L-35 Radioactivity

A particular nucleus represent by the symbol

$$X^{A(p+n)}_{Z=p}$$

X= chemical element(Atomic Symbol)
A= the mass number (atomic weight) =No. of proton + No. of neutron
Z = atomic number = No. of proton
Ex: $_{11}Na^{23}$ no. of proton (Z)=11 , no. of neutron(n) = 23-11=12
Atomic weight=23

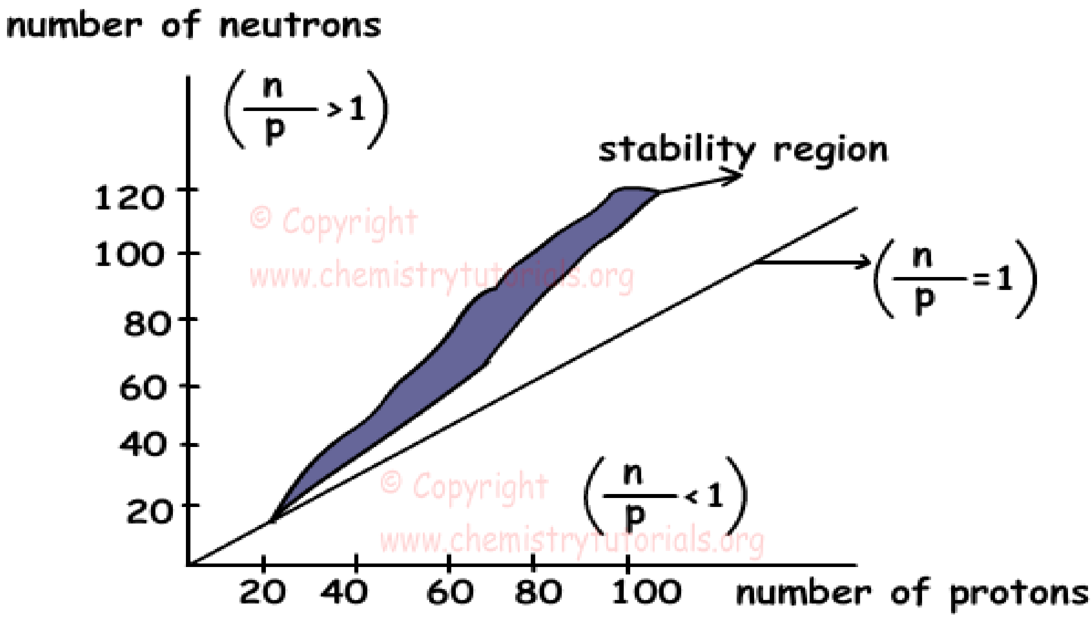
Radiation is the energy or particles that released during radioactive decay.

What is radioactivity?

- **When the binding energy is not strong enough to hold the nucleus of an atom together, is said to be unstable.**
- **Atoms with unstable nuclei are constantly changing as a result of imbalance of energy within the nucleus.**
- **When the nucleus losses a neutron it gives off and is said to be radioactive.**

Stability of nucleus

- **The primary factor in determining an atom's stability is neutron to proton ratio**



- **Isotope: nuclides of the same chemical element with different No. of neutrons called the isotope of that element**
- **If they are not radioactive they are called stable isotopes**
- **And If they are radioactive they are called radioisotopes**

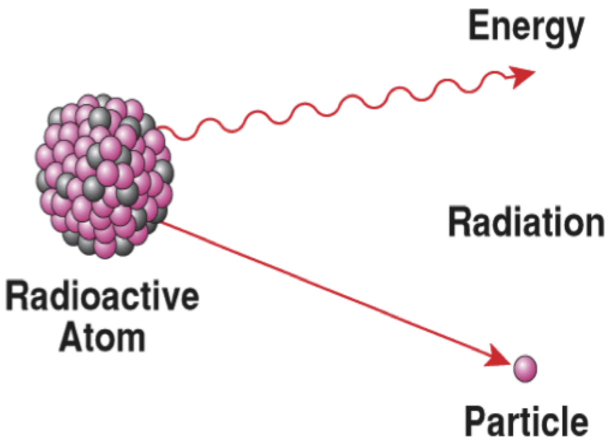
For example: carbon has two stable isotopes ($_6C^{12}$, $_6C^{13}$) and several radioisotopes($_6C^{10}$, $_6C^{11}$, $_6C^{14}$, $_6C^{15}$)

3 isotope for Hydrogen: $_1H^1$ hydrogen $_1H^2$ deuterium $_1H^3$ tritium
Extremely small quantities of radioactive substances used in nuclear medicine for diagnostic (typically less than1µg) which do not affect the normal physiological functioning of the body. These radioactive elements will behave physiologically like its stable counterpart.

Some radioisotope used in nuclear medicine

Iodine has 15 known radioisotope ($I^{125, 127, 131, 135,\ldots}$) Used in many diagnostic ,especially for thyroid function .
$_6C^{14}$, $_1H^3$, Rb^{86} : used in medical research
P^{32} : used for tumor diagnostic.
T^{99m} : Man mode radio isotope .(radio nuclides) emit types of radiation not emitted by natural radioactive substances. The m in T^{99m} stand for met stable, which mean half –stable ,and decays by emitting $\gamma - ray$ only .

Radioactivity is the process by which a nucleus of an unstable atom loses energy by emitting particles of ionizing radiation, As each nucleus disintegrates, in its effort to find a more stable combination, it emits a charged particle that, because of its kinetic energy, is capable of penetrating solid material.



Units of radioactivity:

The amount of radioactivity is measured in units of curie (ci), A curie is equal to 3.7×10^{10} disintegrations per second. A smaller unit, the millicurie (mci), is routinely used in the field of radiologic physics. The SI unit of radioactivity is the *Becquerel*. It is equal to 1 disintegration/s, typically denoted as the reciprocal of 1 second (s-1).

Physics of Nuclear medicine

Unstable nuclei decay by emitting α- or β-particles or γ-rays.

1. α-particle is actually a helium atom that has been stripped of its electrons and consists of two protons and two neutrons.

- **Heavy (4 AMU).**
- **Typical Energy = 4-8 MeV;**

- Limited range (<10cm in air; 60µm in tissue);
- High LET (Quality Factor QF=20) causing heavy damage (4K-9K ion pairs/µm in tissue).
- Easily shielded (e.g., paper, skin) so an internal radiation hazard.
- Eventually lose too much energy to ionize; become He

2. β-particle

- **A negative β-particle (β^-) carrying a unit negative charge (−1e) is called *anegatron*;**
- **a positive β-particle (β^+) carrying a unit positive charge (+1e) is called *apositron*.**

- High speed electron ejected from nucleus; -1 charge,
- Light 0.00055 AMU;
- Typical Energy = several KeV to 5 MeV;
- Range approx. 12mm/MeV in air, a few mm in tissue;
- Low LET (QF=1) causing light damage (6-8 ion pairs/µm in tissue).
- Primarily an internal hazard, but high beta can be an external hazard to skin.
- Aluminum and other light (<14) materials and organo-plastics are used for shielding.
- Note: Beta particles with an opposite (+) charge are called positrons. These quickly are annihilated by combination with an electron, resulting in gamma radiation (Pair Production).

3. Neutrons:

- Neutron ejected from a nucleus; 1 AMU; 0 Charge; Free neutrons are unstable and decay by Beta emission (electron and proton separate) with $T_{½}$ of approx. 13 min.
- Range and LET are dependent on "speed": Slow (<10 KeV), "Thermal" neutrons, QF=3, and Fast (>10 KeV), QF=10.
- Shielded in stages:
  * High speed neutrons are "thermalized" by elastic collisions in hydrogenous materials (e.g., water, paraffin, concrete). The nuclei which are "hit" give off the excess energy as secondary radiation (alpha, beta, or gamma).
  **Slow neutrons are captured by secondary shielding materials (e.g., boron or cadmium).

4. X- and Gamma Rays:

X-rays are photons (Electromagnetic or EM radiations) emitted from electron orbits, such as when an excited orbital electron "falls" back to a lower energy orbit; Gamma rays are photons emitted from the nucleus, often as part of radioactive decay.

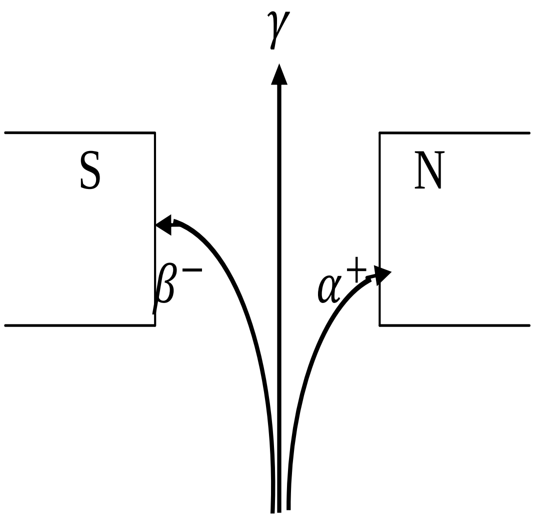
- Gamma rays typically have higher energy (Mev's) than X-rays (KeV's), but both are unlimited.
- No mass; Charge=0; Speed = C; Long range (km in air, m in body);
- light damage (QF = 1); An external hazard (>70 KeV penetrates tissue);

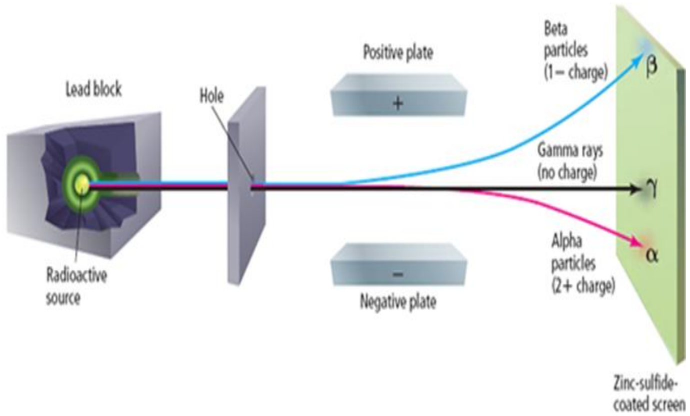
- In addition, the high speed electrons may lose energy in the form of X-rays when they quickly decelerate upon striking a heavy material. This is called Bremsstralung (or Breaking) Radiation.
- Usually shielded with lead or concrete

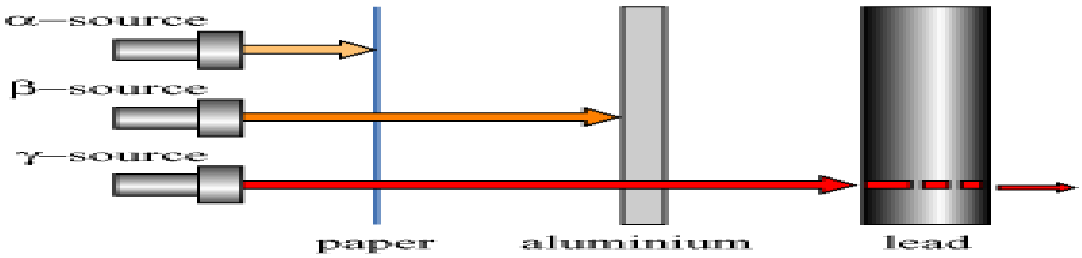
α^+ Few cm in air, very short in tissue few microns High L.E.T

β^- Few meter in air or few mm in tissue, high-speed electron.

γ Very penetrated , physically identical to X-rays but more energy than X-rays used in diagnostic radiology.







Biological effect of ionizing Radiation

The Biological effect of ionizing Radiation caused by the absorption and distribution of the energy in the tissue.

If the radiation were to pass straight through living material without leaving any energy behind , it would have **NO biological effect**

The absorption of α- particles :

Composed

α= 2n+2p

Massα m=6.7 ×10^{-27} Kg. = 7500 time is heavy as an electron (m_e=9.1×10^{-27} Kg.)

Ionization and Excitation for α-particles

Excitation and ionization are the most important ways in which α- particles transfer their energy to the matter.

Ionization

Positively charged exerts a strong attractive force on the negatively charged orbital electrons of the atoms in its track ,may pull one or more of these electrons , this required energy for such interaction causes the dissipation of some of the energy of –particles. A positive ion left behind an (ion pair) (ionization) (34 ev K.E. caused one ion pair . 1ev = 1.6 jouls

Excitation :

Rising of the inner orbital electrons to higher energy level within the atom. It does not involve the removal of electrons from the atoms

Specific ionization(or linear ion density)

The no. of ion pairs formed per unit length of α – particles track, and depends on

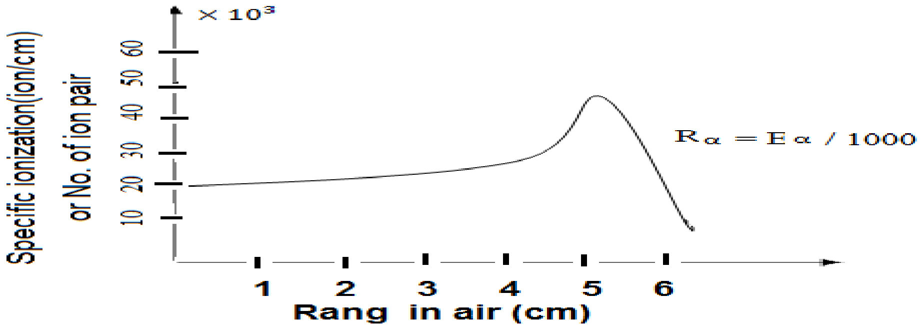
1. **the charge ,**
2. **the density ,**
3. **Atomic no. Z of tissue**

The no. of ion pairs produced is directly proportional to the initial energy of the particles. The rate at which α - particles lost energy along the track is proportional to the square of the α - particles charge:

$dE/dX \sim (\alpha\text{-charge})^2$ where dE : energy , dX : path length

- **deeper penetration of α into tissue more and more interaction (ionization , excitation) occur**
- **Lead to reducing α –particles speed and increases the chances of further interactions. $(1\ Mev)_\alpha$ few cm in air , few micrometer in dens tissue (shorter truck more damaging biologically)**
- **Faster moving particles is less likely to ionize media through which it is passing than a slower one**

i.e $dE/dX \sim 1/E$ dE/ dX :rate of energy loss

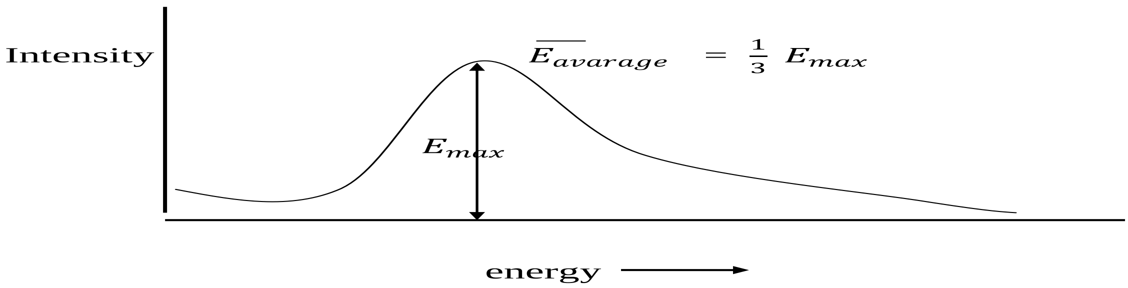


Biological effects

Due to the short range of absorption and inability to penetrate the outer layers of skin, alpha particles are not, in general, dangerous to life unless the source is ingested or inhaled, in which case they become extremely dangerous.

2- The absorption of electrons (β-particles)

- **excitation and ionization occur as described for α –particles.**
- **Due to its small mass and single –ve charge ⟶ it is deflected from orbital electrons path.**
- **Greater density of ionization occur at the end of the track of the electrons .**
- **low energy (small K.E.) (low velocity) ⟶ slowing down increases the probability of interaction (ionizeation , excitation) with media.**
- **α and β from a given sources have fixed energies .**
- **β-ray have a spread energies up to a maximum characteristic the sources.**



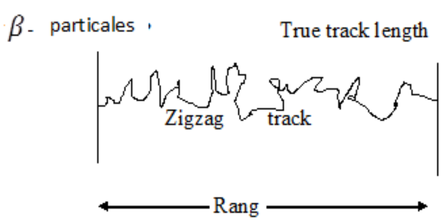
Range of β-particle $R= \frac{1}{2} E_{max}$ **g/cm²**

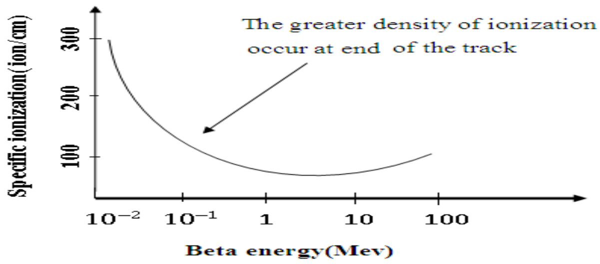
Penetration depth t = R/ ρ where ρ : is density of material

Example : What is the range of a S^{35} beta particle of max. energy (0.168 Mev) in Perspex if the density of Perspex (1.2 g/cm³).Find the penetration depth.

Range of β-particle $R= \frac{1}{2} E_{max} = 0.168/2 = 0.084$ **gm/cm²**

Penetration depth t = R/ ρ = 0.084/1.2 = 0.07 cm = 0.7 mm





3- Absorption of neutrons $_0n^1$ (no charge)

$_0n^1$ has no charge therefore interaction result from direct collision with atomic nuclei are , depends on :

1. **the energy of the $_0n^1{}_s$**
2. **the atomic density**
3. **the masses of the atomic involved).**

$_0n^1$ can penetrate deep into media .

Slow $_0n^1$ (thermal) (0.025-0.1)Kev (4.005 × 10^{-21} – 1.602 × 10^{-17})joule

Interact by captured into atomic nuclei

Fast $_0n^1$ (> 0.02 Mev),(2.304 × 10^{-12}) joules .

Interact by elastic collisions . total transfer of energy possible when two masses particales are equal $m_1(_0n^1) = m_2$(proton (hydrogen) high in living tissue, this intraction of great important for $_0n^1$ therapy