# Radioisotopes in Medicine

by

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- Isotopes are atoms with the same atomic number but different mass numbers .
- Radioactivity is the spontaneous degradation of nucleus & transmission of one element to another with consequent emission of rays ( or ) particles.
- Mass number(A) = number of protons + number of neutrons
- Atomic number (Z)= number of protons
- A-Z= number of neutrons
- radioisotopes occur naturally- as in radium-226, Carbon-12 or artificially altering the atoms by using a nuclear reactor or a cyclotron.
- Radioactivity is the process whereby unstable atomic nuclei release energetic subatomic particles.

| type of radiation | alpha particles (α) | beta particle (β) | gamma rays (γ) |
| --- | --- | --- | --- |
| | each particle is 2 protons + 2 neutrons (it is identical to a nucleus of helium4) | each particle is an electron (created when the nucleus decays) | electromagnetic waves similar to X-rays |
| relative charge | +2 | -1 | 0 |
| ionizing effect | strong | weak | very weak |
| penetrating effect | not very penetrating: stopped by a thick sheet of paper, by skin or by a few centimeters of air | penetrating, but stopped by a few millimeters of aluminum or other metal very | penetrating, never completely stopped, though lead and thick concrete will reduce intensity |
| effect of field | deflected by magnetic and electric field | deflected by magnetic and electric field | not deflected by magnetic or electric fields |

There are over 1000 known radionuclide ,most man made
Iodine has 15 known radioisotopes(131I,123I) , carbon has two stable isotope(12C,13C),and several radioisotopes(11C,14C,15C),
while hydrogen has one isotope, tritium(3H).

## APPLICATIONS OF RADIOACTIVE ISOTOPES

Scientific research, analytical, diagnostic, therapeutic

## Decay " Transformation " Process:-

Each radioactive atoms try to decay to reach the stable state in the following probability .

(dN / dt) α number of total radioactive atom.

$dN/dt = -\lambda N$

$dN/N = -\lambda\, dt$

$N = N_o e^{-\lambda t}$ ...... (1)

N= Number of radioactive atoms after t = time

$N_o$ = Number of radioactive atoms at t = 0 (original number)

λ = decay constant , unit ( sec-1, min-1)

from equation (1):

$dN/dt = (dN_o/dt) * e^{-\lambda t}$

Since $dN_o/dt = A_o = \lambda N_o$ (activity of atoms at t = 0 )

and $dN/dt = A = \lambda N$ (activity of atoms at t )

To calculate the radioactivity at any time t :

$A = A_o e^{-\lambda t}$ ............. (2)

( T 1/2 ) : (half life time ) is the time required for either the number of radioactive atoms or the activity reduce to half of its original value.

At time $t = (T_{1/2})$ ,

$N = (1/2) N_o$ and $A = (1/2) A_o$

Subsitute this condition in equation (1):

$N/N_o = (1/2) = e^{-\lambda T_{1/2}}$

$2^{-1} = e^{-\lambda T_{1/2}}$

By taking Ln of both sides of equation we get:

$-\ Ln\ (2) = -\ \lambda\ T1/2$

$0.693 = \lambda T1/2$

$T1/2 = 0.693\ /\ \lambda$........... (3)

or

$\lambda = 0.693\ /\ T1/2$.....(4)

Note: In equations 1,2,3,4 the unit of time and decay constant must be t (sec) , λ ( $sec^{-1}$) , t ( min ), λ ( $min^{-1}$).

Average life ( mean life ) $Ta = 1/\lambda$

$Ta = 1.44\ T1/2$ ......(5)

$1/\lambda = 1.44\ T1/2$

To calculate the number of radioactive atoms and the activity of the sample:-

In each atomic weight of any element there is constant number of atoms which is called Avogadro number is

equal to [( 6.02 × 1023 ) atoms / Aw ].
This means (1 gm contain 6.02x1023 atoms/Aw).

## Unit of Radioactivity

1. Curie Ci = 3.7 × 1010 disintegration/sec ( This number represent the radioactivity of 1 gram of radium ).
The Curie is a large quantity for nuclear medicine.
1 mCi = 10-3Ci = 3.7 x 107dps
1 µCi = 10-6Ci = 3.7 x 104 dps
1 nCi =10-9Ci = 3.7 x 101 dps
1 pCi = 10-l2Ci = 3.7 x10-2 dps
2.Becquerel ( Bq ) = 1 disintegration / sec ( is small unit )
( KBq =103 disintegration / sec )
( MBq=106 disintegration / sec )

## Example 1

a.If you have 1g of pure potassium 40 (40k) that is experimentally determined to emit about 103 beta rays per second, what is the decay constant λ ?

Solu:

1 gm contain 6.02x1023 atoms/Aw

1 gm contain (6.02/40)x1023 atoms

λ =A/N =103/(1.5x1022)=6.7x10-18 sec-1

b. Estimate the half-life of 40k from the decay constant.

T1/2=0.693/ λ=0.693/6.7x10-18 sec-1

T1/2=1017 sec

since there are 3.15x107 sec/years

T1/2=1017 sec/(3.15x107 sec/year)

=3x109 years

## Example 2

1. Calculate the number of atoms in 1 g of $^{226}$Ra.
2. What is the activity of 1 g of $^{226}$Ra (half-life = 1,622 years)?

Solu:

1. Number of atoms /g = $N_A$/Aw

where $N_A$ = Avogadro's number = $6.02 \times 10^{23}$ atoms per gram atomic weight

Aw is the atomic weight.

Aw is very nearly equal to the mass number.

Therefore, for $^{226}$Ra

Number of atoms/g $= 6.02 \times 10^{23}/226$

$= 2.66 \times 10^{21}$

2. Activity A = λN

Since N= 2.66 x 1021 atoms/g (example above) and:

λ= 0.693/T1/2

= 0.693/(1,622 years) x (3.15 x 107 sec/year)

=1.356 x 10-11 sec-1

Therefore,

Activity = 2.66 x 1021 x 1.356 x 10-11 dps/g

= 3.61 x 1010 dps/g

= 0.975 Ci/g

## Example 3

1.Calculate the decay constant for cobalt-60 = 5.26 years) in units of month$^{-1}$.

2. What will be the activity of a 5000-Ci $^{60}Co$ source after 4 years?

Solu:

1- $T_{1/2} = 0.693 / \lambda$

since $T_{1/2}$ = 5.26 years = 63.12 months.

Therefore,

$\lambda = 0.693 / 63.12 = 1.0979 \times 10^{-2}$ month$^{-1}$

2. t = 4 years = 48 months.

we have:

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

$= 5000\ e^{-(1.0979 \times 10^{-2} \times 48)} = 2952$ Ci

## Example 4

When will 5 mCi of $^{131}I$ ($T_{1/2}$ = 8.05 days) and 2 mCi of $^{32}P$ ($T_{1/2}$ = 14.3 days) have equal activities for $^{131}I$?

Solu:

$A_0$=5 mCi

and

$\lambda=0.693/8.05=8.609\text{x}10^{-2}$ day$^{-1}$

For $^{32}P$:

$A_0$=2 mCi

And

$\lambda=0.693/14.3=4.846\text{x}10^{-2}$ day$^{-1}$

Suppose the activities of the two nuclides are equal after t days. Then,

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

$5 \exp(-8.609\text{x}10^{-2}\text{x } t) = 2 \exp(-4.846\text{x}10^{-2}\text{x } t)$

Taking the natural log of both sides,

$\ln 5 - 8.609 \times 10^{-2} \times t = \ln 2 - 4.846 \times 10^{-2} \times t$

or $1.609 - 8.609 \times 10^{-2} \times t = 0.693 - 4.846 \times 10^{-2} \times t$

or $t = 24.34$ days