Physics of Nuclear Medicine
(Radioisotopes in Medicine)

Radioactivity

A certain natural elements, heavy have unstable that disintegrate to emit various rays. Alpha(α), Beta(β), and Gamma($\boldsymbol{\gamma}$)rays.

- *Alpha ray*

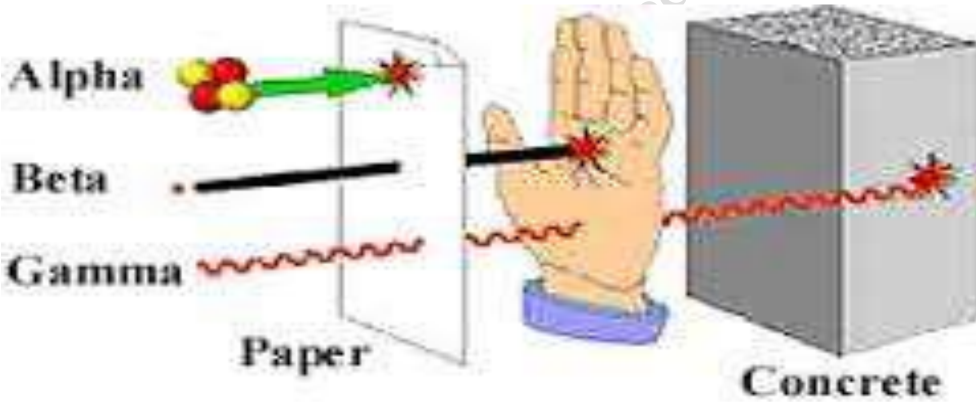
1. Nuclei of helium atoms 2. A few centimeters in air 3. Positively charges 4. Fixed energy

- *Beta ray or negatron (β-)*

1. High-speed electrons 2. A few meters in air 3. Negatively charged 4. Spread of energies

- *Gamma ray*

1. Very penetrating 2. Physically identical to x-ray but much higher energy 3. Fixed energy



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}C,^{13}C)

2-Radioisotopes if they are radioactive. ..Ex: (^{11}C,^{14}C,^{15}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 (α): Is helium atom($^{4}_{2}He$) 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}Po for example, the reaction is:

$$^{210}_{84}Po \rightarrow {}^{4}_{2}He + {}^{206}_{82}Pb$$

Or in general $\quad ^{A}_{Z}X \rightarrow {}^{4}_{2}He + {}^{A-4}_{Z-2}Y$

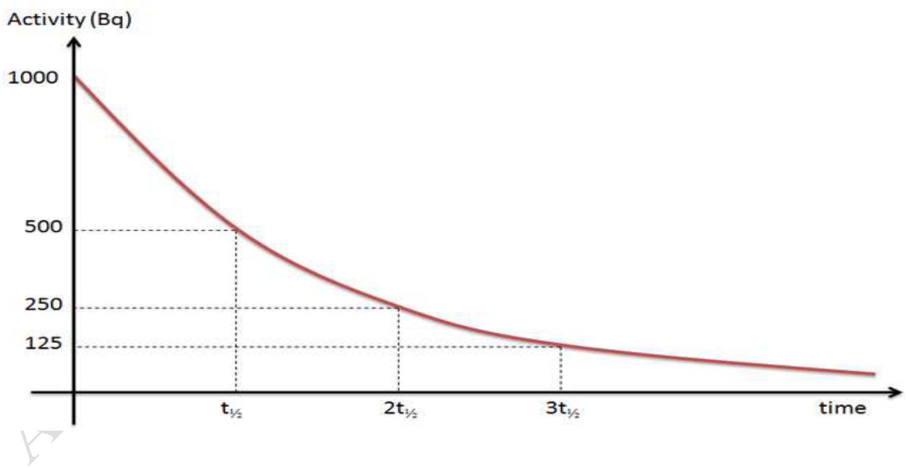
Beta emission:

$$^{32}_{15}\mathbf{P} \longrightarrow {}^{32}_{16}\mathbf{S} + {}^{0}_{-1}\mathbf{e}$$

Or positron $\quad ^{22}_{11}\mathbf{Na} \longrightarrow {}^{22}_{10}\mathbf{Na} + {}^{0}_{1}\mathbf{e}$

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.



$$\mathbf{A = A_0\, e^{-\lambda t} \ldots\ldots\ldots\ (1)}$$

Where:
A : activity in disintegration per second after time(t)
A_o: initial activity
λ : decay constant(sec^{-1},$hour^{-1}$,$year^{-1}$)
t : time since activity (sec, hour, year)

$$\mathbf{T_{1/2} = 0.693 / \lambda \ldots\ldots\ldots\ (2)}$$

A = λN = (0.693/ $T_{1/2}$(mass/atomic weight)×Avogadro number

1 year = 3.15×10^7sec

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

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

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

So $\boldsymbol{\tau = 1.44\ T_{1/2}}$

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

Example .

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

Solution:

$A = \lambda N = \lambda$ (mass/atomic weight)× Avogadro number)

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

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

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

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

$T_{1/2} = 10^{17}/(3.15 \times 10^7) = 3 \times 10^9$ 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 x 1010 dis/s of Bq (Becquerel)

(micro)μ Ci = 10^{-6}Ci , (nano)η Ci = 10^{-9}Ci , (pico)ρ Ci = 10^{-12} Ci

Questions:

1- A solution counting a radioactive isotope which emits β-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_o = 480 counts/min

A = ?

t = 49.04 days

$T_{1/2}$ = 12.26 days

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

$A = A0\ e^{-\lambda t}$

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

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

$A = 480$ counts/min x $1/2^4$
$A = 480/16 = 30$ 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:

$T_{1/2} = 1620$ years $= 1620 \times 3.15 \times 10^7$ s
$\lambda = 0.693/T_{1/2} = 0.693/(1620 \times 3.15 \times 10^7\ s)$
$A = 2\times 10^4$ dis/s
$A = N\lambda$
2×10^4 dis/s $= (m/226) \times 6.02 \times 10^{23} \times 0.693/(1620 \times 3.15 \times 10^7\ s)$
$m = 55\times 10^{-6}$g

3- What is the mass of 1ci of 227Th? If the half-life is 1.90 years.

Solution:

$T_{1/2} = 1.90$ years $= 1.90 \times 3.15 \times 10^7$ s
$\lambda = 0.693/T_{1/2} = 0.693/(1.90 \times 3.15 \times 10^7\ s)$
$A = 1$ ci $= 3.7 \times 10^{10}$ dis/s
$A = N\lambda$
3.7×10^{10} dis/s $= (m/227)\times 6.02\times 10^{23} \times 0.693/(1.90 \times 3.15 \times 10^7\ s)$
$m = 1.21\times 10^{-3}$g

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

Solution:

$\lambda = 0.693/T_{1/2} = 0.693/8$ days
$t = 32$ days
$A = A_0 e^{-\lambda t}$
$m = m_0 e^{-\lambda t} = 200g \times e^{-(0.693/8days)x32days}$
$m = 200g \times e^{-4(0.693)} = 200g \times 1/16 = 12.5g$

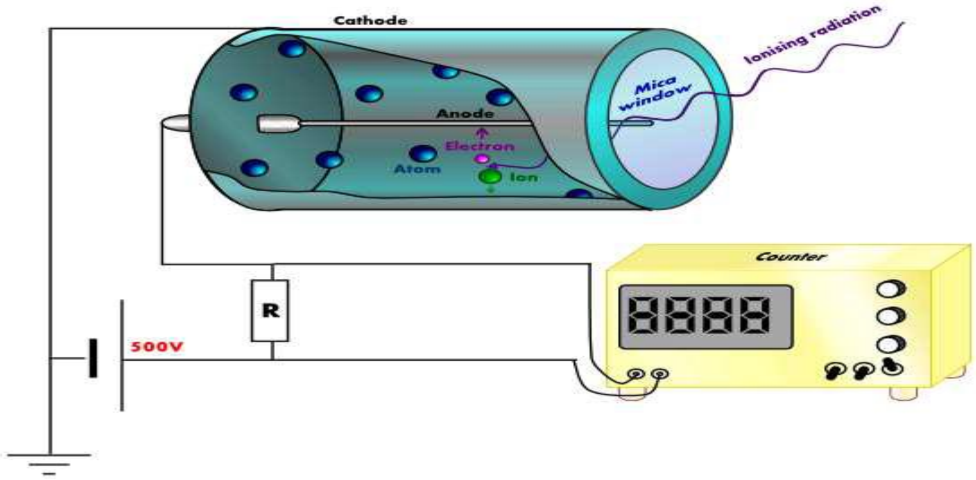
(**<u>H</u>.<u>W</u>**): Radioactive 24Na, which has a half life of 15 h, is sent from laboratory to a hospital . What should be its activity when it leaves laboratory if the activity is to be 10mCi (milli curies) when it used in the hospital 3 h later….(**Answer**: 11.5mCi).

Physics of radioactivity in medicine:

Basic instrumentation and its clinical application :

In nuclear physics used Geiger counter to detect radiations. The principle of GM counters. Even the small amount of ionization produced by a single beta ray entering the tube can trigger discharge, producing a large pulse of electricity that can be heard and a loudspeaker or counted electrically.

Geiger tube consists of a wire anode surrounding by a mental cathode, the space between them being filled with a mixture of gases (often argon or neon with a little bromine or chlorine) at low pressure. There is usually a small glass bead on end of the wire anode to prevent discharge from a point.



When radiation enters the tube via the thin (and fragile) mica window it ionizes the enclosed gas, and a large potential difference maintained between the electrodes causes the ion produced to accelerate rapidly to produce further ionization of the gas by collision, resulting in an a valance of electrons along the whole length of the wire, and resulting pulse of current is fed to a counting apparatus.
If the counter is a scalar each randomly distributed ionization event and resulting current pulse is recorded as a unit of an electrical counting device, and a stop-watch is required in order to calculate the mean rate of received pulses. The mean ionization current measured in counts per minute. If the counter is a rate meter, it dispenses with the need for a stop-watch and gives the counter rate directly.

Clinical Applications:

Nuclear Medicine:-

The clinical uses of radioactivity for the diagnosis of disease.
- The most useful radio-nuclides for nuclear medicine are those that emit gamma rays.
- Since **γ** – rays is very penetrating **γ** emitting radioactive element inside the body can be detected outside the body.

In nuclear physics used Geiger counter to detect radiations.

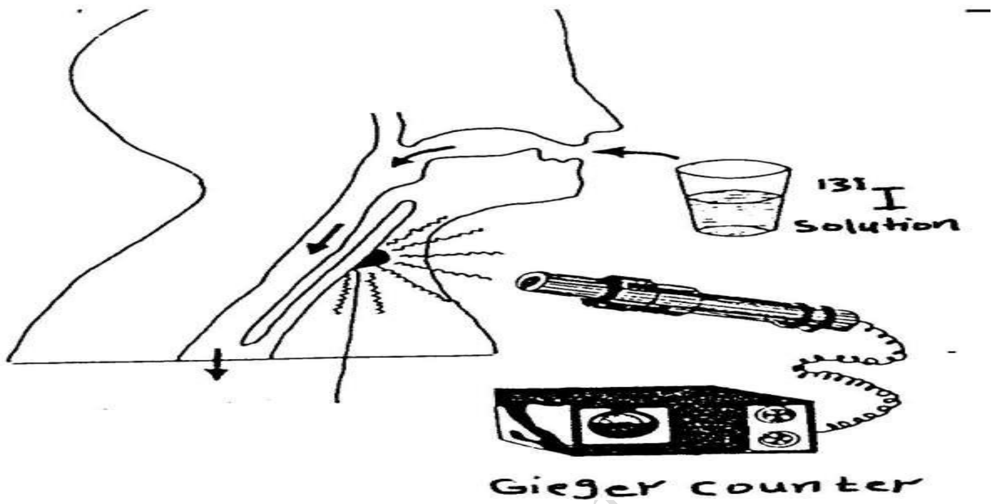
Evaluate thyroid function (24 hours uptake test).

The thyroid uses iodine in the production of hormones that control the metabolic rate of the body:

Hypothyroid- a person with underactive thyroid will take up less iodine than a person with normal thyroid function **(euthyroid).**

Hyperthyroid- a person with over active thyroid will take more iodine

For the 24hr uptake to test, a small amount of ^{131}**I** about 300KBq (~ 8μci) in a liquid or capsule, is given by mouth, and 24hr later the amount of ^{131}**I** in the thyroid is counted for 1 min. The same original amount of ^{131}**I** …the standard……. Is set aside at the beginning of the study and 24hr later it is placed in a neck phantom and also counted for 1 min.



Since the ^{131}**I** in the patient and in the standard decay at the same rate, no correction needs to be made for the decay of the ^{131}**I**. After correction are made for background counts. The ratio of the thyroid counts to the standard counts times' 100 gives percent 24-hr uptake.

Normal 10 – 40 % ---------------→ average 20 %

Hyperthyroid ----------------→ above 40 %

Hypothyroid -----------------→ less than 10%

values for euthyroids range from about 10 to 40%, with an average of around 20%, If the uptake is above 40% the patient may be hyperthyroid, patients with uptakes of less than 10% may be hypothyroid or may have recently taken in a lot of stable iodine and temporarily oversupplied.

<u>Ex</u>.: In 24 hours uptake test the standard counts rate is 2000 c/min and the thyroid counts rate is 20 c/sec. What is the type of thyroid?

Solution//

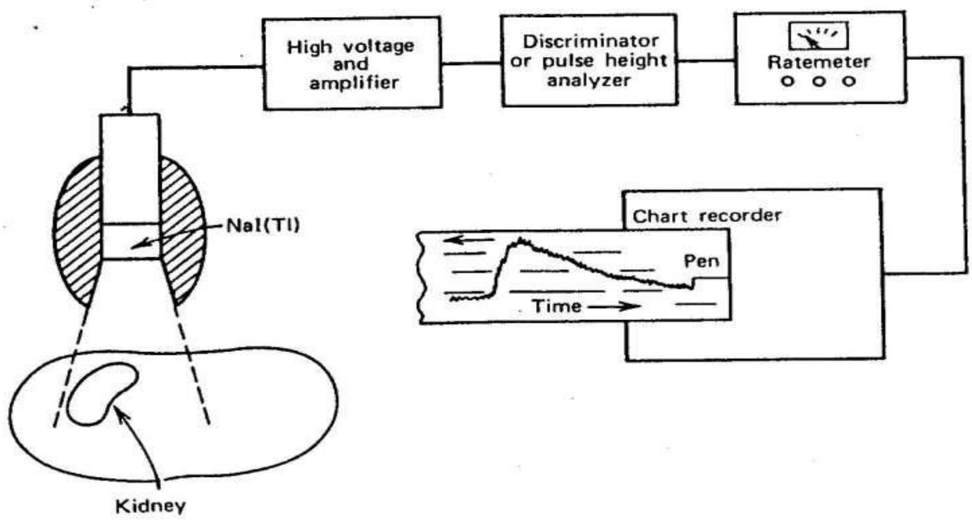
20 x 60 = 1200 c/min

(Thyroid counts/standard) x 100

= (1200/2000) x 100 = 60%

Thyroid is hyperthyroid

TO TEST KIDNEY FUNCTION:



Kidney function is also often studied with scintillation detectors. About 7MBq (~200µci) of ^{131}I labeled hipuric acid is injected into the bloodstream, and a sit is removed from the blood by the kidneys the radioactivity of each kidney is monitored and record the change in the radioactivity with time.

TO MEASURE BLOOD VOLUME

Dilution techniques The technique is used to determine the blood volume.

About 200KBq(5µ ci) of 131I labeled albumin is injected into an arm vein, and after about 15 min. A blood sample is drawn from the other arm and counted (if the patient's blood contains radioactivity from a previous study, a pre-injection sample of the blood must also be drawn and counted). The net count rate and volume of the sample is compared to the count rate and volume of the injected material to determine the blood volume.

It is common to dilute an equal amount of radioactive material in a known volume of water and then count a sample after the water and material have mixed well.

For example:

If 5ml of ^{131}**I** labeled albumin, as used in example was diluted in 1 liter of water, it would be found that a 5ml sample of water would have account rate of about $\mathbf{5 \times 10^2}$ counts/s.

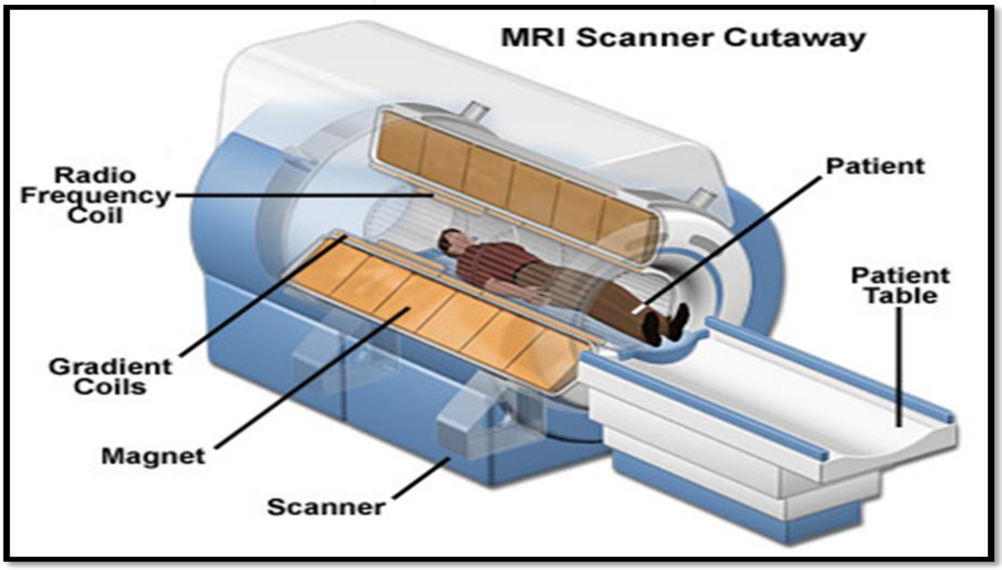
EX.:

What is the blood volume of a patient if **5ml** of ^{131}**I**-labled albumin with net count rate of $\mathbf{10^5}$ counts/s was injected into the blood and the net count rate of a 5ml blood sample drawn 15 min later was $\mathbf{10^2}$ counts/s?

Solution: $V_{blood} \times$ count rate $_{blood} = V_{injected\ albumin} \times$ Count

Rate $_{\text{injected albumin}}$ $= X \times 10^2 = 5 \times 10^5$
$X = 5000$ml

Magnetic Resonance Imaging (MRI)
• A way of obtaining diagnostic images of the body
• Uses electromagnetic radiation
• Does *not* use ionising radiation
• Very versatile
• Excellent tissue contrast and resolution –anatomy and pathology
• A typical image
• Shows Lumbar spine and cord
• MRI allows for different types of tissue contrast
• Provides lots of information
Anatomy Pathology , *Blood flow* ..etc.
The MRI Scanner consists of:
• Powerful magnet
• Patient table
• Magnetic gradients (for localising the signal)
• Radio-frequency (RF) coils that transmit RF into the patient and receive the signal
• Computer
• VDU
Note : Clinical MRI typically between 0.2T and 1.5T. *It's very strong!*

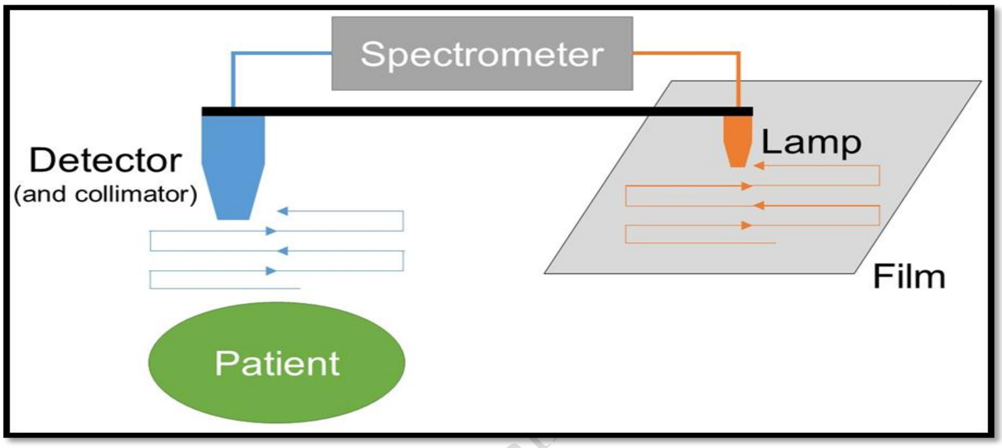


Nuclear medicine imaging device :-
Imaging: producing picture of the distribution of the radioactivity The two principal devices used to produce nuclear medicine images are :

1- The rectilinear scanner.
2- The gamma camera.

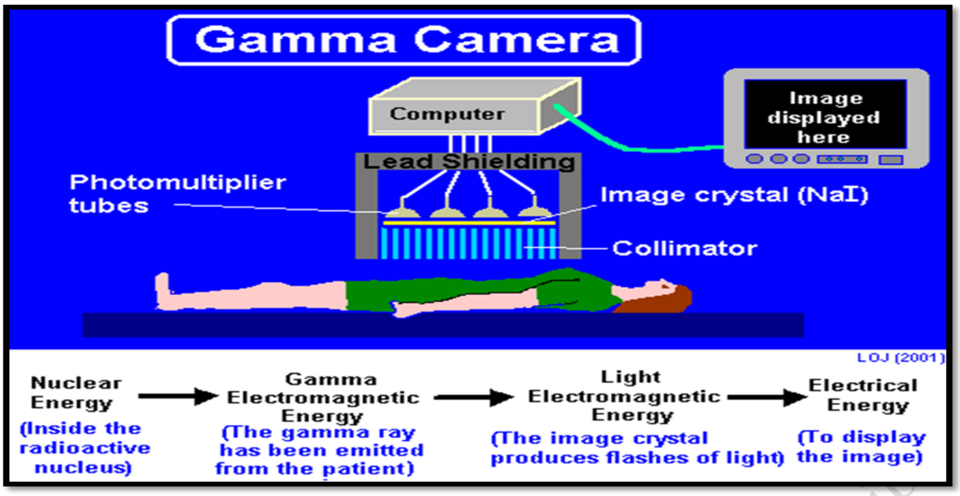
1-Rectilinear scanner :-

The NaI (Ti) detector of a rectilinear scanner moves in a raster pattern over the area of interest , making a permanent record of the count rate , or a map of the radiation distribution in the body. The image is made by moving a small light source over a photographic film as shown in figure below. The intensity of the light increases with an increase in activity, producing corresponding dark areas on the film.



2-The gamma camera:-

It has a large NaI(Ti) scintillation crystal about 1 cm thick and 30 cm to 45 cm in diameter. The scintillation are viewed through a light pipe by an array of 19 or 37 PMTs .When a gamma ray interacts somewhere in the crystal , the light from the scintillation produces a large signal in the closest PMT and weaker signals in PMTs further away . These signals are electronically processed to determine the (x,y)coordinates of the scintillation and causes a bright spot to appear at the corresponding (x,y) location of the CRT. The bright spot is then recorded on the film in the camera.



Rectilinear scanner	Gamma camera
1-Imaging time is 20 min	Imaging time 1-2 min.(obtain dynamic informatio
2-Focus collimator is used	A parallel hole collimator is used
3-Less resolution	High resolution (it can distinguish two sources ab 5 mm apart when they are held close to collimator)
4- It is not possible to use short hal life radio nuclides	It is possible to use radio nuclides with very shor half-life min. or less.

Radiation Doses in Nuclear medicine:-

In general, the radiation dose to the body from a nuclear medicine procedure is:

1- Non uniform since radioisotopes tend to concentrate in certain organs, while it is impossible to measure the radiation received by a particular patient ,it is possible to calculate the dose to various organs of a standard man .The organ receiving the largest dose during a procedure is sometimes referred to as the critical organ.
2- The dose can vary considerably from one individual to another.
3- The dose to a particular organ of the body depends on the physical characteristics of the radio-nuclides what particles it emits , their energies and on the length of the radio-nuclides is in the organ. Two factors determine the length of time the radio-nuclides is in the organ, or the effective half-life ($T_{1/2\ Bio}$) .The biological half-life of an element is the time needed for one half of the original atoms present in an organ to be removed from the organ ,and it is independent of whether the element is radioactive.

$$T_{1/2\ eff.}=[(T_{1/2\ Bio.} \times T_{1/2\ Phy.})/(T_{1/2\ Bio.}+T_{1/2\ Phy.})]$$

Note:- If either biological or physical half-life is much shorter than other , the effective half-life is essentially equal to the shorter value(see Ex .).

EX: A-what is the effective half-life of (^{131}I)in the thyroid if ($T_{1/2bio.}$=15 days) and ($T_{1/2phy.}$=8 days)?

Solu./

$$T_{1/2eff}. = \frac{(T_{1/2bio})(T_{1/2phy.})}{T_{1/2bio} + T_{1/2phy.}} = \frac{(15days)(8days)}{15days + 8days} = 5.2days$$

B-what is the effective half –life of (^{131}I) hippuric acid (used for Renogram) if half of it is excreted in the urine in 1hr (i.e $T_{1/2bio.}$=1hr)?

Solu./

$$T_{1/2eff}. = \frac{(1hr)(192hr)}{1hr + 192hr} = 0.99hr$$

C- what is the effective half-life of ^{18}F in bone if ($T_{1/2bio.}$=7days) and ($T_{1/2phy.}$=110min.)?(7 days≈10^4min.)

Solu./

$$T_{1/2eff}. = \frac{(110\min)(10^4\min)}{110\min + 10^4\min} \approx 109\min$$

A common procedure in nuclear medicine is to count the number of gamma rays detected from a patient in 1 min.

The reading obtained when a source is counted is the gross count N_g .

If you repeated the measurent with the radioactive source a bent you normally would not get a reading of Zero, the natural radioactivity in all materials ,cosmic rays and sometimes electronic circuits contribute to the background count N_b .

If N_g and N_b are each the counts for 1min ,then the rules for obtaining the net count N_{net} and the standard deviation of the net count σ_{net} are :

$$\mathbf{N_{net} = N_g - N_b}$$

$$\sigma_{net} = \sqrt{N_g + N_b}$$

If N_g is counted for t_g minutes and N_b is counted for t_b minutes then the gross count rate is N_g/t_g and the background count rate is N_b/t_b ,the standard deviation of the gross count rate is :

$$\sigma_g = \frac{\sqrt{N_g}}{t_g}$$

,and the standard deviation of the background count rate is:

$$\sigma_b = \frac{\sqrt{N_b}}{t_b}$$

The net count rate is :

$$\frac{N_{net}}{\min} = \frac{N_g}{t_g} - \frac{N_b}{t_b}$$

The standard deviation of net count rate is given by

$$\sigma_{net} = \sqrt{\sigma_g{}^2 + \sigma_b{}^2}$$

<u>Ex:</u> A-if the gross count for 1 min is 400 and the background count for 10min is 1000..what is the net count and its standard deviation?

<u>Solu :/</u>

$$N_{net} \pm \sigma = (400 - 100) \pm \sqrt{400 + 100} = 300 \pm 23$$

<u>B</u>- if the gross count for 4 min is 1600 and the background count for 10min is 1000 …what is the net count rate and its standard deviation?

<u>Solu:/</u>

$$\sigma_g = \frac{\sqrt{1600}}{4} = 10 counts / \min$$

$$\sigma_b = \frac{\sqrt{1000}}{10} = 3.16 counts / \min$$

$$\frac{N_{net}}{\min} = \frac{1600}{4} - \frac{1000}{10} = 300 counts / \min$$

Finally, to get the standard deviation of the count rate.

$$\sigma_{net} = \sqrt{\sigma_g{}^2 + \sigma_b{}^2} = \sqrt{(10)^2 + (3.2)^2} \approx 10.5 counts / \min$$

Or …..
$$\frac{N_{net}}{\min} \pm \sigma = 300 \pm 10.5 counts / \min$$

<u>Note</u> : ^{32}P a pure beta emitter has been used in the treatment of Polycythemia Vera , a disease that causes an overproduction of red blood cells ,while ^{32}P reduces red blood cell production ,this form of therapy became less popular as the risks of ionizing radiation became better known.

(H.W):

1.Describe the steps in the 24-hr thyroid uptake test?
2.Give one advantage and one disadvantage of a solid state semiconductor over a NaI (T1) detector?
3.What is a Reno gram ?

Physics of Radiation Therapy

Early attempts were not a great success; however, today radiation therapy is recognized as an important tool in the treatment of many types of cancer.
Currently three major methods are used alone or in combination to treat cancer: *surgery*, *radiation therapy* and *drugs* (***chemotherapy***).
About half of all cancer patients receive radiation as part or all of their treatment.
The success of radiation therapy depends on:
1. The type and extent of the cancer
2. The skill of the radiotherapist, the physician who specializes in the treatment of cancer with radiation
3. The kind of radiation used in the treatment.
4. The accuracy with which the radiation is administered to the tumor**.**
5. The responsibility of the radiological physicist (last factor).

There is evidence that an error of (5-10) % in radiation dose to tumor can have a significant effect on the results of the therapy .Too little radiation does not kill the entire tumor; while too much can produce serious complications in normal tissue.
The basic principle of radiation therapy is to maximize damage to the tumor while minimizing damage to normal tissue. This is generally accomplished by directing a beam of radiation at the tumor from several directions, so that the maximum dose occurs at the tumor.
Some normal tissues are more sensitive radiation than others. Ionizing radiation, such as x-rays and γ-rays, tearing electrons off atoms to produce (+ve) and (-ve) ions.
It also breaks up molecules; the new chemicals formed are no use to the body and can be considered a form of poison.
The units are used to measure the amount of radiation to the patient:-
1-**Erythematic dose**: - the quantity of x-rays that caused *Redding of the skin*.
2-**Exposure (Roentgens (R))** .

$$1R=2.58\times10^{-4}\ c/kg \text{ of air.}$$

3-**Absorbed dose (rad)**.The (rad) is defined as 100 ergs/g. that is a radiation beam that gives 100ergs of energy to 1g of tissue an absorbed dose of 1(rad) or gray =100(rad).

The (rad) can be used for any type of radiation in any material; the roentgen (R) is defined only for x-rays and γ-rays in air.

The *radiotherapist* is a physician who has had three or four years of training in oncology (the study of cancer) and the treatment of cancer with ionizing radiation ,in a modern medical center one or more *radiotherapy technologists* work with him and give the treatment ,they have had two or three years of training after high school .

In addition ,a *radiological physicist* and a *dosimetry technician* ,often called a *dosimetrist* ,look after the calibration of the therapy equipment and aid in planning the treatment .

In the very early days of radiation therapy the unit used to measure the amount of radiation to the patient was the *erythema dose* –the quantity of x-rays that caused a reddening of the skin .

Stating in about 1930 radiation to the patient was measured in Roentgen (r) ,a unit based on ionization in air, the term *exposure* had not yet been introduced ,since the roentgens was defined in terms of ionization in air it was an inappropriate unit to use for radiation absorbed by a part of the body .

In about 1950 the quantity *absorbed dose* was introduced and the unit *rad* was defined to measure it ,from 1950 to 1975 the rad was the official unit of absorbed dose.

The rad is defined as 100ergs/g ,that is a radiation beam that gives 100 ergs of energy to 1g of tissue an absorbed dose of 1rad .

The terms *dose* and *absorbed dose* are used interchangeably in radiotherapy) ,the rad can be used for any type of radiation in any material ,the roentgen (R) is defined only for x-rays and gamma rays in air.

The rad can be related to the exposure in roentgens ,the rad was defined so that for x-rays and gamma rays an exposure of 1 R would result in nearly 1rad of absorbed dose in soft tissue (water) ..in bone the ratio of rads to roentgens depends on the energy of the x-ray photons ,at the energies used in diagnostic radiology the ratio of rads to roentgens in bone is about 4 that is , 1 R exposure results in about 4rads of absorbed dose, at high energies used in modern radiotherapy the ratio of rads to roentgens is nearly 1for both bone and soft tissue.

In 1975 the International Commission on Radiological Units (ICRU) adopted the ***gray*** (GY) as the international (SI) unit of dose.

Some types of radiation are more effective in killing cells or have a higher relative biological effect (*RBE*).

RBE(Relative Biological Effect)

The ratio of the number of gray of 250 KVp x-rays needed to produce a given biological effect to the number of grays of the test radiation needed to produce the same effect.

Radiation that produces dense ionization generally is more lethal and has an RBE greater than 1 ,the RBE depends on the biological experiment used to measure the effect and is not the same for all tissues (Look table lists some approximate RBE values for several different types of radiation).

particle	RBE
Electrons or beta rays	1
X-rays or gamma rays	1
Fast neutrons	5
Alpha particles	>10

In a modern radiation therapy center, a simulator is used to allow the radiation therapist planning the treatment to see what normal structures will be in the treatment beam.

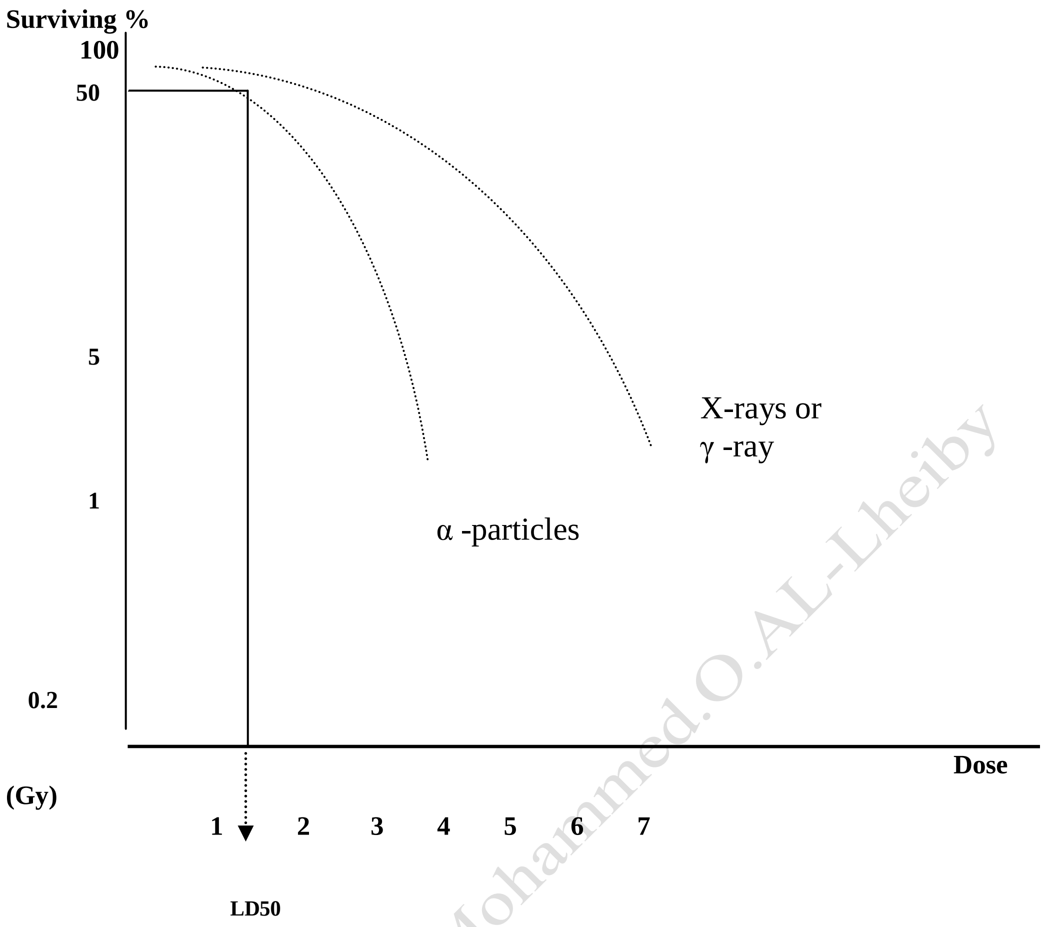
A simulator is a special fluoroscopic diagnostic x-ray unit with an image intensifier and TV screen ,the x-ray unit is positioned in the same physical arrangement as the therapy unit that will give the treatment ,that is ,it simulates the therapy unit ,the therapist can change the location and size of the beam by remote control while he watches the image on the TV screen ,after he has determined the best size and location of the beam ,he marks the beam location with colored ink on the patient's skin.

LD_{50}:-

The quantity of radiation that will kill half of the organisms in a population (cells, mice, people, …etc) is called *the lethal dose* for 50% or LD_{50}.

30 $\longrightarrow$ in 30 days

LD_{50} $\longrightarrow$ kill 50%



Oxygen effect:- **see ch.7(HOT)**

Brachy therapy :-

A short distance therapy .Radium source is put into or on the surface of tumors.

- Advantage:- of brachy therapy is that gives a very large dose to the tumors with minimum radiation to the surrounding tissue.
- Disadvantage:-is the non uniformity of the dose since the radiation is much more intense near the source .Concerns radiation safety .The therapist is close to the source and to the patient (another source).

The possibility of using radium to destroy cancer was recognized almost immediately and a method was developed in which sources of radium were put into or on the surface of tumors ,this short-distance therapy or *Brach therapy* is still a standard treatment method for certain types of cancer especially cancer of the female reproductive organs.

The advantage of Brach therapy is that it gives a very large dose to the tumor with minimum radiation to the surrounding normal tissue, its main disadvantage is the non uniformity of the dose since the radiation is much more intense near the source, although using a number of sources helps make the dose more uniform.

Another disadvantage concerns radiation safety ,the therapist must be close to the sources while they are being put in place ,the patient is a "radiation source" during the days the sources are in place and nurses and others are thus exposed to the radiation .

Other radiation sources:

The use of π^- (pi minus) mesons for radiotherapy is being investigated. These particles plays an important role in nucleus of the atom ,but there lifetime is only 10^{-8}sec ,they can be produced in the high – energy accelerators used for physics research ,until recently ,not enough π^- mesons have been available for radiotherapy ,the recent construction of the Los Alamos Meson Physics Facility (LAMPF) at a cost of 5.6×10^7 \$ makes possible the production of π^- meson beams of sufficient intensity for therapy ,the LAMPF will be used for both physics research and π^- meson radiotherapy .

A proton beam of about 1 MA will be accelerated to an energy of about 800 Mev, the power in the beam will be:

$P=IV=(10^{-3})\,(8\times10^{8})=8\times10^{5}W$ or almost 1megawatt.

The ability of densely ionizing radiation such as π^- mesons and fast neutrons to eliminate some or all of the oxygen effect is expected to make these types of radiation more effective in treating cancer.

<u>Ex2 :-</u> In 24 hour uptake test ,the standard counts rate is 2000 c/min and the background counts rate is 200 c/min and the thyroid counts rate is 20 c/sec .What is the type of thyroid ?

<u>Solution :-</u>

$20 \times 60 = 1200$ c/min

(Thyroid counts – background)/(standard counts – background)x100

$(1200-200)/(2000-200)\times100=55\%$

So thyroid is hyperthyroid.

<u>Megavoltage therapy :</u>

Megavoltage therapy has three major advantages:

1. The maximum dose occurs below the skin and this skin-sparing effect greatly reduces the pain from the treatment
2. The high energy is almost completely in the *Compton Effect* region and unlike 250kvp radiation, dose not give a large dose to the bone
3. The greater penetrating ability permits better treatment of tumors deep inside the body.

(H.W)

1.What does LD_{50} mean?
2.Define: RBE, rad?
3.What is brachytherapy? Give one major advantage and one major disadvantage of brachytherapy?
4.Why are π^- meson beams of interest in radiotherapy ?Give one advantage and on disadvantage of π^- meson therapy?

Radiation production in medicine:

The science of protecting workers and the public from unnecessary radiation is known as *radiation protection*.
It involves the accurate measurement of radiation to radiation workers and the public and the design and use of methods to reduce this radiation.
Ionizing radiation has always been present on the earth, all of our ancestors lived in a continuous sea of ionizing radiation and so do we. This natural radiation or *background radiation* comes from several sources.
About 20% of this background radiation comes from natural radioactivity in our bodies –primarily potassium 40(^{40}K), typically, 30 to 40% of the background radiation comes from cosmic rays from outer space.
One source of natural radiation is the air we breathe, Radon gas one of the radioactive daughter products of the radium family, is present in the air.
**If you are a cigarette smoker (*and we hope you are not*!) ,the smoke that enters your lungs may give them up to five times the radiation a nonsmoker receives ,this may be a contributing factor to lung cancer in cigarette smokers.
Medical radiation exposures come from therapeutic uses of x-rays and radioactivity, diagnostic uses of radioactivity (nuclear medicine) and diagnostic uses of x-rays.
The biological effects of ionizing radiation are of two general types ***somatic*** and ***genetic***.
Somatic effects affect an individual directly (loss of hair, reddening of the skin, etc), while *genetic effects* consist of mutations in the reproductive cells that affect later generations.
Since genetic effects occur only when reproductive cells are irradiated, the gonads should be shielded during x-ray studies when possible.

In order to evaluate the genetic effects of x-rays on thee population, the concept of *genetically significant dose* (**GSD**) is useful.
The GSD due to an exposure depends on the dose to the individual's ovaries or testes and the individual's age, which determines the probability of that person becoming a parent in subsequent years.
Thus x-raying women over 50 *yr*. old, who normally have little change of having babies, contributes very little to the GSD of the population.
Exposure of the reproductive oranges of children results in the maximum contribution to the GSD of the population, since their potential for producing off spring is at maximum.

<u>Radiation protection units and limits:</u>

The *rem* is a unit for the *quantity dose equivalent* (DE),the (DE) is defined as the rads times the quality factor (QF) of the radiation or DE=(rads) (QF).
The QF takes into account the increased damage done by certain types of radiation, a rad of densely ionizing radiation dose much more damage to a cell than a rad of x-rays ,gamma rays or beta rays and is assigned a larger QF.
The QF is related to the relative biological effect (RBE) ,both (RBE) and (QF) are due to the increased biological effects of densely ionizing radiation.
However, the RBE for a particular radiation is often different for different types of cells, while the QF is arbitrarily defined to be a constant for a particular radiation.

Unit	Recommended use	Definition
Becquerel (Bq	The SI unit for radioactivity	1 Bq=1 nuclear transformation /se
Curie (Ci)	This unit for radioactivity is bein replaced by the SI unit Bq	1 Ci =3.700×10^{10} nuclear transformation /sec
Gray (Gy)	The SI unit for absorbed dose	1 Gy=1J/kg
Rad	This unit for absorbed dose is bei replaced by the SI unit GY	1 rad =0.01J/kg =100erg/g
Roentgen (R)	The unit of exposure for x-rays ar gamma rays	1R=2.58×10^{-4} coulomb/kg of air
Rem	The unit of dose equivalent	The dose equivalent in terms is numerically equal to the absorbe dose in rads multiplied by the quali factor and any other future modifyi factors (such as the radiation rate
Rap	A unit of exposure-area product th measures the radiation insult to th patient from diagnostic x-rays. Th unit is not yet generally accepte	1 rap=100R cm^2

Many crystalline materials give off light when heated after being exposed to radiation; this light is called *thermo luminescence* (**TL**).

Some natural minerals like fluorite (calcium fluoride) give off large amounts of TL when heated due to the large exposure they have accumulated from natural radioactivity over centuries ,since all materials have some natural radioactivity ,the phenomenon is very common and was probably observed over 2000years ago when fluorite was used in making lead.

Many hospitals and radiologists have a policy of not x-raying female patients who are or may be pregnant except in emergency situations.

In an emergency, they make every effort to shield the fetus from radiation, since a woman may not know she is pregnant unit she misses a menstrual period, it is a common policy to take x-rays only during the 10 days following the last period, this is known as the *10-day rule*.

Radiation protection in radiation therapy:

We can calculate the amount of shielding that is needed to reduce the gamma radiation from a ^{60}Co source to a safe level.

We first explain how to calculate the exposure rate from the gamma rays from a particular radionuclide source, the basic equation for $\mathbf{I}_\gamma$, the radiation intensity in roentgens per hour, is:

$$I_\gamma = \frac{\Gamma N}{D^2}$$

Where ***D*** is the distance in meters from a source of ***N*** *megabecqurels* or *curies* of radioactivity and **Γ** (gamma) is a constant for the particular radionuclide that depends on the number and energies of the gamma rays emitted per disintegration (e.g. , 3.5×10^{-5} Rm^2/MBq hr for ^{60}Co).

Radiation protection in nuclear medicine:

The nuclear medicine physician should:

1. Determine whether the study is necessary or desirable
2. Use the right radiopharmaceutical; sometimes different radiopharmaceuticals are in similar containers.
3. Use the right amount of the radiopharmaceutical; for ^{99m} Tc it is necessary to have a calibration device.
4. Give the radiopharmaceutical to the right patient; in a busy department it is easy to make mistakes.
5. Make sure the detection equipment is working correctly; there are standard test procedures for gamma cameras and scanners.

(H.W)

1.What are the source of background radiation ?

2.What is meant by GSD?

3.Calculate the exposure rate (0.3 m) from a syringe containing (500 M Bq) of ^{99m}Tc for a brain scan?(*Ans*.10Mr/hr)
4.If you have a (10 M Bq) ^{137}Cs source ,at what distance from it will the exposure rate be (0.01 R/hr)? (*Ans*.9.2 cm)