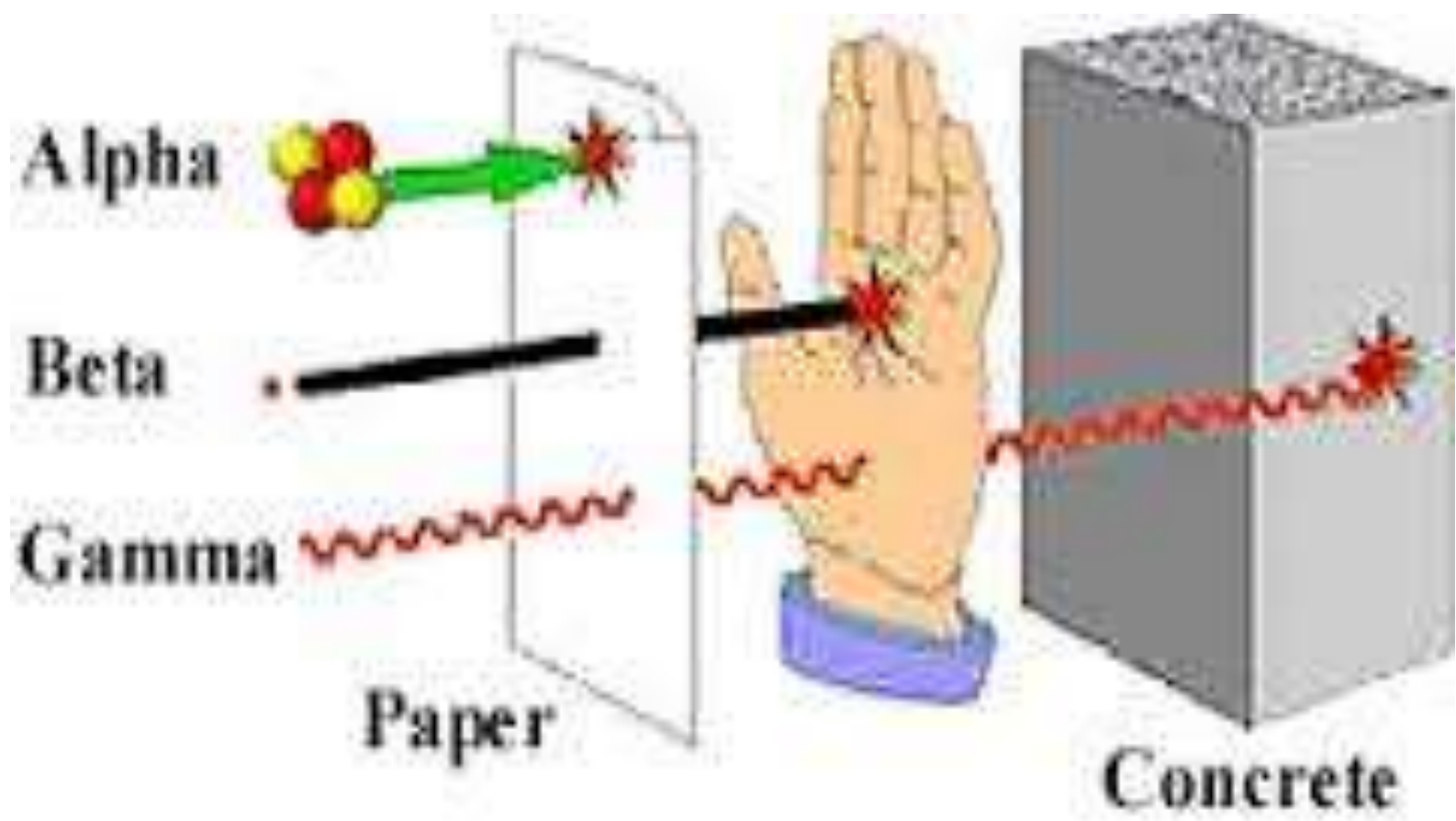


# **PHYSICS OF NUCLEAR MEDICINE**

# **Radioactivity**

**A certain natural elements, heavy have unstable that disintegrate to emit various rays. Alpha( $\alpha$ ), Beta( $\beta$ ), and Gamma( $\gamma$ ) rays.**

<b>Alpha(<math>\alpha</math>)</b>	<b>Beta(<math>\beta</math>)</b>	<b>Gamma(<math>\gamma</math>)</b>
<b>1-Positive charge</b>	<b>Negative charge</b>	<b>Without charge</b>
<b>2-Affected by magnetic &amp; electric field</b>	<b>Affected by magnetic &amp; electric field</b>	<b>Doesn't affected</b>
<b>3-Stop in a few centimeter of air (low penetrating power)</b>	<b>It is stopped in a few meters of air and a few millimeters of a tissue (the penetrating power is more than <math>\alpha</math> and less than <math>\gamma</math>)</b>	<b>High energy photon (high penetrating power).</b>
<b>4-Is Helium atom (<math>{}_2\text{He}^4</math>)</b>	<b>High speed electron</b>	<b>It is photon</b>
<b>5-Has a fixed energy for a given source</b>	<b>Has spread of energy up to max</b>	<b>Has a fixed energy for a given source</b>



## Isotopes

**Nuclei of a given element with different numbers of neutrons.**

**There are two types:**

**1-Stable isotopes if they are not radioactive.**

**Ex: ( $^{12}\text{C}$ ,  $^{13}\text{C}$ )**

**2-Radioisotopes if they are radioactive. Ex:**

**( $^{11}\text{C}$ ,  $^{14}\text{C}$ ,  $^{15}\text{C}$ )**

## **Radio-nuclides:**

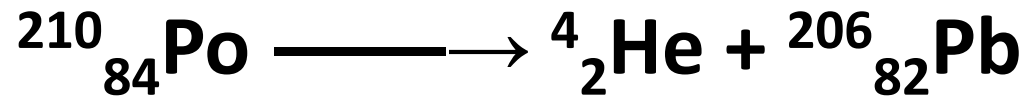
**Is used when several radioactive elements are involved.(Radioisotopes are used when referring to single element).**

## **Neutrino:**

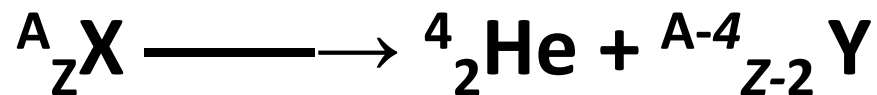
**A mass less, charge less, particle, Takes up the difference in energy between the actual beta energy and the maximum beta energy.**

## Alpha ( $\alpha$ ):

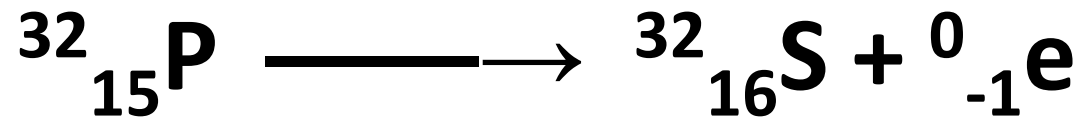
Is helium atom ( ${}^4_2\text{He}$ ) with mass number ( $A$ ) = 4 and atomic number ( $Z$ ) = 2. The result of alpha emission is a daughter whose atomic number is two less than of the parent, and whose atomic mass number is four less than that of the parent. In the case of  ${}^{210}\text{Po}$  for example, the reaction is



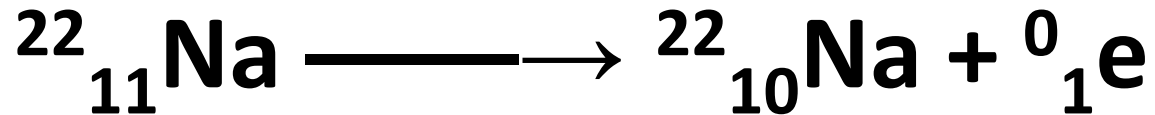
Or in general



## Beta emission:



Or positron





# Activity of Radioactive materials

**-half-life**

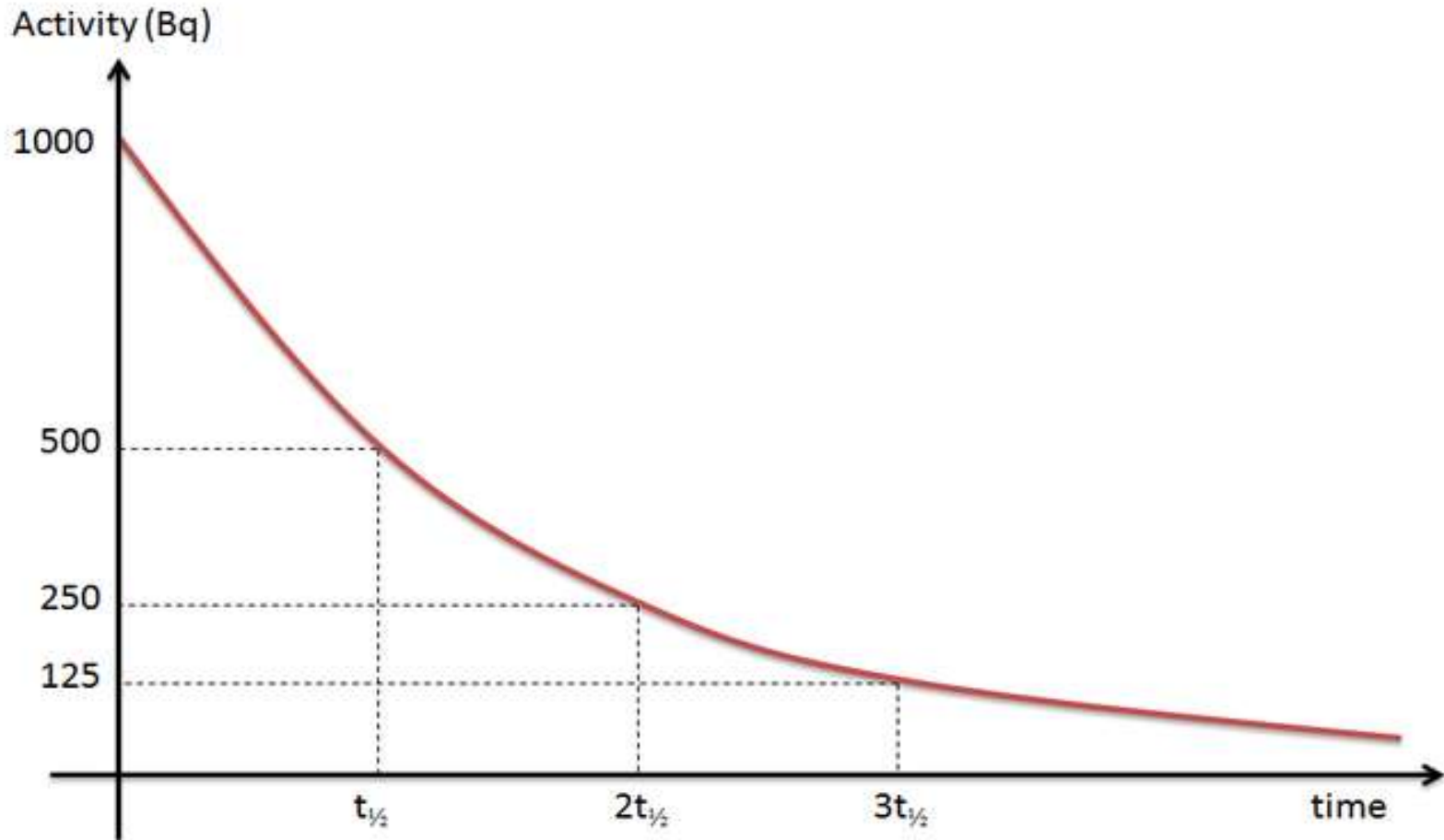
**-mean life**

**-decay constant**

**-background**

## Half life ( $T_{1/2}$ ):

The time needed for half of the radioactive nuclei to decay.



$$A = A_0 e^{-\lambda t} \dots\dots\dots (1)$$

**Where:**

**A : activity in disintegration per second after time(t)**

**A<sub>0</sub>: initial activity**

**λ : decay constant(sec<sup>-1</sup>,hour<sup>-1</sup>,year<sup>-1</sup>)**

**t : time since activity (sec, hour, year)**

$$T_{1/2} = 0.693 / \lambda \quad \text{.....} \quad (3)$$

$$A = \lambda N = (0.693 / T_{1/2} (\text{mass/atomic weight}) \times \text{Avogadro number})$$

$$1 \text{ year} = 3.15 \times 10^7 \text{ sec}$$

$T_{1/2}$  = should be in second

The average or mean time  $T = 1/\lambda$

$$1/\lambda \text{ from the equation (3)} = 1.44 T_{1/2}$$

$$\text{So } T = 1.44 T_{1/2}$$

$T$  mean life time (tau) is the average lifetime of a radioactive particle before decay.

## Example 1.

- a. If you have 1g of pure potassium 40 ( $^{40}\text{K}$ ) that is experimentally determined to emit about  $10^5$  beta rays per second. What is the decay constant  $\lambda$ ?

### Solution:

$$A = \lambda N = \lambda (\text{mass/atomic weight}) \times \text{Avogadro number}$$

$$10^5 = \lambda \times 1/40 \times 6.02 \times 10^{23}$$

$$\text{So } \lambda = 6.7 \times 10^{-18} \text{ s}^{-1}$$

- b. Estimate the half-life of  $^{40}\text{K}$  from .

$$T_{1/2} = 0.693 / \lambda = 10^{17}$$

$$T_{1/2} = 10^{17} / 3.15 \times 10^7 = 3 \times 10^9 \text{ years}$$

## **Back ground counts:**

**Is the counts without the radioactive source and this is due cosmic rays, natural radioactivity .....etc**

## Units of activity:

The unit of activity of radioactive is Ci (Curie)

1 Ci =  $3.7 \times 10^{10}$  dis/s of Bq  
(Becquerel)

(micro) $\mu$  Ci =  $10^{-6}$ Ci

(nano) $\eta$  Ci =  $10^{-9}$ Ci

(pico) $\rho$  Ci =  $10^{-12}$  Ci



## Questions:

**1- A solution containing a radioactive isotope which emits  $\beta$ -particles with half-life 12.26 days' surroundings a Geiger counter which records 480 counts/minute. What counting rate will be obtained 49.04 days later?**

## Solution

$$A_0 = 480 \text{ counts/min}$$

$$A = ?$$

$$t = 49.04 \text{ days}$$

$$T_{1/2} = 12.26 \text{ days}$$

$$\lambda = 0.693 / T_{1/2} = 0.693 / 12.26 \text{ days}$$

$$A = A_0 e^{-\lambda t}$$

$$A = 480 \text{ counts/min} \times e^{-(0.693/12.26 \text{ days}) 49.04 \text{ days}}$$

$$A = 480 \text{ counts/min} \times e^{-4(0.693)}$$

$$A = 480 \text{ counts/min} \times 1/2^4$$

$$A = 480/16 = 30 \text{ counts/min}$$

**2- Radium 226 has a half life of 1620 years. What is the mass of a sample which undergoes 20000 disintegrations per second?**

## Solution:

$$T_{1/2} = 1620 \text{ years} = 1620 \times 3.15 \times 10^7 \text{ s}$$

$$\lambda = 0.693 / T_{1/2} = 0.693 / (1620 \times 3.15 \times 10^7 \text{ s})$$

$$A = 2 \times 10^4 \text{ dis/s}$$

$$A = N \lambda$$

$$2 \times 10^4 \text{ dis/s} = (m/226) \times 6.02 \times 10^{23} \times 0.693 / (1620 \times 3.15 \times 10^7 \text{ s})$$

$$m = 55 \times 10^{-6} \text{ g}$$

**3- What is the mass of 1ci of  $^{227}\text{Th}$ ?  
If the half-life is 1.90 years.**

## Solution:

$$T_{1/2} = 1.90 \text{ years} = 1.90 \times 3.15 \times 10^7 \text{ s}$$

$$\lambda = 0.693 / T_{1/2} = 0.693 / (1.90 \times 3.15 \times 10^7 \text{ s})$$

$$A = 1 \text{ ci} = 3.7 \times 10^{10} \text{ dis/s}$$

$$A = N \lambda$$

$$3.7 \times 10^{10} \text{ dis/s} = (m/227) \times 6.02 \times 10^{23} \times 0.693 / (1.90 \times 3.15 \times 10^7 \text{ s})$$

$$m = 1.21 \times 10^{-3} \text{ g}$$

**4- Iodine-131 is used to destroy thyroid tissue in the treatment of an overactive thyroid. The half – life of  $^{131}\text{I}$  is 8 days. If a hospital receives a shipment of 200g of  $^{131}\text{I}$ , how much  $^{131}\text{I}$  would remain after 32 days?4**

## Solution:

$$\lambda = 0.693 / T_{1/2} = 0.693 / 8\text{days}$$

$$t = 32 \text{ days}$$

$$A = A_0 e^{-\lambda t}$$

$$m = m_0 e^{-\lambda t}$$

$$m = 200\text{g} \times e^{-(0.693/8\text{days}) \times 32\text{days}}$$

$$m = 200\text{g} \times e^{-4(0.693)} = 200\text{g} \times 1/16 = 12.5\text{g}$$



**5- If 10mg of iodine-131 is given to a patient, how much is left after 24 days? The half – life of  $^{131}\text{I}$  is 8 days.**

## Solution:

$$t = 24\text{days}$$

$$\lambda = 0.693 / T_{1/2} = 0.693 / 8\text{days}$$

$$m = m_0 e^{-\lambda t}$$

$$m = 10 \times 10^{-3}\text{g} \times e^{-(0.693/8\text{days}) \times 24\text{days}}$$

$$m = 10^{-2}\text{g} \times e^{-3(0.693)} = 10^{-2}\text{g} \times 1/8 = 1.25$$

$$\times 10^{-3}\text{g} = 1.25\text{mg}$$

**6- Technetium -99m ( $^{99\text{m}}\text{Tc}$ ) is used for brain scans, if a laboratory receives a shipment of 200gm of this isotope and after 24 hours only 12.5 g of this isotope remain, what is the half-life of  $^{99\text{m}}\text{Tc}$ .**

$$m_0 = 200\text{g}$$

$$m = 12.5\text{g}$$

$$t = 24 \text{ hr}$$

$$m = m_0 e^{-\lambda t}$$

$$m_0/m = e^{\lambda t}$$

$$200/12.5 = e^{24 \lambda}$$

$$16 = e^{24 \lambda}$$

$$\text{Log } 16 = 24 \lambda \text{ Log } 2.7$$

$$\lambda = 0.116 \text{ hr}^{-1}$$

$$T_{1/2} = 0.693/0.116 = 6 \text{ hr}$$

**7- Mercury-197 is used for kidney scans and has a half-life of 3 days. If the amount of mercury -197 needed for a study is 1.0 g and the time allowed for shipment is 15 days, how much mercury -197 will need to be ordered.**

$$m = 1\text{g}$$

$$m_o = ?$$

$$T_{1/2} = 3 \text{ days}$$

$$\lambda = 0.693/3\text{days}$$

$$m_o/m = e^{\lambda t}$$

$$m_o/1 = e^{(0.693/3\text{days})15\text{days}}$$

$$m_o = 32\text{g}$$

**8- The half –life of strontium  
– 90 is 25 years, how much  
half-life will it take for 10g of  
it to be reduced to 1.25g.**

**Answer: 3  $T_{1/2}$**

**9-The half-life of  $^{99m}\text{Tc}$  is 6 hours, after how much time will 1/16 of the radioisotope remain.**

**Answer: 24 hours**



**10- Radioactive  $^{24}\text{Na}$ , which has a half life of 15 h, is sent from laboratory to a hospital . What should be its activity when it leaves laboratory if the activity is to be 10mCi (milli curies) when it used in the hospital 3 h later.**

**Answer: 11.5mCi**