X-Ray production

by

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- X – rays:- electromagnetic radiation (EMR) of very short wave length & very high penetrating power. It is very useful in diagnosis & radio therapy
- The amount of energy carried by each photon depends on the frequency of radiation:

$E = h \upsilon = h c / \lambda$

Where

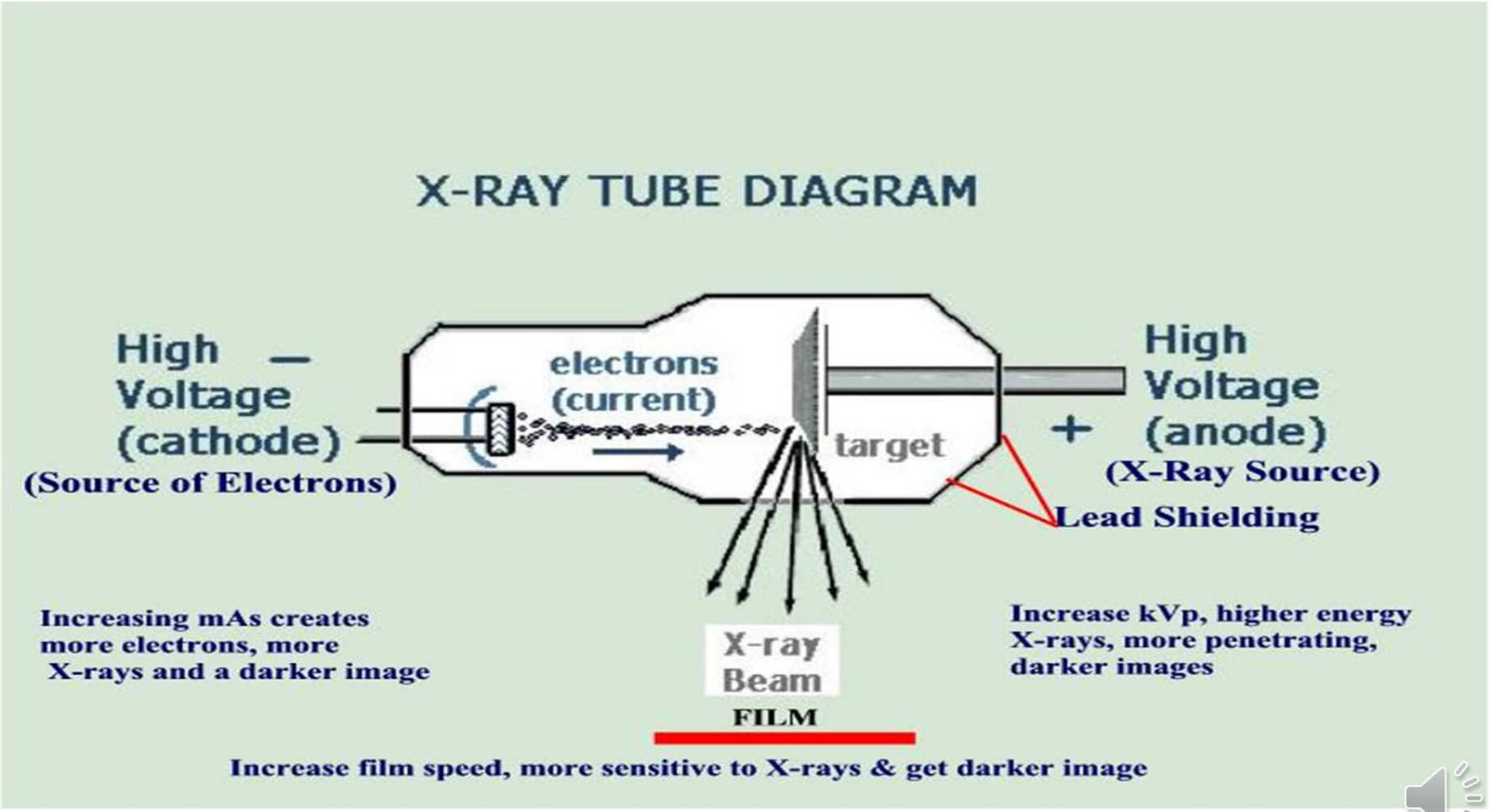
- h = Plank's constant = 6.6×10^{-34} (joule. sec)
- c = velocity of light = 3×10^{8} m/sec
- υ = frequency of radiation

X – rays production :

To produce photons of X – rays we need :

1. A filament (is a concave part of cathode) which is a source of electrons.
2. Target (anode) which is strike by the electrons which have a negative charged and these electrons are repelled by the cathode at attracted to the anode reaching it with very high kinetic energy.
3. High positive voltage applied between the cathode and anode to accelerate the negative electrons. In diagnostic radiography, this usually within the range 40 to 120 Kev.
4. An evacuated space (with low pressure 10^{-6} tor) : which is accelerate the electrons from the cathode to the anode.

5. The space between the tubes insert and the shield is filled with oil, the oil converts heat from the insert to the tube shield(oil used to cool the target).



Production of X-Rays

NOTE: The energy of most electrons striking the target (99.8%) is dissipated in the form of heat. The remaining few energy (0.2%) produce useful X- rays.

* The intensity of X – ray beam produced when the electron strike the anode is highly dependent on the anode material:

1. the higher the atomic number (Z) of the target, the more efficiency X-ray are produced.
2. The target material used should also have a high melting point since the heat produced when the electrons are stopped in the surface of the target is substantial.

- Nearly all X – ray tubes use tungsten targets. The atomic number (Z) of tungsten is 74, and its melting point is about 3400 C°
- Production of x-ray:-

There are two different mechanisms by which X-rays are produce.

1-Bremsstrahlung(continuous)X-Ray:-

When the electron get close enough to the nucleus of a target atom to be diverted from its path and emits an x-ray photon that has some of its energy of the nucleus.

And it is also called white radiation since it is analogous to white light and has a range of wavelengths.

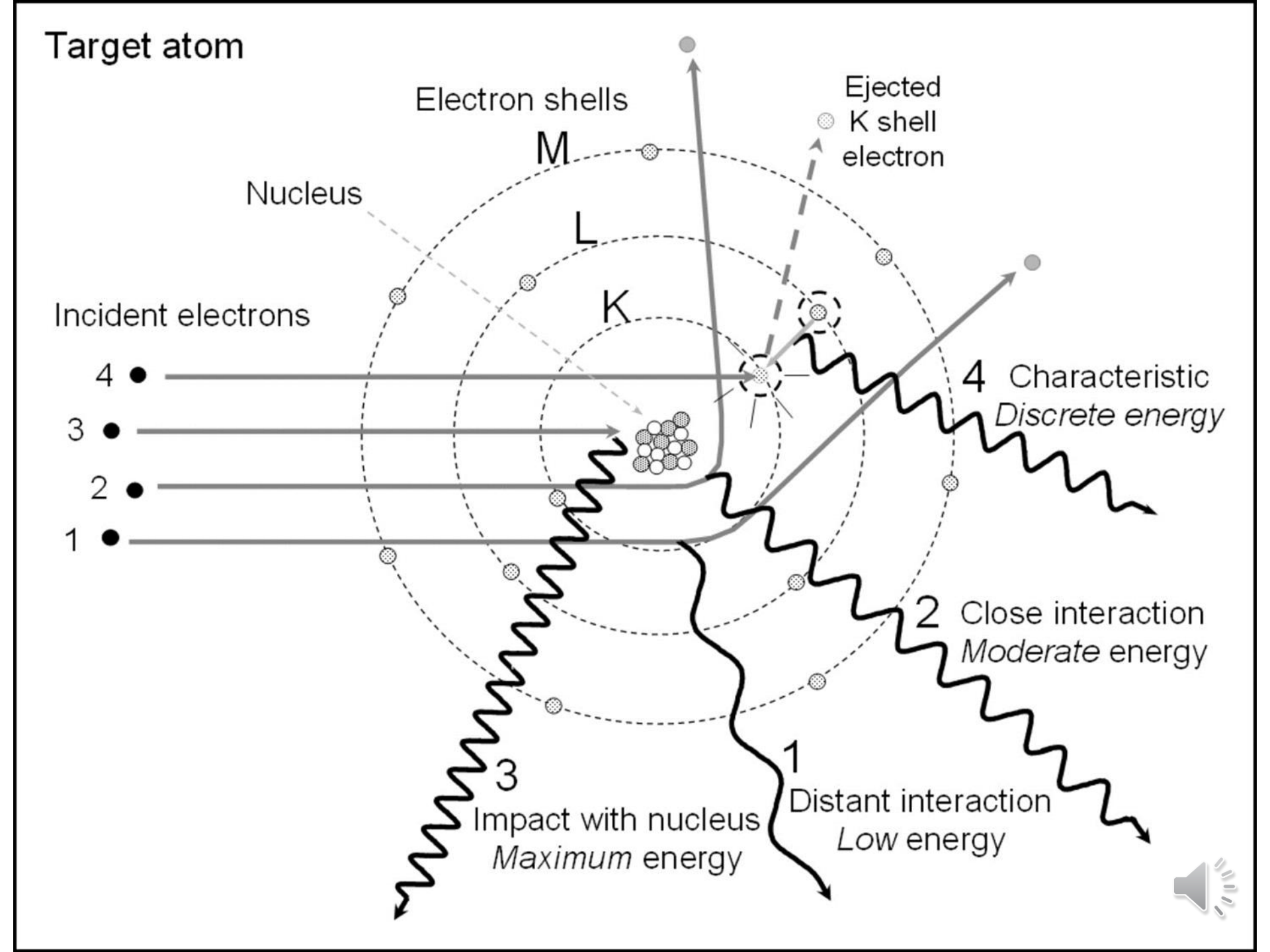
The amount of Bremsstrahlung produced depends upon two factor:

1. the Z of the target ,the more protons in the nucleus the greater the acceleration of electrons.
2. the kilovolt peak-the faster the electrons ,the more likely they will penetrate into the region of the nucleus.

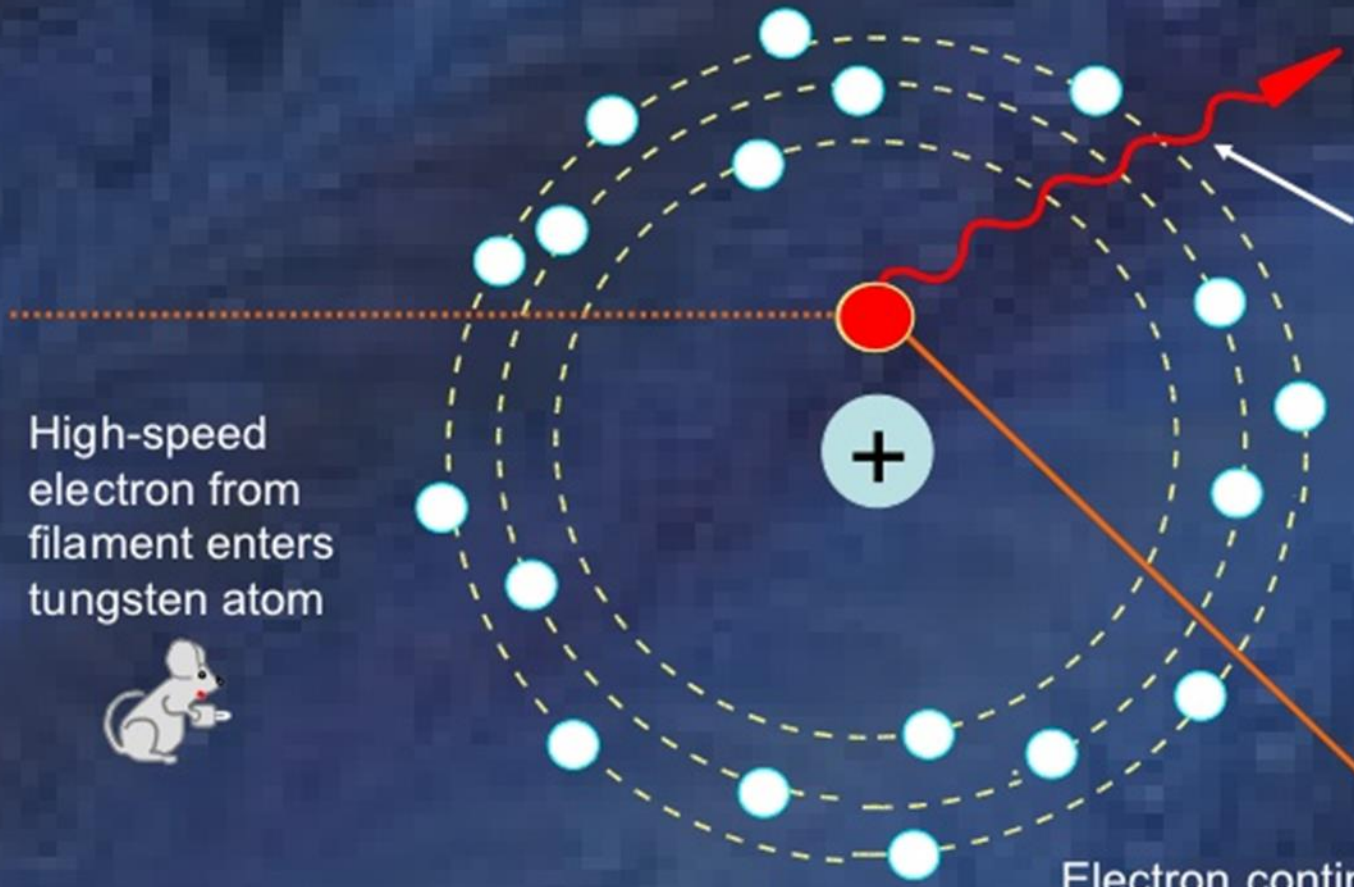
2-Characteristic X-ray:

A-fast electron strikes a K electron in a target atom and knocks out of its orbit and free of the atom. The vacancy in the K shell is filled almost immediately when an electron from an outer shell of the atom falls into, as indicated in figure, and in the process, a characteristic K X-ray photon emitted.

when an electron falls from the L level to the K level is called a Kα characteristic x-ray and that emitted when an electron falls from the M shell to the K shell is called a Kβ x-ray.


Target atom
Electron shells
M
L
K
Nucleus
Ejected
K shell
electron
Incident electrons
4
3
2
1
4 Characteristic
Discrete energy
2 Close interaction
Moderate energy
1
Distant interaction
Low energy
3
Impact with nucleus
Maximum energy

Bremsstrahlung X-ray Production



High-speed electron from filament enters tungsten atom

Electron slowed down by positive charge of nucelus; energy released in form of x-ray

Electron continues on in different direction to interact with other atoms until all of its energy is lost

X-ray Energy Spectra

X-rays photons produced by an X-ray machine are heterogeneous in energy.

The spectrum of x-rays produce by a modern x-ray generator is shown in figure,

- The broad smooth curve is due to the bremsstrahlung
- The spikes represent the characteristic X-ray.

Many of the low energy (soft) x-ray photons produced are absorbed in the glass walls of the x-ray tube.

* The purpose of added filtration is to enrich the beam with higher energy photon by absorbing the lower energy components of the spectrum, and hence improving the penetration power of the beam.

X-ray Spectra

- Incident electrons are decelerated by positive nuclei in the anode.
- Some of the KE is converted into electromagnetic photons. This is known as the *braking radiation*.
- The photons have a continuous range of energies.
- The max. photon energy is:
  $E_{max} = eV$
  Where V is the tube voltage