level system. For example, chromium ions account for the lasing ability of ruby crystal.

The rate of excitation of the atom is proportional to:

i) The number of atoms available for excitation in the lower energy state.

ii) The energy density of the incident radiation.

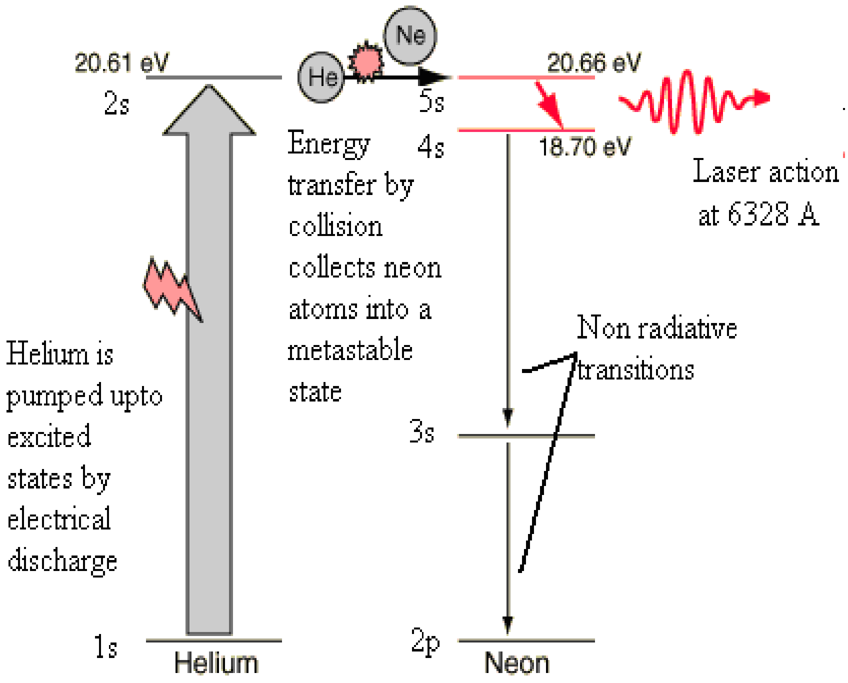
Let atom from the ground state E_1 be pumped up to an excited state. E_3 by absorption of light energy from an intense, continuous source that surrounds a lasing material. Atoms in the state E_3 decay spontaneously to state E_2, which is metastable. Thus atom reach E_2 much faster than they leave E_2. This results in an increased number of atoms in the state E_2 (N_2) as compared to the number in E_1 (N_1). Hence $N_2 > N_1$. Thus population inversion is achieved. In the situation of inverted energy distribution, there will be emission of power instead of absorption. This is the basis of laser operation.

3. **Stimulated emission:**
   Let an electron already in an excited state (E_2) and a photon of energy hν on it. This incident photon incident increases the probability that the electron will return to the ground state (E_1) by emitting a second photon having the same energy, phase, direction and state of polarization. This process is stimulated emission or induced emission. If population inversion has already been achieved, then there will be more emission than absorption of photon.

4. **Amplification:**
   The process of stimulated emission is enhanced by using mirrors at the end of the assembly of lasing material. The emitted photons move back and forth and thus suffer multiple reflections. They continue stimulating other atoms to emit photons. As the process continuous the number of photons are multiplied. This chain reaction of similar process is called amplification.

HELIUM-NEON LASER

It is the most common type gas laser, used in Physics Laboratories. Its discharge tube is filled with 85% helium and 15% neon gas. Here neon is the lasing or active medium in the tube. Helium and neon have nearly identical metastable states 20.61eV and 20.66eV, respectively. The high voltage electric discharge excites the electrons in some of the helium atoms to 20.61eV state. These excited helium atoms collide with neon atom each one transferring its own 20.61eV energy to the electron in neon atom along with 0.05eV of kinetic energy from the moving atom. As the result the electrons in neon atoms are raised to 20.66eV state. In this way the population inversion is sustained in neon gas, relative to energy level of 18.70eV state, by direct collision with the same energy electrons of atom as shown in Fig.



The spontaneous emission from neon atoms initiates Laser action, while stimulated emission causes the electrons in neon to drop from 20.66eV to 18.70eV level and red Laser light of wavelength 632.8nm corresponding to 1.96eV energy is generated.

APPLICATIONS OF LASER:

- **Medicine and surgery:**
  Laser is used in removing tumors and breaking stones in kidney and gall bladders. It is used as micro – surgical tool in welding detached retina and unclogging of diseased artery.
- **Industry:**
  It is used for precision cutting, welding and drilling of tiny holes in various materials. It is used to vaporize certain substances that comes in its way. Hence it is used in machining and drilling.

- **Holography:**
  It is used in the productions of Holograms. A laser show is one of the most spectacular event to be watched.

- **Computer:**
  It is used in printing and photographic recording of output date of a computer.

- **Audio – visual display:**
  It is used in compact – disk audio and video system to for reproducing a superb quality sound and picture. It is employed for obtaining images of moving objects.

- **Communication:**
  It is used in telephone communication along optical fibre to transmit both sound and picture at the speed of light. It can be used in TV communication for having more number of channels (Up to millions).

- **Space:**
  Laser can be used as range finder over very long distances. Laser gyroscopes are being used in modern aircrafts for navigation.

- **Environment:**
  It can be used as detector of pollutants in atmosphere.

- **Mensuration:**
  It is used for measuring speed of light to define standard meter. The precise measurement of a meter bar by interferometry has been made with an accuracy of 1 part in 10 million.

- **Research:**
  Laser is used in precise measurement of velocity of a fluid using Doppler’s effect. it offers a means of exploring molecular structure. Efforts are being made to achieve controlled nuclear fusion and develop fusion power reactors using lasers.