Attenuation of X-rays

by

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Attenuation of X-rays:

Is the reduction of x-ray beam due to the absorption & scattering of some of photons of the beam.

- To measure the un attenuated (transmitted) beam intensity I, we use.

$I = I_o\, e^{-\mu x}$ ----------(1)

where

I_o = initial beam intensity.

I= un attenuated (transmitted) beam intensity.

μ = linear attenuation Coefficient.

e = 2.718

x = Thickness of the attenuator such as (brain tumor, bone, aluminum)

Linear attenuation Coefficient (μ): measure the probability that photon interact (absorbed or scattered) per unit length it travel in specified material.

It depends on:

1-energy of x-rays , 2-atomic number (Z) 3-density (ρ) of material

Half value thickness HVT ($x_{1/2}$) : is the thickness of material which reduce the intensity of the beam of radiation one – half of its value (50%).

At time $x = x_{1/2}$ then I=(1/2)I_o

Substitute this condition in the equation (1) :

$I = I_o e^{-\mu x}$

$(1/2) I_o = I_o e^{-\mu x_{1/2}}$

$(1/2) = e^{-\mu x_{1/2}}$

$2^{-1} = e^{-\mu x_{1/2}}$

By taking Ln of both sides we get:

$- \ln(2) = -\mu x_{1/2} \ln e$

$0.693 = \mu x_{1/2} \rightarrow x_{1/2} = 0.693 / \mu$

Biological Effects :

Mass attenuation – coefficient :a portion of X-ray energy that will be absorbed by the biological material & can produce changes at the cellular level.

The mass attenuation coefficient (μ/ρ) is obtained by dividing the linear coefficient by the density of the material.

Therefore independent of density and depends only on the atomic number and photon energy.

$\mu_m = \mu / \rho$

Therefor the equation

$I = I_o \, e^{(-\mu/\rho).\rho x}$

Interaction of X-rays with matter:

There are three types of interaction between X-ray with matter contribute to attenuation.

1. Photoelectric effect (P.E):

The photoelectric effect is one way x-ray lose energy in the body.

- It occur when the incoming x-ray photon transfers all of its energy to an electron which escapes from the atom.
- P.E is more apt to occur in the intense electric field near the nucleus than in the outer levels of atom and it is more common elements with high (Z) than in those with low Z.

- When the energy of the x-ray is just slightly greater the binding energy of electron, the probability that P.E effect will occur increase.

In the other word :

- The energy of the photon is completely absorbed by the electron(e^-). The (e^-) eject out of the atom & the atom will be positive ion.
- Probability of photon electric occur at low X-rays energies.
- It usually occur at a high atomic number (Z) of material. e.g.:

Muscles ≤ 30 KeV

Bone ≤ 50 KeV

2. Compton effect (C.E):

- Another important X-ray lose energy in the body is done by C.E. Compton
- suggested that an X-ray photon can collide with loosely bound outer electron much.
- At the collision, the electron receives part of energy and the remainder is given to a Compton scattered photon ,which then travels in a direction different from that of the original x-ray.

In the other word :

- The energy of the photon is partially absorbed by the electron (e^-) which is ejected out of the atom, the atom will be positive ion.
- The energy of a photon is reduce from hυ to hύ ,and they scattered in different direction.

C.E. occur greatest at low Z material. e.g.:

* In water or soft tissue C.E. is more probable occur than P.E effect at energy ≥ 30 KeV.
* In bone C.E. is more probable occur than the P.E. effect at energy ≥ 100 KeV.
* At 30 kev bone absorbed x-ray about 8 times better than tissue due to P.E effect.

3. Pair Production (P.P):

P.P is the third major way x-ray give up energy.

- When a very energetic photon enters the intense electric field of the nucleus ,it may converted into two particles an electron and positron (β)(positive electron).
- Providing the mass of the two particles requires a photon with an energy of at least 1.02Mev and the remainder of the energy over 1.02 Mev is given to the particles as kinetic energy.
- After it has spent its kinetic energy in ionization it does a death dance with an electron Both then vanish ,and their mass energy usually appear as two photon of 511 kev each called annihilation radiation

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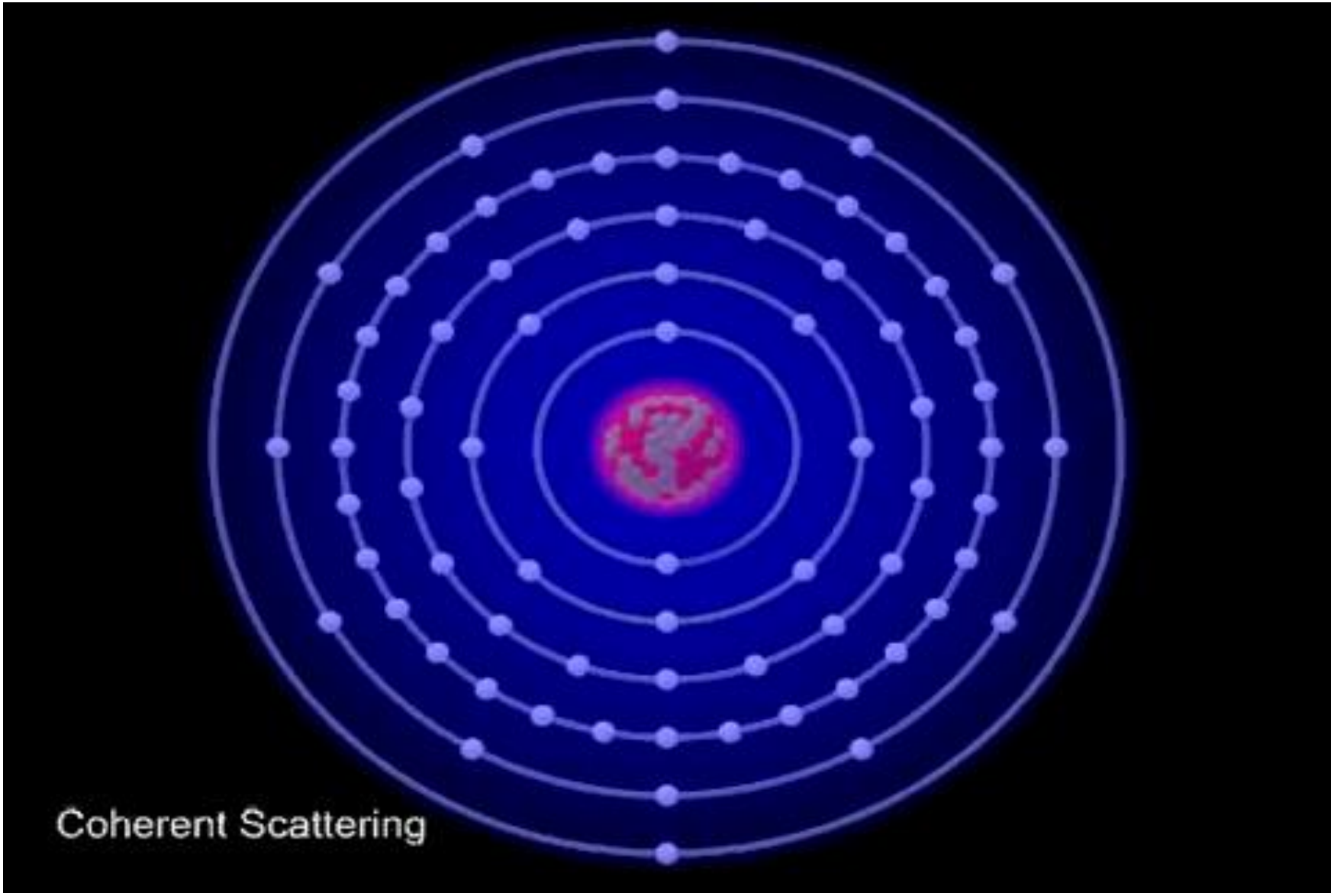
- Since a minimum of 1.02 Mev is necessary for P.P, this type of interaction is only impotent at very high energies.

* P.P is more apt occurs in high Z element than low Z element.

* P.P. is no use diagnostic radiology because of high energy needed .

* P.E. is more useful used in diagnostic than Compton effect because it need low energy and primate us to see bone & other heavy material such as bullets in the body.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