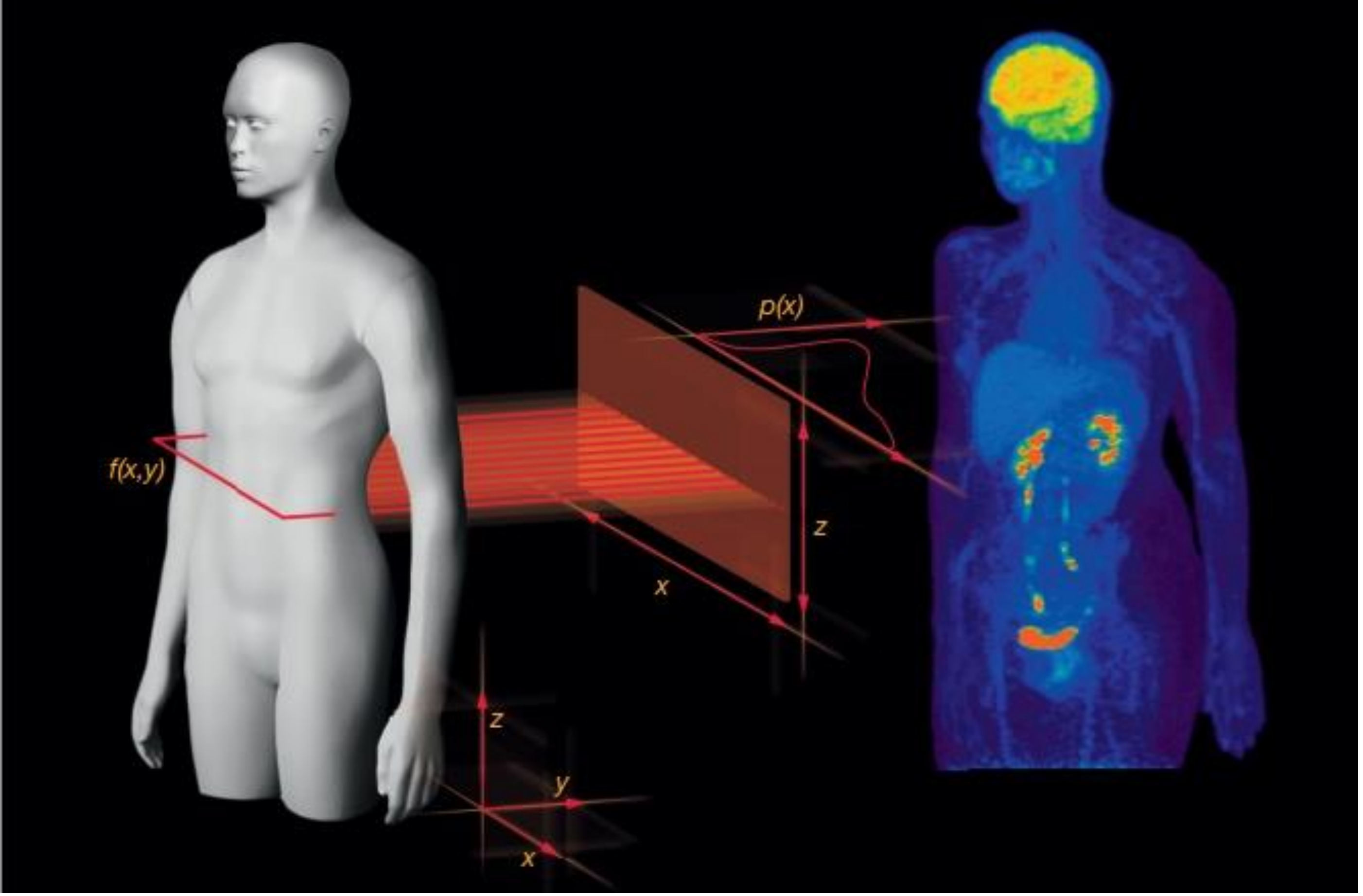

Physics of Nuclear Medicine

Lecture 03:

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Lecture Aims:

- Scintillation counter
- Types of radioactive rays

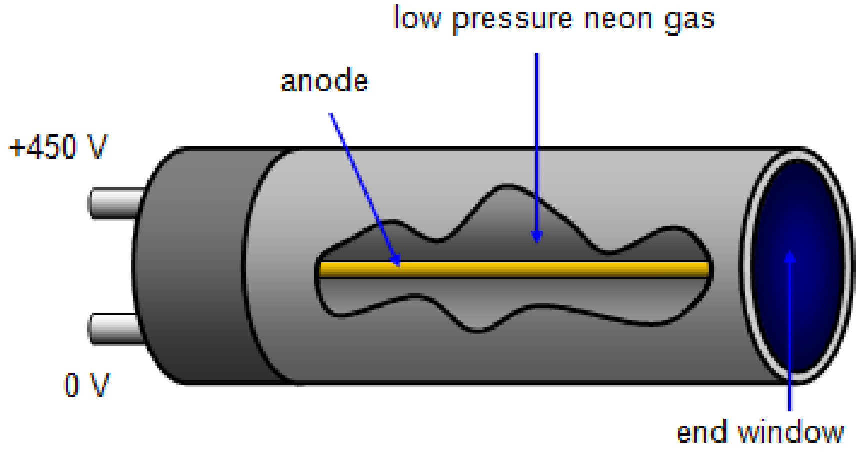
Townsend discharge:

- The Townsend discharge or Townsend avalanche is a gas ionization process where free electrons are accelerated by an electric field, collide with gas molecules, and consequently free additional electrons.
- Those electrons are in turn accelerated and free additional electrons.
- The result is an avalanche multiplication that permits electrical conduction through the gas.
- The discharge requires a source of free electrons and a significant electric field; without both, the phenomenon does not occur.

Types of Geiger–Müller counter:

End Window Type: -

- For alpha particles, low energy beta particles, and low energy X-rays, the usual form is a cylindrical end-window tube.
- This type has a window at one end covered in a thin material through which low penetrating radiation can easily pass.. The other end houses the electrical connection to the anode.



Pancake tube type: -

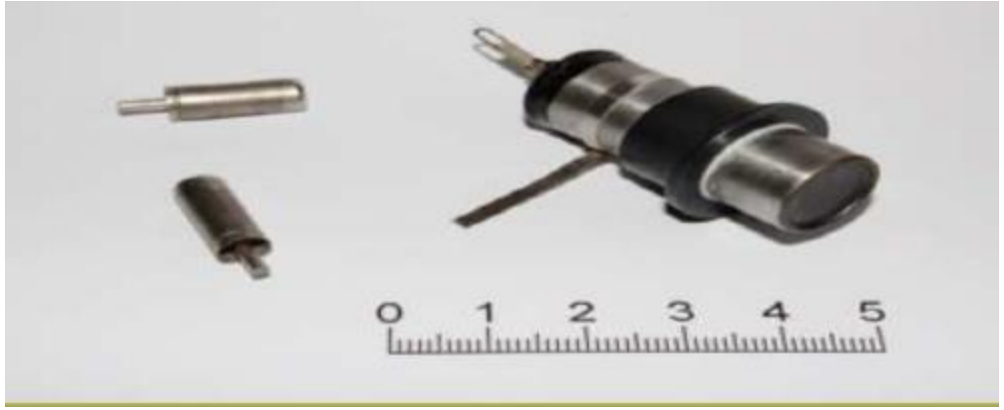
- The pancake tube is a variant of the end window tube, but which is designed for use for beta and gamma contamination monitoring. It has roughly the same sensitivity to particles as the end window type, but has a flat annular shape so the larges window area can be utilized with a minimum of gas space.
- The anode is normally multi-wired in concentric circles so it extends fully throughout the gas space.

Windowless Type:-

- This general type is distinct from the dedicated end window type, but has two main sub-types, which use different radiation interaction mechanisms to obtain a count.

1. Thick walled:

- Used for high energy gamma detection, this type generally has an overall wall thickness of about 1-2 mm of chrome steel. Because most high energy gamma photons will pass through the low density fill gas without interacting, the tube uses the interaction of photons on the molecules of the wall material to produce high energy secondary electrons within the wall.



2. Thin walled

Thin walled tubes are used for:

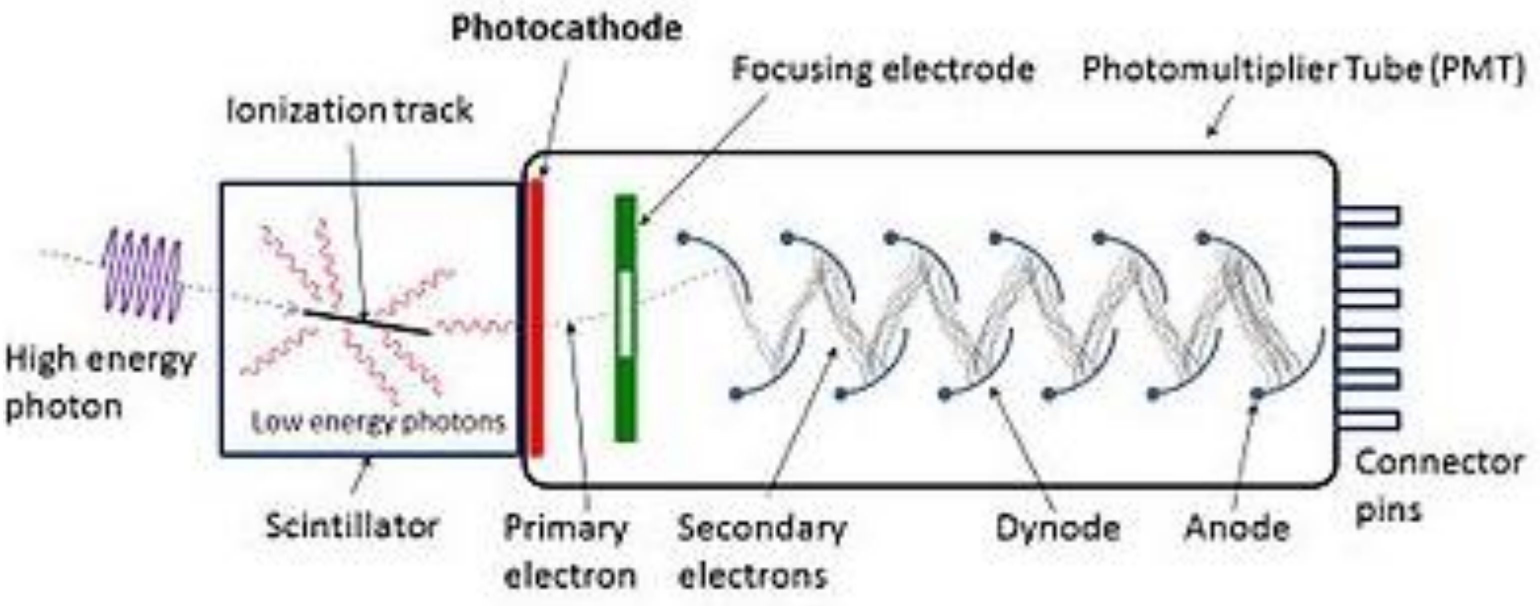
- High energy beta detection, where the beta enters via the side of the tube and interacts directly with the gas, Low energy gamma and X-ray detection.
- The lower energy photons interact better with the fill gas so this design concentrates on increasing the volume of the fill gas by using a long thin walled tube and does not use the interaction of photons in the tube wall.

Application:

- To detect or estimate radioactivity in a tissue or organ *in situ*
- To detect radioactive emission from a biological sample
- To estimate or detect radioisotope in metabolites

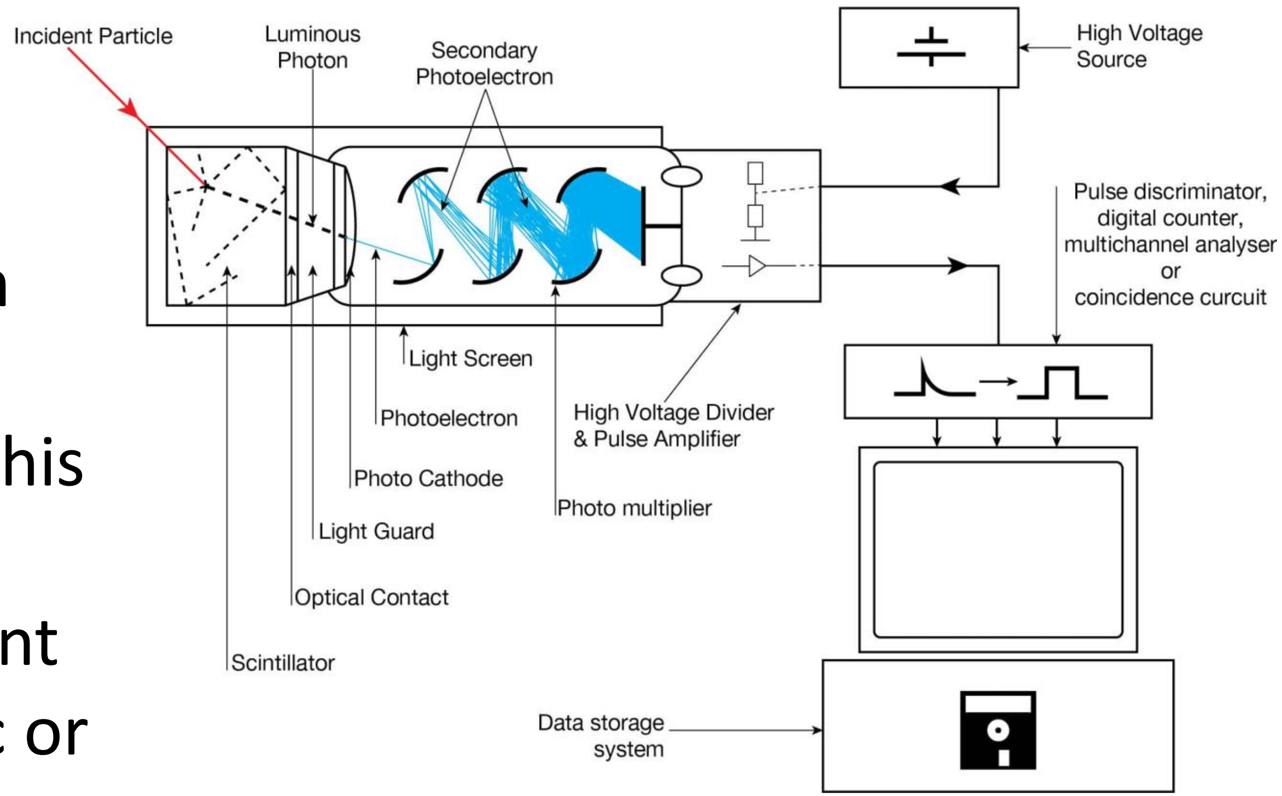
Scintillation counter

scintillation counter is an instrument for detecting and measuring ionizing radiation by using the excitation effect of incident radiation on a scintillator material, and detecting the resultant light pulses.



Structure of Scintillation counter:

- It consists of a scintillator which generates photons in response to incident radiation. a sensitive photomultiplier tube (PMT) which converts the light to an electrical signal and electronics to process this signal.
- Scintillator consists of a transparent crystal, usually a phosphor, plastic or organic liquid.

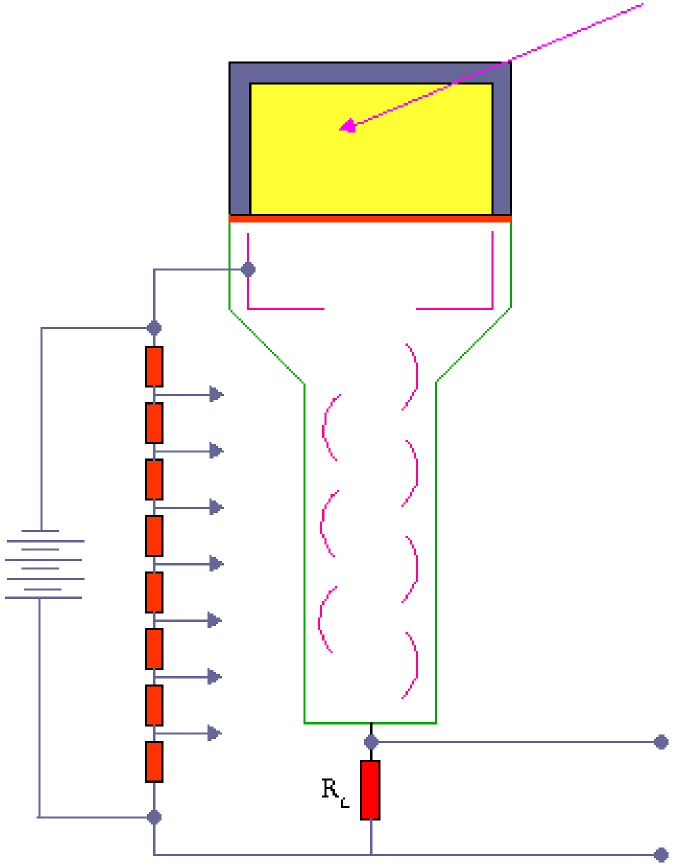


Principle:

- When high energy atomic radiations are incident on a surface coated with some fluorescent material, then flashes of lights are produced.
- The scintillations are detected with the help of a photomultiplier tube that gives rise to an equivalent electric pulse.

Working:

- When an ionizing particle passes into the scintillator material, atoms are ionized along a track.
- The photon from the scintillation strikes a photocathode and emits an electron which accelerated by a pulse and produce a voltage across the external resistance
- This voltage is amplified and recorded by an electronic counter.



Application:

- Scintillation counters are used to measure radiation in a variety of applications including handheld radiation survey meters, personnel and environmental monitoring for radioactive contamination, medical imaging, radiometric assay, nuclear security and nuclear plant safety.
- scintillation counters designed for freight terminals, border security, ports, scrap metal yards and contamination monitoring of nuclear waste.

Types of Radioactive Rays

- There are three types of radioactive rays which are:-
  - Alpha (α)
  - Beta (β)
  - Gamma (γ) rays

Alpha ($^{4}_{2}He$)

- An alpha particle is a **helium nucleus** whose mass number is 4 and nuclear charge (Atomic number) is +2.

Alpha- Particle Decay

- For proton- rich heavy nuclei, a possible mode of decay to a more stable is by alpha particle emission.

Alpha decay

- Has largest **ionizing power**

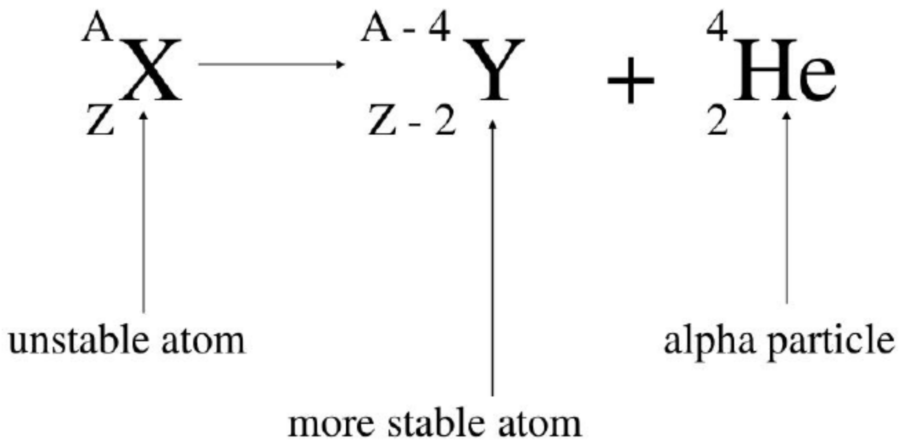
  Ability to ionize molecules & atoms due to largeness of α-particle

- has lowest **penetrating power**

  Ability to penetrate matter

- Skin, even air, protect against α-particle radiation

Alpha particle …

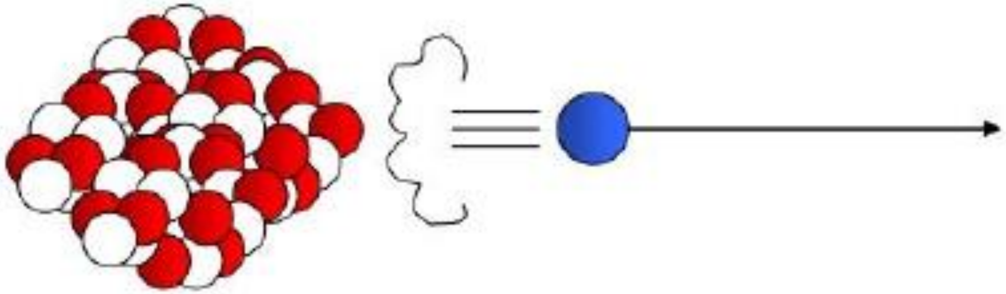


- When a radioactive element emits an α-particle, the mass number of the daughter element is decreased by 4 units and atomic number gets decreased by 2 units.

- $^{215}_{84}Po \xrightarrow{-^{4}_{2}He} {}^{211}_{82}Pb + {}^{4}_{2}He$

Beta Decay

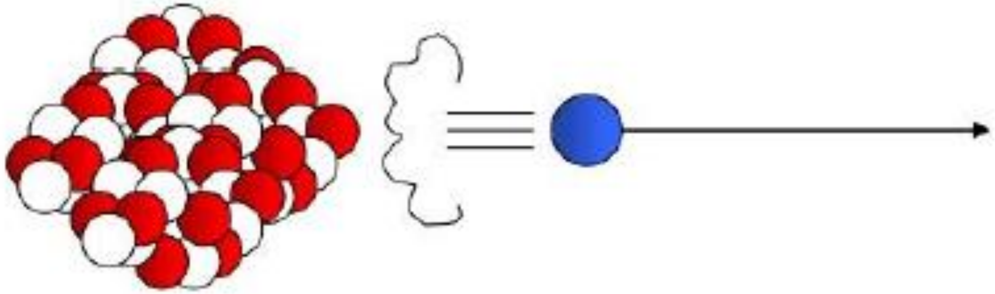
A beta particle (Denoted by β) is a fast moving electron which is emitted from the nucleus of an atom undergoing radioactive decay.



Beta decay occurs when a neutron changes into a proton and an electron.

Beta Decay

As a result of beta decay, the nucleus has one less neutron, but one extra proton.

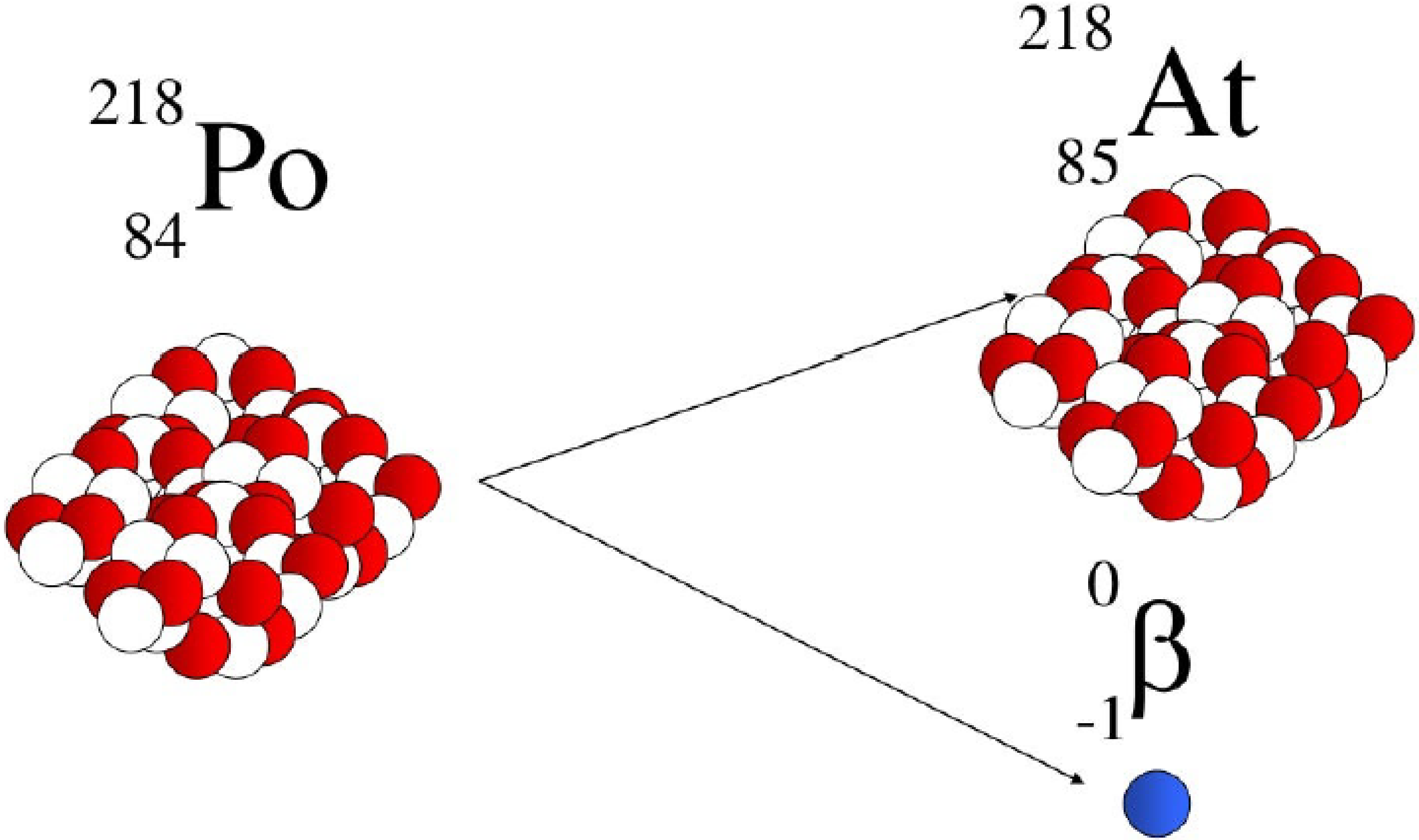


The atomic number, Z, increases by 1 and the mass number, A, stays the same.

Beta Decay

- Many different names are applied to this decay process:
- Electron decay, beta minus decay, negatron decay, negative electron decay, negative beta decay or simply **Beta Decay**

Beta Decay



Comparison between a β-particle and electron

a) Both the particles are negatively charged which is equal to -1.

b) When an atom lose an electron, a cation of the same element is formed. On the other hand, when the nucleus lose a β –particle a new neutral element is obtained.

Gamma Decay

Gamma rays are not charged particles like α and β particles.

Gamma rays are electromagnetic radiation with high frequency.

When atoms decay by emitting α or β particles to form a new atom, the nuclei of the new atom formed may still have too much energy to be completely stable.

This excess energy is emitted as gamma rays (gamma ray photons have energies of ~ 1×10^{-12} J).

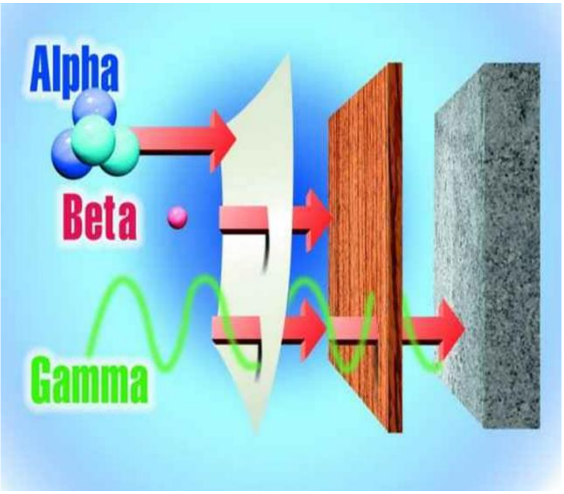
Gamma Rays. Gamma rays are **electromagnetic waves / photons** emitted **from the nucleus** (center) of an atom.

Gamma Decay

Very often, a nucleus that undergoes radioactive decay is left in an excited energy state. The nucleus can then undergo a second decay to a lower energy state by emitting photon. Photon emitted in that way is called Gamma rays.

$$ {}^{A}_{Z}X \longrightarrow {}^{A}_{Z}Y + \gamma $$

	Alpha (α)	Beta (β)	Gamma (γ)
Nature	It's a nucleus of helium $^{4}_{2}He$. Two protons and two neutrons	It's an electron e^-	It's an electromagnetic wave
Charge	+2	-1	0
Mass	Relatively large	Very small	No mass
Speed	Slow	Fast	Speed of light
Ionizing effect	Strong	Weak	Very weak
Most dangerous	When source is inside the body	When source is outside the body	When source is outside the body



Absorption of γ rays

- Many nuclides emit γ rays of more than one wavelength. If γ-rays of a λ are selected, their absorption is an exponential faction of absorber thickness, i.e.

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

Absorption…

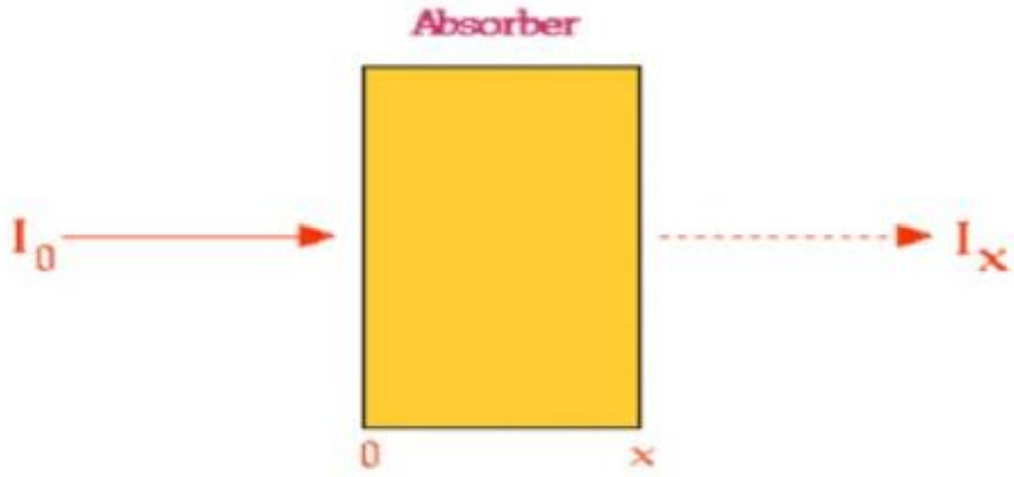
$$I = I_o e^{-\mu d}$$

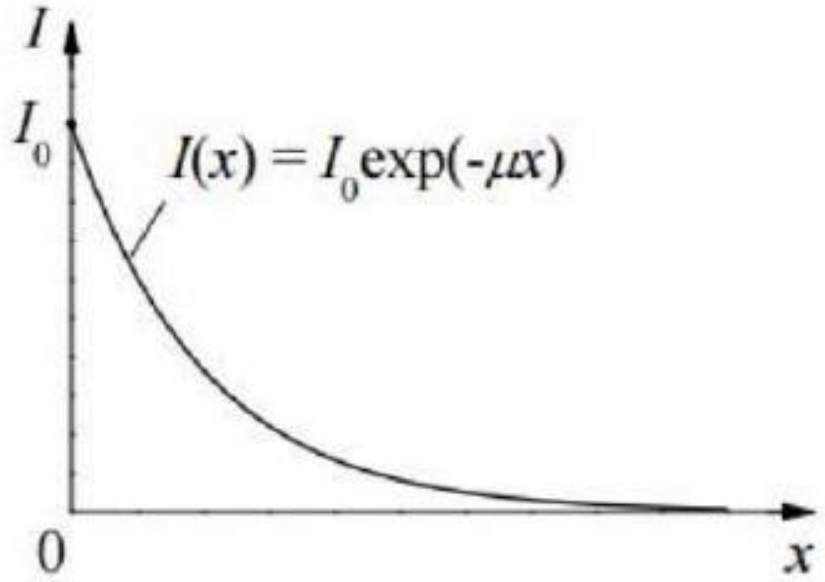
I = the intensity transmitted by a thickness by a thickness d of absorber.

I_0 = the intensity of the $\gamma -$ rays incident on the absorber

μ = the linear absorption coefficient (or attenuation coefficient) of the absorber (Unit

γ −rays passing through an absorber





- Also hold for x- rays

Ex: The intensity of gamma radiation from a given source is 1. On passing through 36 mm of lead, it is reduced to 1/8. the thickness of lead which will reduce the intensity to 1/2 will be:

A. 18 mm

B. 12 mm

C. 6 mm

D. 9 mm