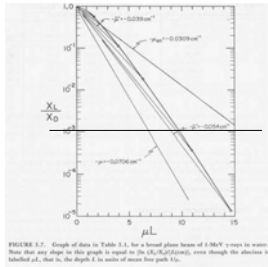


Absorbed dose in radioactive Media

Two limiting cases

- In a small radioactive object (volume V) CPE is well approximated at any internal point that is at least a distance d from the boundary of V. If $d \ll 1/\mu$ then all photons escape and D is equal to the energy per unit mass in the medium given to cp.
- In a large radioactive object ($r \gg 1/\mu$) RE is well approximated and D then the sum of the energy per unit mass of medium that is given to cp and γ -rays in radioactive decay

How large is large enough?



It depends on the attenuation coefficient

For intermediate sizes we need to calculate the Absorbed Fraction (AF)

$$AF = \frac{\gamma\text{-ray radiant energy absorbed in target volume}}{\gamma\text{-ray radiant energy emitted by source}}$$

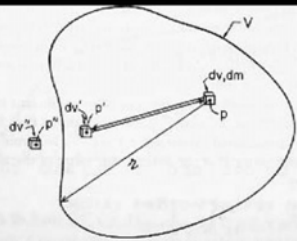


FIGURE 5.1. Illustration of the reciprocity theorem as applied to estimate the γ -ray dose at point P within a homogeneous, uniformly radioactive object V. (See text.)

1. V is surrounded by another volume with homogeneous medium identical to V but not radioactive (organ in the body)
2. V is surrounded by vacuum (object in air).

1. V is surrounded by another volume with homogeneous medium identical to V but not radioactive

$$AF_{dv, V} = \frac{\bar{\epsilon}_{dv, V}}{R_{dv}}$$

Ratio of energy of D under RE $\rightarrow AF_{dv, V} = \frac{\bar{\epsilon}_{V, dv}}{R_{dv}}$

Part of energy that is spent in V $\leftarrow \bar{\epsilon}_{dv, V}$
 radiant energy emitted by source in dv $\leftarrow R_{dv}$

$$AF_{dv, V} = \frac{1}{4\pi} \int_{\theta=0}^{\pi} \int_{\phi=0}^{2\pi} (1 - e^{-\mu z}) \sin \theta \, d\theta \, d\phi$$

energy escaping V \leftarrow

$$\overline{AF}_{dv, V} = \frac{\sum_{i=1}^n (AF_{dv, i})(\bar{R}_{di})}{\sum_{i=1}^n (\bar{R}_{di})} = \frac{\sum_{i=1}^n (AF_{dv, i})(\bar{R}_{di})}{R_{dv}}$$

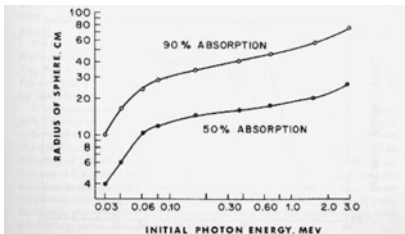


FIGURE 3.2. Radius of unit-density tissue sphere needed to absorb 50% and 90% of the emitted photon energy from a central point source in an infinite homogeneous medium. (After Rosenfild et al., 1968.) Reproduced with permission of the authors and The Society of Nuclear Medicine.

2. V is surrounded by vacuum.

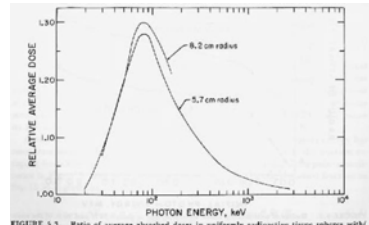


FIGURE 3.5. Ratio of average absorbed doses in uniformly radioactive tissue spheres with/without surrounding non-radioactive tissue medium. Lower curve: 750-g (5.7-cm-radius) sphere; upper curve: 2.5-kg (8.2-cm-radius) sphere. (Data from Khan, 1968.)

$$\bar{r} = \frac{1}{4\pi} \int_{\theta=0}^{\pi} \int_{\phi=0}^{2\pi} r \sin \theta \, d\theta \, d\phi$$

by $\mu_{en} \approx \bar{\mu}'$ in the straight-ahead α

$$\Delta V_{\alpha, V} \approx 1 - e^{-\mu_{en} \bar{r}}$$

$$\Delta F_{\alpha, V} = \frac{1}{4\pi} \int_{\theta=0}^{\pi} \int_{\phi=0}^{2\pi} (1 - e^{-\mu_{en} r}) \sin \theta \, d\theta \, d\phi$$

Radioactive disintegration processes

	ΔZ	ΔA
α -particle	-2	-4
β^- -particle†	+1	0
β^+ -particle†	-1	0
γ -ray	0	0

1 atomic mass unit (amu) = $\frac{1}{12}$ of the mass of the $^{12}_6\text{C}$ nucleus
= 931.50 MeV

1 electron mass (+ or -) = 0.51100 MeV

Alpha disintegration

Heavy nuclei emits an alpha particle
It happens mainly in heavy nuclei

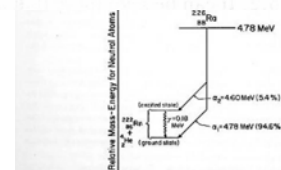
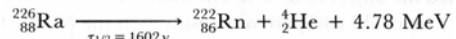


FIGURE 5.4. Atomic energy level diagram for $^{226}\text{Ra} \rightarrow ^{222}\text{Rn}$, showing branching in the mode of disintegration. Note that the rest-mass energy of the ^{226}Ra atom has been augmented by that of the ^4He atom so that the vertical scale need not be expanded to include the loss of energy equivalent to the α -particle mass (4.4 × 938 MeV).

Absorbed dose from α -disintegration

$$E_{\alpha} = 0.946 (4.78 \text{ MeV}) + 0.054 (4.60 \text{ MeV})$$

$$= 4.77 \text{ MeV}$$

Under CPE, if n disintegrations occurred in each gram of matter

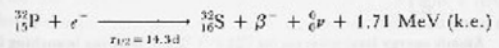
then $D = 4.77n \text{ MeV}$

Under RE, $D = 4.78n \text{ MeV}$, because it includes the 0.18 MeV photons

In the nonstochastic limit we use average branching ratios.

Beta disintegration

Nuclei having excess neutrons tend to emit an electron
Nuclei having excess protons tend to emit a positron



^{32}S is positively charged and then captures an electron

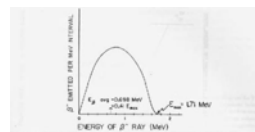


FIGURE 5.5. β^- ray spectrum emitted from ^{32}P . The average energy of the particles is 0.48 MeV. The electron may be alternatively labeled β^- ; maximum energy (1.71 MeV) is made the origin for the positron spectrum.

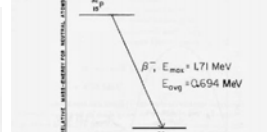


FIGURE 5.6. Atomic energy level diagram for $^{32}\text{P} \rightarrow ^{32}\text{S}$ β^- disintegration.

Tables for dose estimation in Appendix C

- Appendix C is based on tables of Dillman and Von der Lage (1975).
- Its gives
 - The types of radiation emitted
 - The mean energy per particle
 - Equilibrium dose constant=energy contributed to the absorbed dose, per unit activity and time, under RE (or CPE for cp)