The University of Jordan / Physics Department
Solutions for Extra Suggested Problems
Giancoli / Seventh edition / chapter 31

Prof. Mahmoud Jaghoub

Q47] $AD = 4.5\,kGy = 4.5\times10^3 \frac{J}{kg}$ (allowed limit)

$E_{e^-} = 1.6\,MeV = 1.6\times10^6 \times 1.6\times10^{-19}\,J$.

$E_{total} = 4.5\times10^3 \frac{J}{kg} \times 5\,kg$ (allowed total energy)

$= 22.5\times10^3\,J$.

$\therefore$ number of e^- (to reach allowable limit) $= \frac{E_{tot}}{E_{e^-}} \simeq 8.79\times10^{16}$

Q48] a) ${}^{131}_{53}I \longrightarrow {}^{131}_{54}Xe + \beta^- + \bar{\nu}$ (you are not expected to know this decay equation. But you should know the changes in Z and N for β decay).

b) $N = 0.05\,N_0$

$\frac{N}{N_0} = 0.05 = e^{-\lambda t}$

$0.05 = e^{-\frac{\ln 2}{t_{1/2}} t} \Rightarrow \ln(0.05) = -\frac{\ln 2}{t_{1/2}} t$

$t = -\frac{\ln(0.05)}{\ln 2} t_{1/2} = \frac{-\ln(0.05)}{\ln 2}(8) \simeq 34.6$ days.

L2

(c) $A = \lambda N \Rightarrow N = \frac{A}{\lambda} = \frac{A}{\left(\frac{\ln 2}{t_{1/2}}\right)} = \frac{A\, t_{1/2}}{\ln 2}$

$\therefore N = \frac{(1\times10^{-3}\times3.7\times10^{10}\ s^{-1})(8\times24\times60\times60\ s)}{\ln 2}$

$N = 3.6896\times10^{13}$ nuclei

$n = \frac{N}{N_A} = 6.129\times10^{-11}$ moles.

number of moles

mass = $n \times$ molar mass

$= 6.129\times10^{-11}\ \text{moles} \times 131\ \frac{\text{grams}}{\text{mole}} = 8\times10^{-9}$ grams

$= 8$ ngrams

nano $= 10^{-9}$

Q71] All three sources have the same activity

$A = 35\ mCi = 35\times10^{-3}\times3.7\times10^{10}\ s^{-1}$.

$A = 1295\times10^{6}\ s^{-1}$ (or decays/s)

To determine their relative danger of the three sources we should compare their relative effective doses.

Remember $ED = AD \times RBE$

for source A

$$ED_A = \underbrace{\left(\frac{A\,E_\gamma}{m}\right)}_{\text{AD per second}} \times RBE$$

$$ED_A = \frac{A}{m} \times 1\,MeV \times 1 = \left(\frac{A}{m} \cdot MeV\right) \quad \left(\text{in units of } Sv/s\right)$$

$$ED_B = \frac{A}{m} \times 2\,MeV \times 1 = 2\left(\frac{A}{m} \cdot MeV\right)$$

$$ED_C = \frac{A}{m} \times 2\,MeV \times 20 = 40\left(\frac{A}{m} \cdot MeV\right)$$

$$\Rightarrow \quad ED_C : ED_B : ED_A$$

$$40 : 2 : 1$$

$\Rightarrow$ In order of <u>increasing</u> danger we have

$$A \longrightarrow B \longrightarrow C$$

least dangerous — A; most dangerous — C

The University of Jordan / Physics Department
Solutions for suggested Problems
Giancoli / seventh edition / Chapter 31
Prof. Mahmoud Jaghoub

Q38] $ED_{\alpha} = ED_{x\text{-rays}}$

$AD_{\alpha}\, RBE_{\alpha} = AD_{X}\, RBE_{X}$

$350 \times 20 = AD_{X} \times 1$

$\Rightarrow AD_{x\text{-ray}} = 7000$ rad.

Q40] $AD = 2.5\ Gy = 2.5 \times 1\frac{J}{kg} = 2.5\ J/kg.$

$m = 65\ kg \Rightarrow$

Absorbed energy $= 2.5\frac{J}{kg} \times 6\ kg = 162.5\ J.$

Q41] $E_p = 1.2\,MeV = 1.2\times10^{6}\times1.6\times10^{-19}\,J$

tumer mass $= 0.20\,kg$.

a) $ED = AD \times RBE \Rightarrow 1.0\,rem = AD \times (1)$

$\Rightarrow \quad AD = 1.0\,Rad \quad (= 0.01\,Gy)$.

b) absorbed energy by tumer E_{tumer}

$$E_{tumer} = M_{tumer} \times AD$$
$$= 0.2\,kg \times 0.01\,J/kg$$
$$= 0.002\,J.$$

$\Rightarrow$ number of absorbed protons is n

$$n = \frac{E_{tumer}}{E_p} = \frac{0.002\,J}{1.2\times10^{6}\times1.6\times10^{-19}\,J/proton}$$

$\therefore \; n \approx 1.04\times10^{10}$ protons.

Q44] $A = 1.6\ mCi$

$= 1.6 \times 10^{-3} \times 3.7 \times 10^{10}\ Bq$

$= 5.92 \times 10^{7}\ Bq \quad (1\ Bq = 1\ decay/s)$

Need to administer 32 Gy to a tumer.

$1\ mCi \longrightarrow 10\ mGy/min$

$1.6\ mCi \longrightarrow X$

$$\therefore X = \frac{1.6\ mCi}{1\ mCi} \times 10\ mGy/min$$

$$= 16\ mGy/min$$

$\Rightarrow$ a 1.6 mCi delivers 16 mGy/min

required time t is given by

$$t = \frac{32\ Gy}{16\ mGy/min} = \frac{32\ Gy}{16 \times 10^{-3}\ Gy/min}$$

$$= 2000\ min \approx 33.3\ hrs \approx 1.4\ days.$$

Q46] $^{57}_{27}Co$ emits 122 keV γ-rays.

energy of each γ is $E_\gamma = 122 \times 10^3 \times 1.6 \times 10^{-19}$ J

$A = 1.55 \mu Ci = 1.55 \times 10^{-6} \times 3.7 \times 10^{10}$ Bq
$= 57350$ decays/s (Bq)

Radiated energy per second E is given by

$E = A E_\gamma$ (in units of J/s)

Absorbed energy by person per second is

$E_{absorbed} = 0.5 E$ (J/s)
since only 50% of γ-rays interact with the body.

Absorbed energy per day $E_{tot} = E_{absorbed} \times 24 \times 60 \times 60$

$\therefore E_{tot} = 0.5 \left(A E_\gamma \frac{J}{s}\right)\left(24 \times 60 \times 60 \frac{s}{day}\right)$

$= 0.5 A E_\gamma \times 24 \times 3600 \frac{J}{day} =$

$\Rightarrow AD = \frac{E_{tot}}{m} = \frac{E_{tot}}{65} \simeq \frac{4.836 \times 10^{-5} \text{ J/day}}{65 \text{ kg}}$

$\simeq \frac{7.44}{10^7} \overset{Gy}{\frac{J}{kg}} \times \frac{1}{day} = 7.44 \times 10^{-7} \frac{Gy}{day}$