Medical physics module
semester 1

Session 2

Lec.1

Physics of diagnostic X-ray

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Objectives

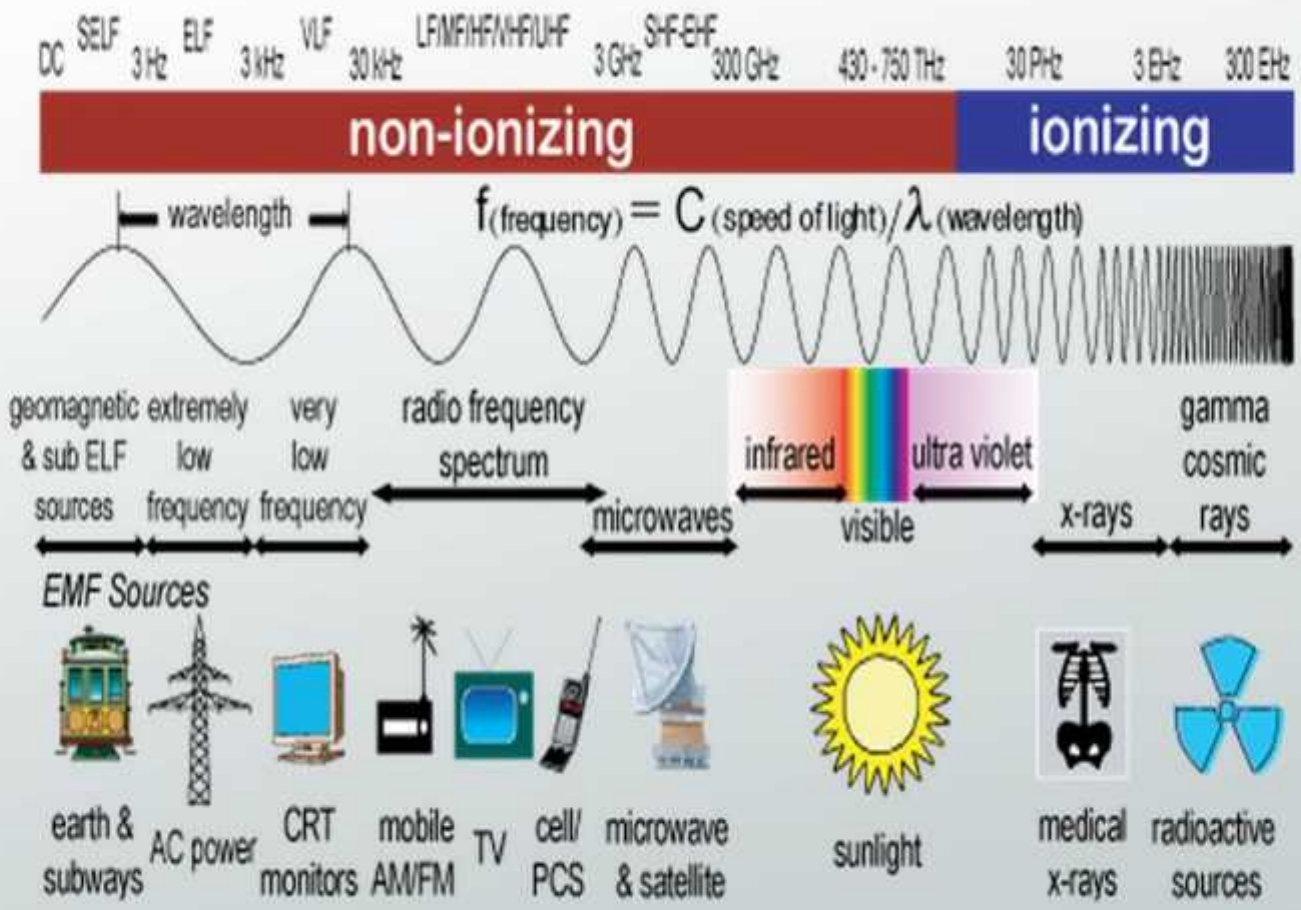
- Definition of x-ray
- The main parts of X-ray unit with x-ray production.
- How X-rays absorbed.
- Biological effects of radiation.
- Application of X-ray in medicine.

Obj. 1

Definition X-Ray

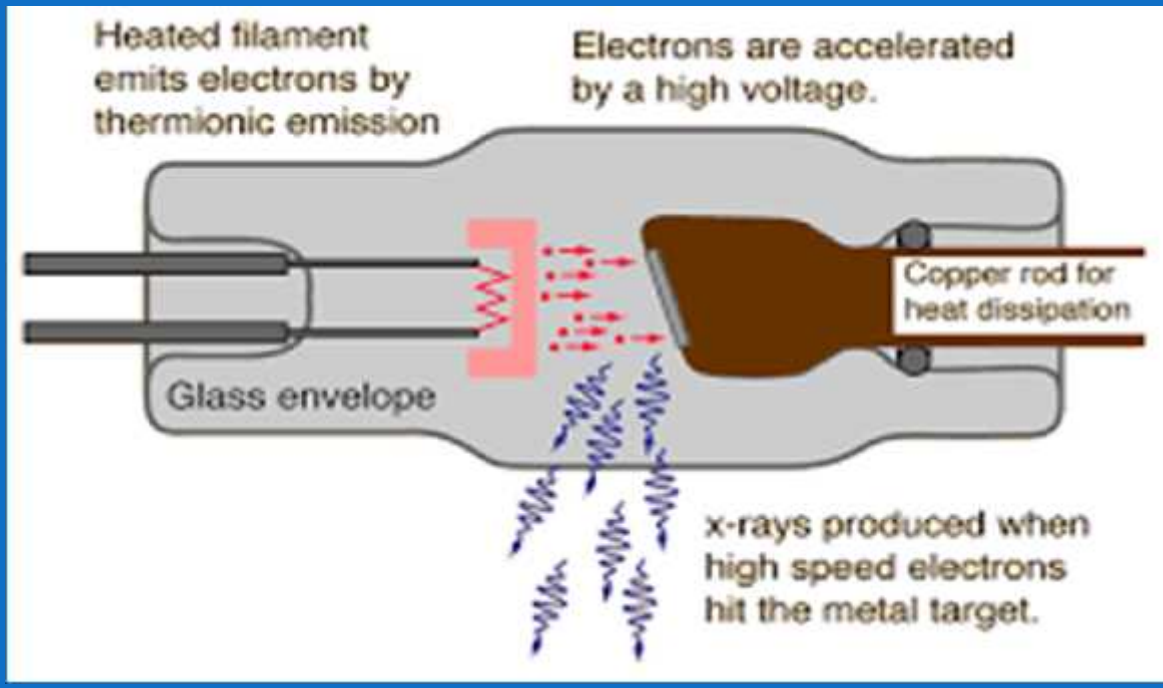
Is form of electromagnetic radiation similar to visible light but with shorter wave length.

THE ELECTROMAGNETIC SPECTRUM



Obj.2
The main parts of X-ray unit with X-ray production

- Source of electron filament or cathode.
- Evacuated space to speed electrons.
- High positive potential to accelerate electrons.
- Target or anode which the electrons hit to produce X-Ray.


Heated filament
emits electrons by
thermionic emission
Electrons are accelerated
by a high voltage.
Copper rod for
heat dissipation
Glass envelope
x-rays produced when
high speed electrons
hit the metal target.

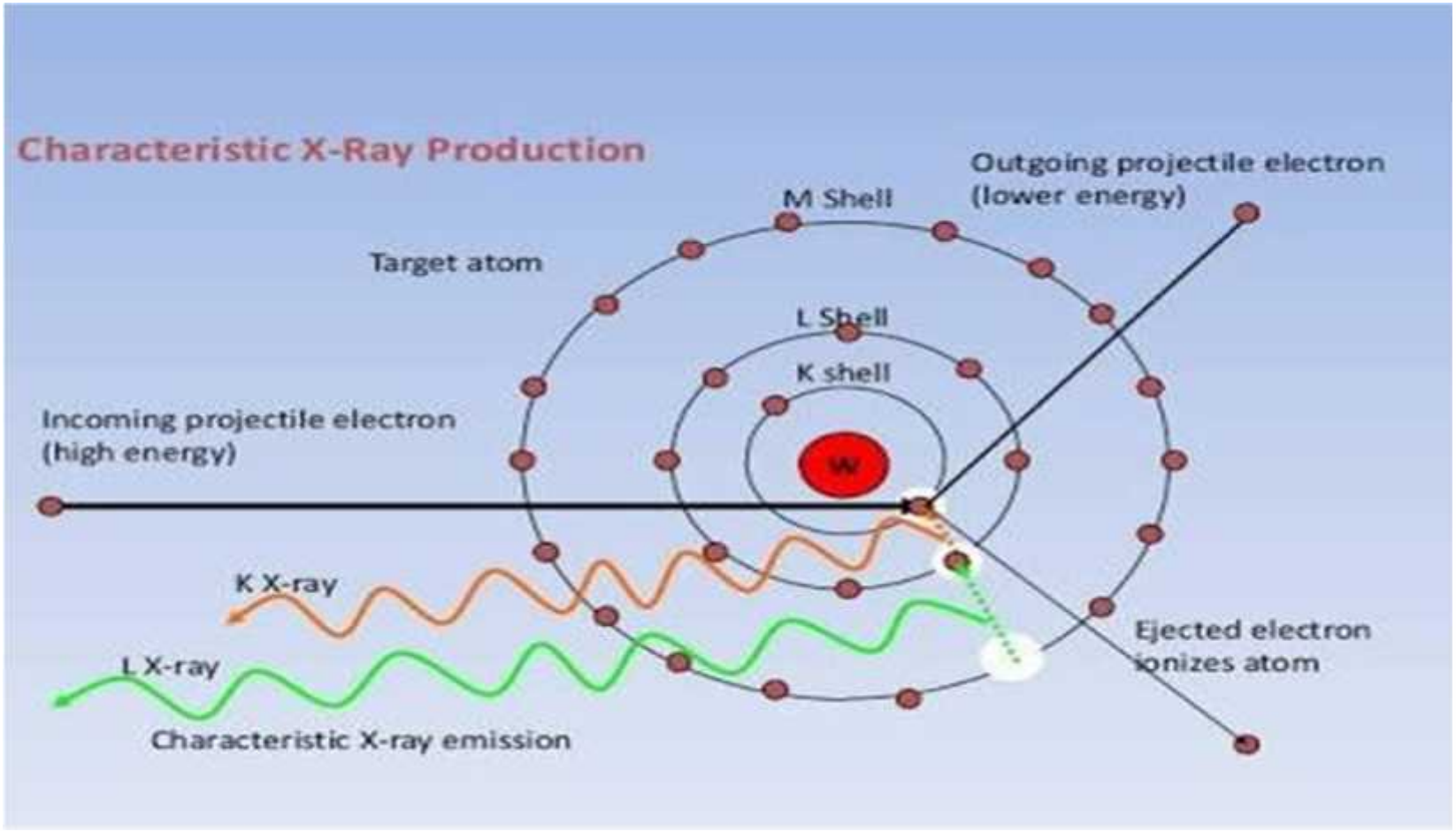
X-ray production

X-rays are generated via interactions of the accelerated electrons with electrons of ***tungsten*** nuclei within the tube anode.

Characteristic X-ray generation

This is filled by an outer shell electron with a loss of energy emitted as an X-ray photon .

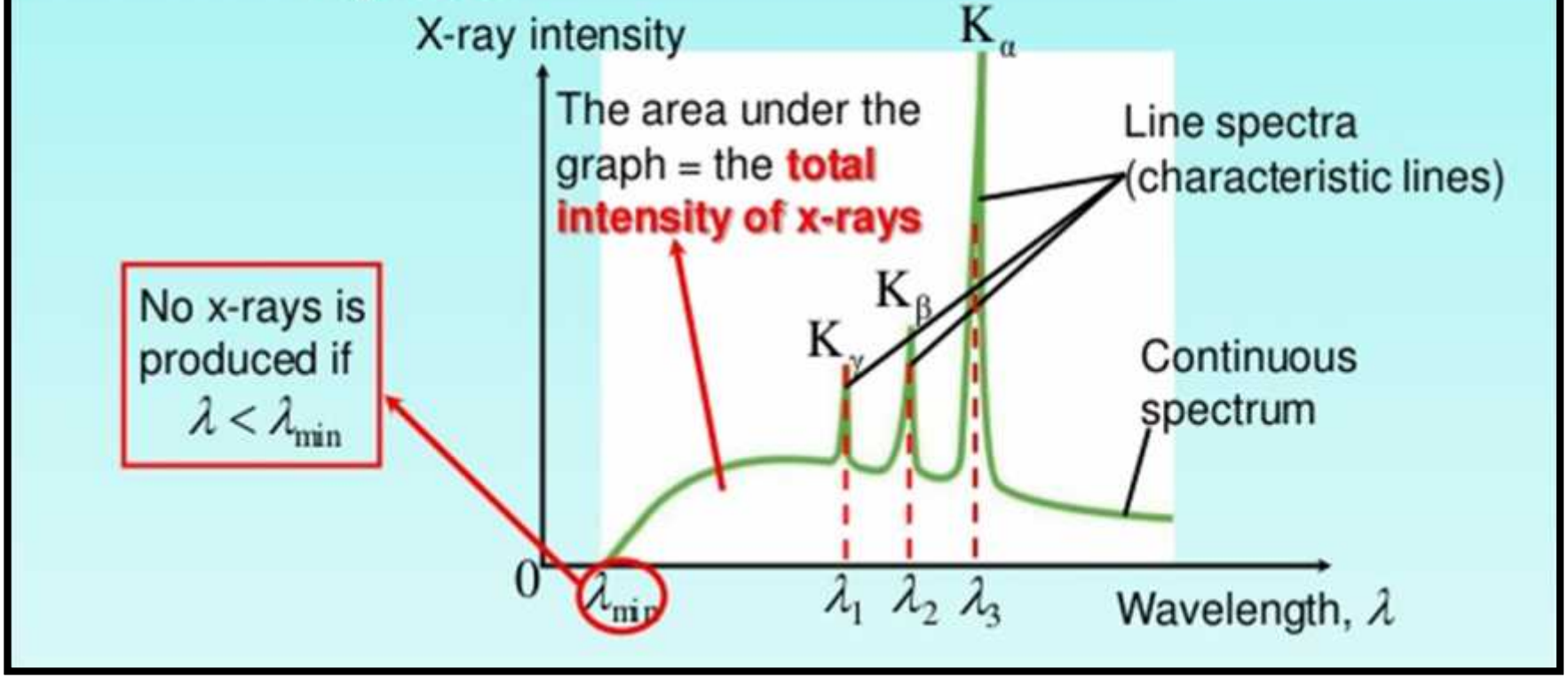
The Principle of Generation of X-ray



Type X-Ray

There are two types of X-ray generated characteristic radiation and bremsstrahlung radiation.

- Since there are two types of x-rays are produced in the x-ray tube, hence the x-ray spectra consist of **line spectra** (known as **characteristic lines**) and **continuous spectrum** as shown in Figure 6.3.

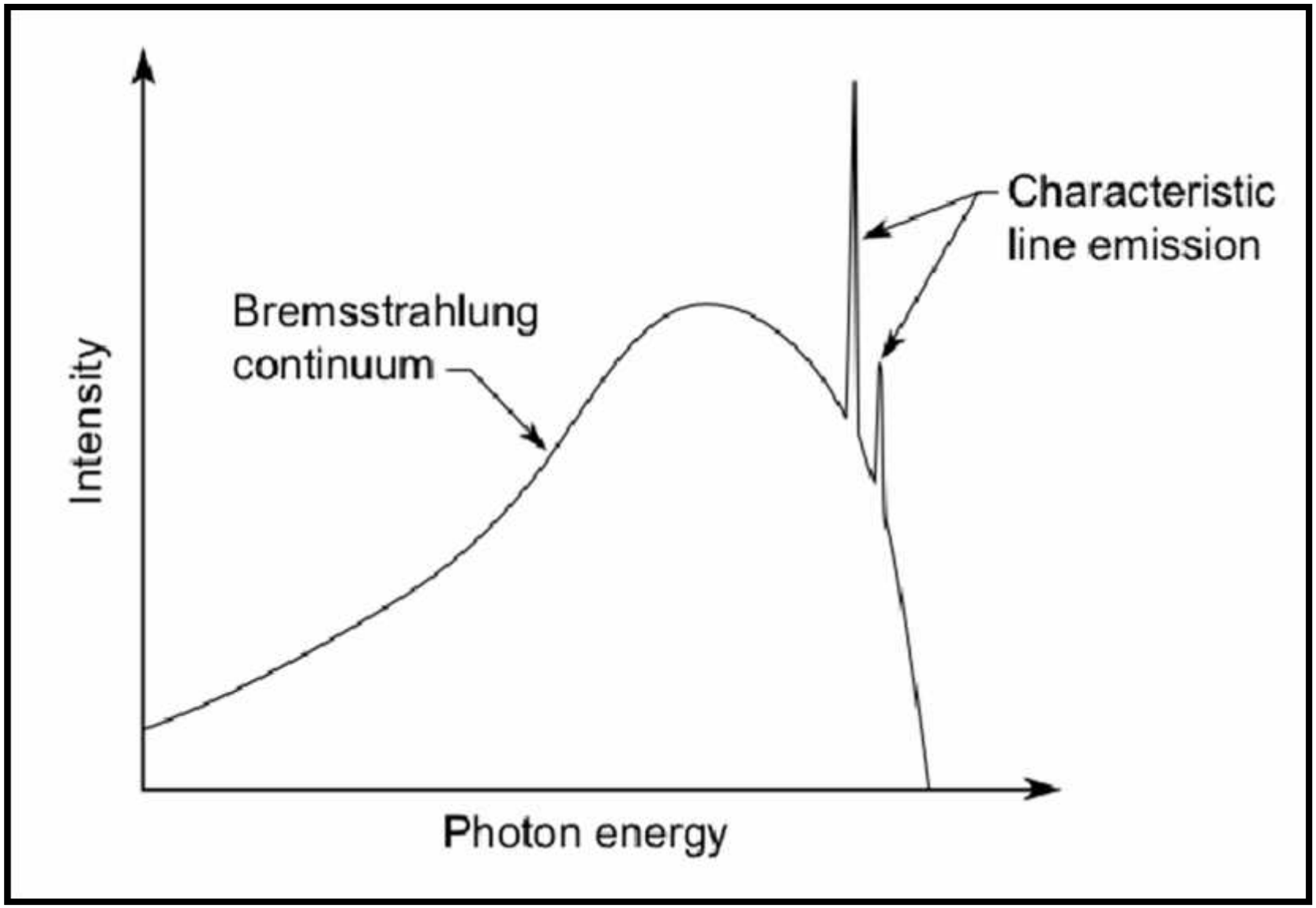


Also may an electron falls from L level to the K level is called Kα and from M shell called Kβ X-ray

Bremsstrahlung/Braking X-ray generation

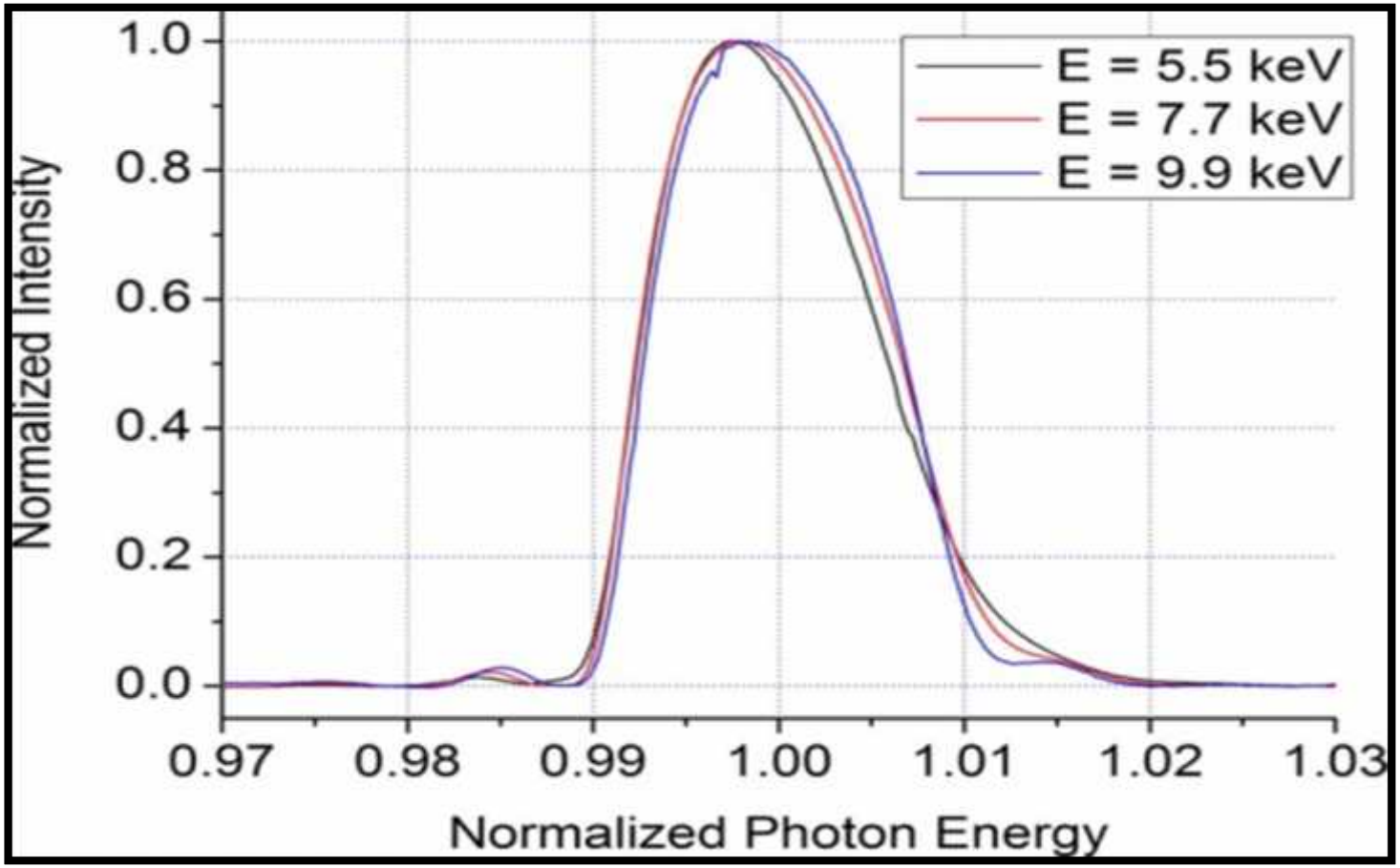
When an electron passes near the nucleus it is slowed and its path is deflected.

Energy lost is emitted as a bremsstrahlung X-ray photon.


Intensity
Bremsstrahlung
continuum
Characteristic
line emission
Photon energy

X-Ray image

- The intensity of X-Ray beam depends on the atomic number of the target.
- For higher atomic number, the more efficiently X-Ray produced.


E = 5.5 keV
E = 7.7 keV
E = 9.9 keV
Normalized Intensity
Normalized Photon Energy
1.0
0.8
0.6
0.4
0.2
0.0
0.97
0.98
0.99
1.00
1.01
1.02
1.03

All x-ray tubes use tungsten

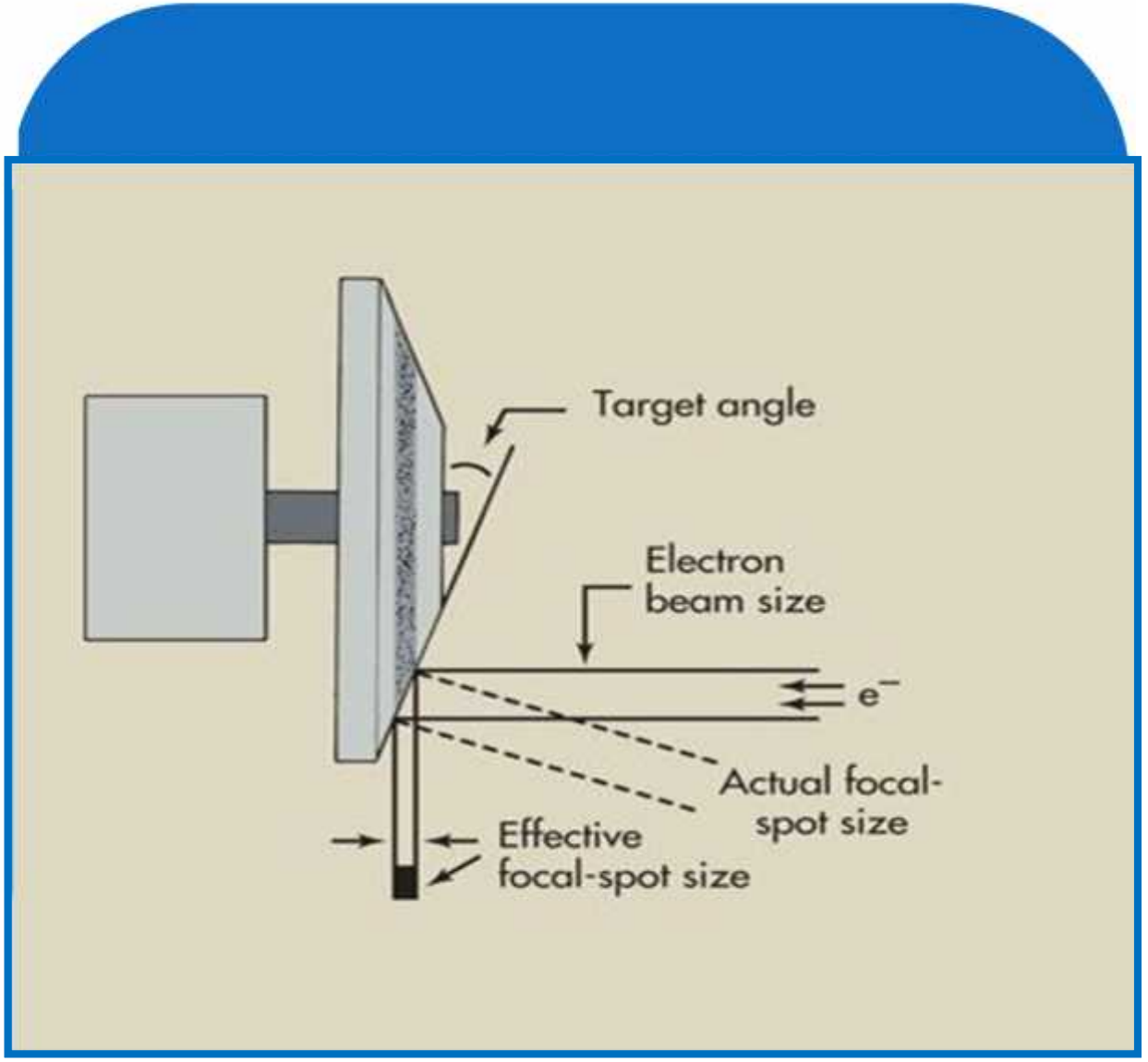
Z = 74 melting point 3400 C^o

Target should have high melting point since the heat produced when the electrons are stopped in the surface of the target.

So to avoid over heating

Use line –focus principle

Rotating anode 3600 rpm.


Target angle
Electron
beam size
e⁻
Actual focal-
spot size
Effective
focal-spot size

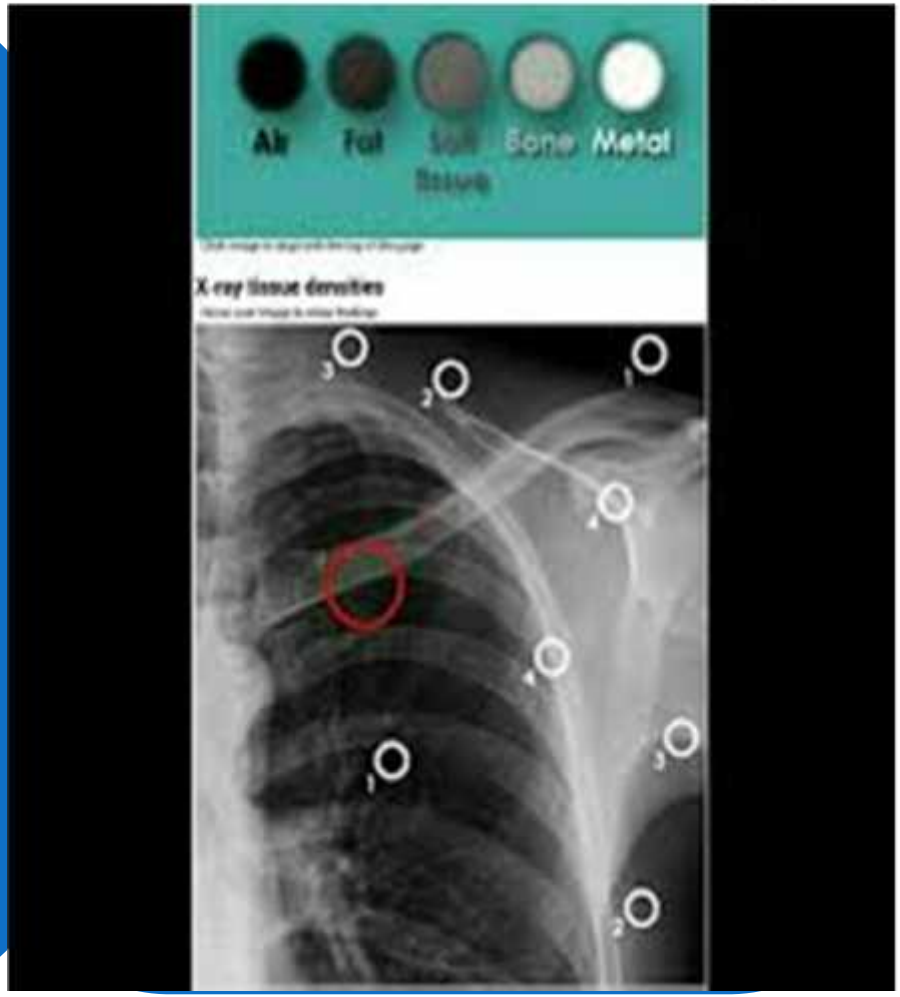
Obj.3

How X-Rays are absorbed

X-rays are not absorbed equally well by all materials if they were, they would not be very useful in diagnosis.

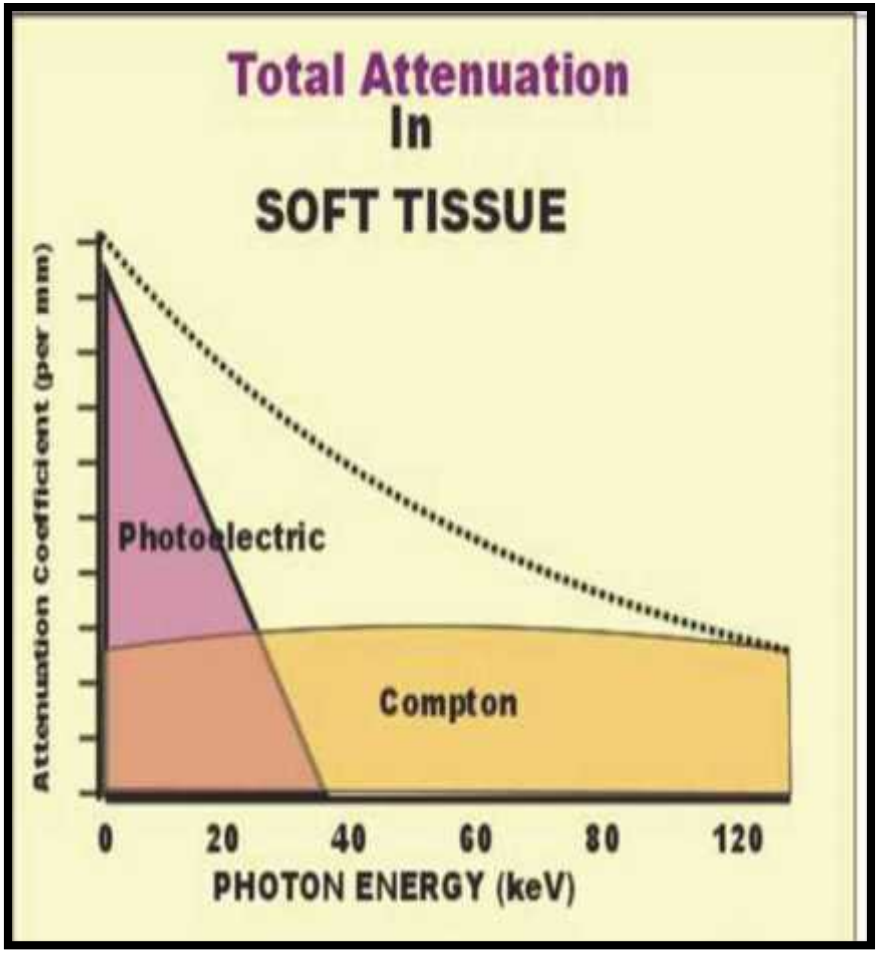
Heavy elements such as calcium are much better absorbers of X-ray than light elements such as carbon ,oxygen and hydrogen

The soft tissue, fat, muscle all absorb about equally and difficult to distinguish from each other in X-ray

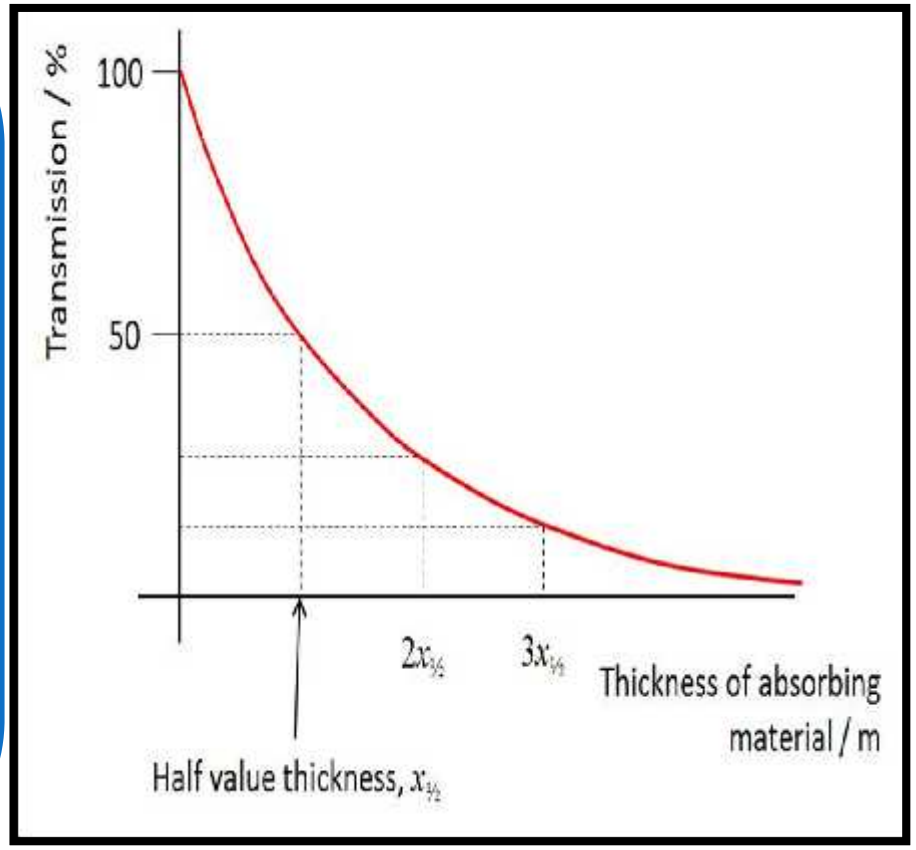


Attenuation of X-ray

Mean reduction due to absorption and scattering of some photon



The intensity of X-ray beam decrease exponentially



$$\ddot{\alpha} = \ddot{\alpha}_{\circ}\, \acute{\eta}^{-\acute{\omega}\grave{\imath}}$$

Where e = 2.718

x = Thickness of attenuator

μ= Linear attenuation coefficient (depend of energy of photon)

The Half Value Layer (HVL)

For X-ray beam is the thickness of a given material that reduce the beam intensity by one half

Photoelectric effect

All of photon energy is given to electron which then escapes from the atom .

HVL is related to attenuation coefficient by:

$$HVL = 0.693/\mu$$

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X- Ray loses energy in three ways :

1- Photoelectric effect

So this photo electron uses some of its energy to get away from nucleus

This occur in intense electric field

Occur in high Z materials (iodine)

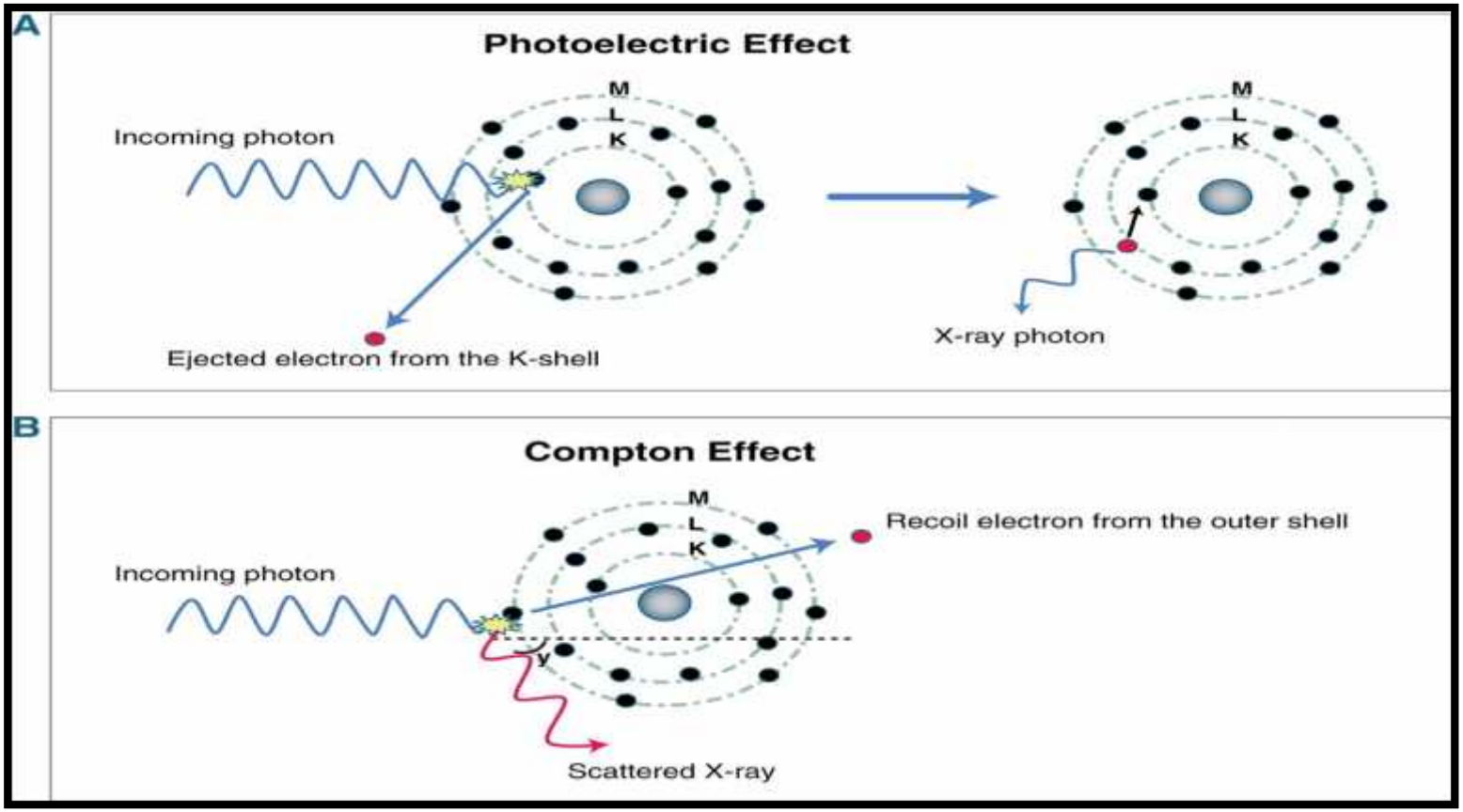
2- Compton effect

An X-ray photon collides with a loosely-bound outer electron so collide with other electron . At the collision the electron gains some energy and the remainder given to Compton travelling in a different direction of original X-ray

3- Pair production

An X-ray photon with an energy greater than (1.02 *MeV*) enters the intense electric field at the nucleus.

It may be converted into particles, a positron and an electron.


A
Photoelectric Effect
Incoming photon
M
L
K
Ejected electron from the K-shell
X-ray photon
B
Compton Effect
Incoming photon
Recoil electron from the outer shell
Scattered X-ray

Obj.4

Biological effects of radiation X-ray can cause:

- **Immediate effects (radiation sickness)**
- **Long term effects which may occur many years (cancer)**
- **Several generations later(genetic effects)**

Uses in medicine

Diagnostic ..Imaging ..X-ray..CT scan .


Thank
you