## 31-4] Passage of radiation through Biological matter Damage

⊖ Nuclear radiation includes :-

$\alpha$, $\beta^+$, $\beta^-$, n, $\pi$, $\gamma$, P, .....

⊛ X-rays are also a radiation but <u>NOT</u> nuclear radiation as X-rays

⇒ They don't originate from the nucleus - X rays are emitted from transitions of electrons between atomic energy levels.

Nuclear radiation and $\alpha$-rays are called ionizing radiation why?

$\xrightarrow{\text{ion}} Na^+ + \bar{e}$ free ($\bar{e}$)

When radiation passes through matter, it ionizes the atoms (( produce free $\bar{e}$ and positive ions )).

⊛ When radiation passes through matter, it can cause considerable damage.

⇓

Metals and structural materials become brittle and become weak due to the passage of radiation. "هش"



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## * Biological Damage :-

Damage of Biological cells is primarily due to the ionization that is caused by the radiation.

⇓

- Free electrons and positive ions can interfer with the normal operations of the cell like, for example ⟹ important chemical reactions.

- Knocking off electrons from atoms and molecules may also change their structure which eventually interfers with the normal activity and functions of the cell.

- Radiation may also damage the "DNA". Each alteration to the "DNA" can affect a gene and alter the molecules it codes for.



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## 31-5] Measurement of Radiation - Dosimetry :-

Controlled use of radiation can be used for diagnosis and also for the treatment of cancer. Radiation is also used to kill malignant ((cancerous)) cells.

* Therefore, it is important to quantify the amount or dose of radiation. This is known as "dosimetry"

* The strength of a radioactive source is specified by stating its "activity" at a given time :-

Remember :- $A = A^{\circ} e^{-\lambda t}$

* Therefore, activity decreases with time. Therefore, we must state the time when we specify the activity particularly when the radioactive source has a short half-life.

* SI unit of activity is the Bequerel ((Bq)) :-

1 Bq = 1 decay/s.

⊛ Another common used unit is the Curie

$1\ Ci = 3{,}7 * 10^{10}\ Bq$



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⇒ 1 Ci is the activity of exactly 1 gram of radium.

* Note that activity gives the number of decays per second. But it gives no information regarding the effect of radiation on Biological tissues.

## * Exposure :-

Measured in units of Roentgen (R)

1 Roentgen :- Amount of X-rays or γ-radiation that deposits $0.873 \times 10^{-2}$ J of energy per 1kg of Air.

NOTE :- The definitions of exposure has limited :-

① radiation type to α-rays and γ radiation

② matter where energy is deposited to air

[ nothing about Biological tissues or the effect of radiation on Biological tissues ]



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* Absorbed Dose ((AD)) :- $\frac{E}{M}$

The energy deposited per Kg in any medium by any radiation type.

$\frac{2\ J}{50\ kJ} = \frac{1}{25}\ Gy$

Units :- Grey (Gy) or Rad

1 Gy = 1 J/Kg

1 Rad = 0,01 J/Kg ⇒ $\boxed{1\ Gy = 100\ rad}$.

* Note that AD applies to any radiation and matter.

* Question :- Which is more dangerous to living tissues, an absorbed dose of 1 Gy of alpha radiation OR 1 Gy of gamma radiation (Note the same absorbed dose but the radiation is different). ⇒ "In fact, absorbed dose doesn't specify the danger of a given radiation to living tissues

Effective Dose (ED) :- ← We need a better assesment

$$\boxed{ED = AD * RBE}$$

RBE :- relative biological effectiveness of a given type of radiation defined as the number of rads of X-rays or X-radiation that produces the same biological damage as 1 rad of the given radiation

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| Radiation type | RBE |
|---|---|
| X and γ rays | 1 |
| β (electrons) | 1 |
| Protons | 2 |
| slow neutrons | 5 |
| fast neutrons | ≈ 10 |
| α particles and heavy ions | ≈ 20 |

* for α - particles, RBE = 20 / 1 rad = 0.001 J/Kg

∴ This means that 1 rad of α-radiation produces the same biological damage as 20 rads of X-rays or γ-rays.

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* Units :-

| AD | | ED |
|---|---|---|
| Gray (Gy) | → | Sievert (Sv) |
| Rad | → | rem |

Since $\left[\begin{array}{l} 1\ Gy = 100\ rad \\ \therefore 1\ Sv = 100\ rem \end{array}\right]$

* Note :- RBE has no dimensions ((No unit))

⊛ Human Exposure to radiation :-

We are constantly exposed to radiation comming from different sources ; like :-

- cosmic rays
- natural radioactivity in rocks and soil .



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* Upper limit Effective Dose per person per year in The US :-

From natural radioactive background :- 300 mrem
↳ $10^{-3}$ rem

From X-rays and scans ≈ 60 mrem
↳ $10^{-3}$ rem

Additional allowed in US 100 mrem

Maximum Total allowed in US ≈ 460 = 4.6 mSv

* Upper limit effective Dose per person per year for radiation workers (hospitals, power plants, research) ≈ 20 mSv

Such workers wear badges called TLD (( thermoluminescent dosimeter )) to monitor the radiation levels workers are exposed to.

* Large doses of radiation cause symptoms like :- nausea, fatigue, Loss of Body hair. In general called " radiation sickness ". very large doses can be fatal. A dose of 10 SV over a short period is usually fatal.

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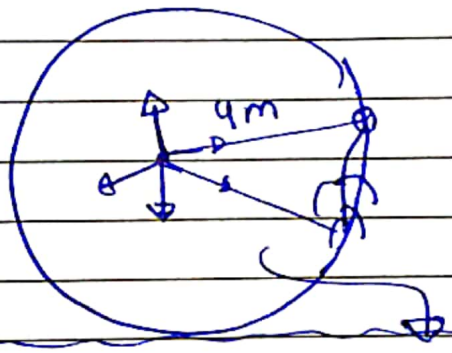
* As we move further away from the radiation source, our bodies will be exposed to lesser amount of radiation.

∴ Intensity of radiation (Energy / unit area) is proportional to "$\frac{1}{r^2}$".

* $\frac{\text{Energy intercepted by body}}{\text{Total energy (radiated)}} = \frac{\text{Surface area of Body}}{4\pi r^2}$

$4\pi r^2$ → surface area of the sphere




Example 31-11] :- limiting the dose. A worker in an environment with a radioactive source is warned that she is accumulating a dose too quickly and will have to lower her exposure by a factor of 10 to continue working for the rest of the year, If the worker is able to work farther away from the source, how much away is necessary ?

Intensity $\propto \frac{1}{r^2}$ → need a reduction by a factor of 10

$I \rightarrow \frac{I}{10}$ ⇒ If she is 4m away from the source

⇒ $I \rightarrow \frac{I}{(4)^2} = \frac{I}{16}$, this is a reduction of more than a factor of 10.

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Example 31-12 ]:- Whole-Body dose.

What whole Body dose is recieved by a 70kg laboratory worker exposed to a 40-mCi $^{60}_{27}Co$ source, assuming the person body has cross-sectional Area of $1.5 m^2$ and is normally about 4m from the source for 4hr per day? $^{60}_{27}Co$ emits rays of energy 1.33 Mev and 1.17 Mev in quick succession, Approximately 50% of the rays interact in the body and deposit all their energy (( The rest pass through ))

Note:- The radiation that passes through the body of the worker ( $E_{worker}$) is only a fraction of the total energy ( $E_{Total}$) emitted by the source.

$$\frac{E_{worker}}{E_{Total}} = \frac{A_{body}}{A_{Total}} = \frac{1.5}{\frac{4}{3}\pi (4)^2}$$

$$\therefore E_{worker} = 7.5 \times 10^{-3} E_{Total}$$

$\Rightarrow$ Energy radiated per each decay $= E_\gamma = (1.33 + 1.17)$
$= 2.5$ Mev

Total radiated energy per second (( for all decays ))

$$E_{Total} = A E_\gamma = (40 \times 10^{-3} \times 3.7 \times 10^{10} \times 2.5 \times 10^{+6} \times 1.6 \times 10^{-19}) J$$

$$\therefore E_{Total} = 5.92 \times 10^{-4} J/s$$ (total radiated energy by the source per each second)

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⇒ Energy deposited in the worker's body per second is :-

$$E = \frac{1}{2} E_{Total} = \left(\frac{1}{2}\right) * \left(7{,}5 * 10^{-3}\ E_{Total}\right)$$

$$= \left(\frac{1}{2}\right) * \left(7{,}5 * 10^{-3} * 5{,}92 * 10^{-4}\ \frac{J}{s}\right)$$

$$E = 2{,}22 * 10^{-6}\ J/s$$

$$AD = \frac{E}{m} = \frac{2{,}22 * 10^{-6}\ J/s}{70\ kg} = 3{,}17 * 10^{-8}\ \frac{J}{kg} * \frac{1}{s}$$

$$\therefore AD = 3{,}17 * 10^{-8}\ \frac{Gy}{s}$$

Absorbed dose in 4hr is $AD_{4hr}$

$$AD_{4hr} = AD * 4 * 60 * 60 = 3{,}17 * 10^{-8}\ \cancel{s}\ \frac{Gy}{\cancel{s}} * 14400$$

$$AD_{(4hr)} = 4{,}56 * 10^{-4}\ Gy$$

$$ED = AD * RBE = 1 * 4{,}56 * 10^{-4} = 4{,}56 * 10^{-4}\ Sv$$

$$= 0{,}456\ mSev$$

$$= 45{,}6\ mrem$$

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