Radioisotopes in Medicine

by

Dr.Suha Shayal Abdul-Hassan

- 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 .

$(dN / dt) \alpha$ number of total radioactive atom.

$dN/dt = -\lambda N$

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$N = N_0 e- \lambda t$ ...... (1)

N= Number of radioactive atoms after t = time

N_0 = Number of radioactive atoms at t = 0 (original number)

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

from equation (1):

$dN/dt = (dN_0/dt) * e-\lambda t$

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:

$- \ln (2) = - \lambda T_{1/2}$

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

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

or

$\lambda = 0.693 / T_{1/2}$.....(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) $T_a = 1/\lambda$

$T_a = 1.44\ T_{1/2}$ ......(5)

$1/\lambda = 1.44\ T_{1/2}$

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 = 6.02×10^{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 131I ($T_{1/2}$ = 8.05 days) and 2 mCi of 32P ($T_{1/2}$ = 14.3 days) have equal activities for 131I?

Solu:

$A_0 = 5$ mCi

and

$\lambda = 0.693/8.05 = 8.609\times10^{-2}$ day^{-1}

For 32P:

$A_0 = 2$ mCi

And

$\lambda = 0.693/14.3 = 4.846\times10^{-2}$ day^{-1}

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

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

$5 \exp(-8.609\times10^{-2} \times t) = 2 \exp(-4.846\times10^{-2} \times t)$

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